IBM Research

Information and Communication Technology
Portfolio Review
San Francisco, CA

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Economizer Based Data Center Liquid Cooling with Advanced Metal Interfaces

IBM Research
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Project 1/31/2010- 3/31/2012
Project type - R&D

Project Objective/ Goal

Goal is to reduce Data Center cooling energy consumption from todays 25-40% of total energy to 5% of current total energy.

Why are you doing what your doing ?

- Achieve Data Center cooling energy reduction by implementing economizer based liquid cooling using outdoor, ambient air cooling.

What is the need for this?

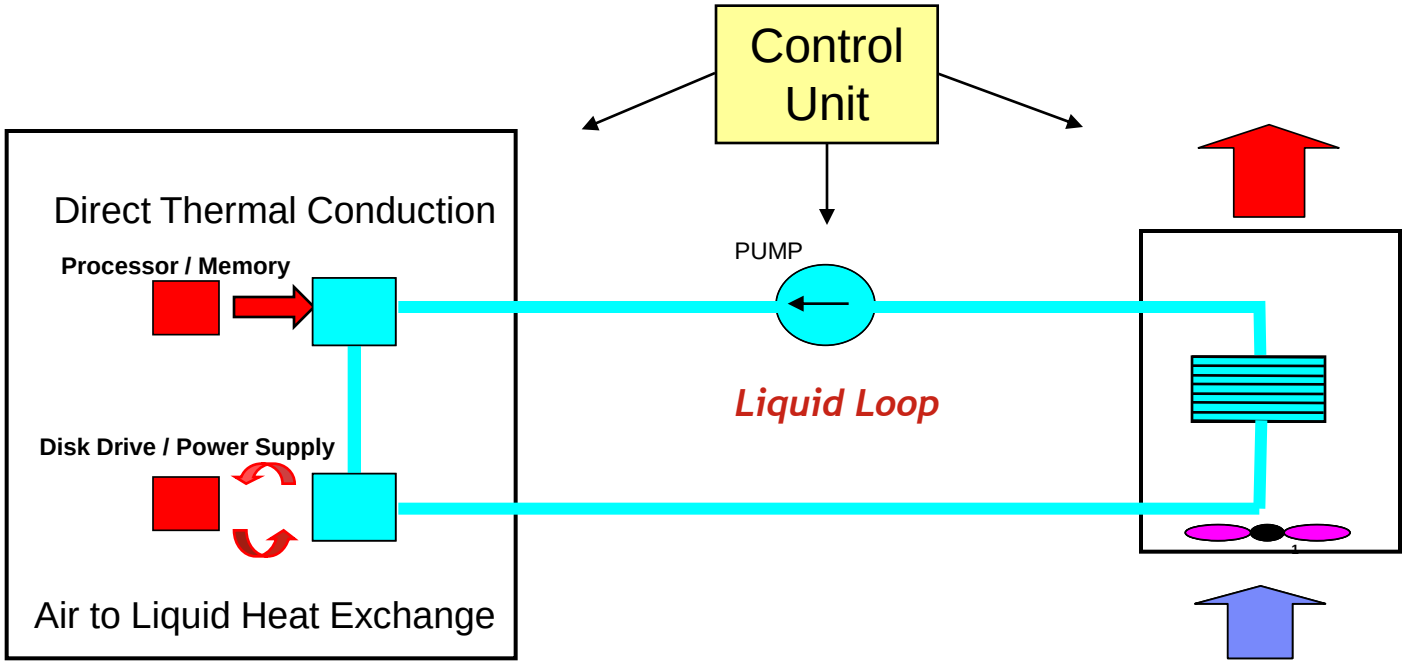
- Current Data Center cooling accounts for 25-40% of total energy usage.
- Need for more energy efficient Data Center cooling solutions to replace energy intensive HVAC cooling solutions.
- Energy cost is a key element in Server total cost of ownership.

Approach, Results, Deliverables

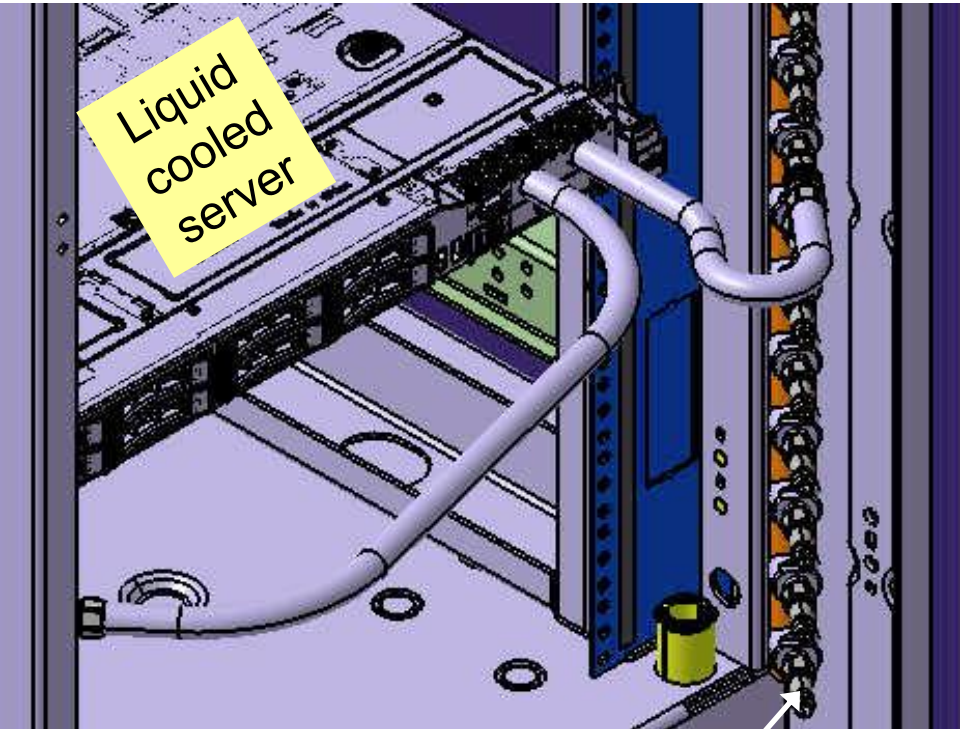
- **Project Approach**
- **Anticipated Results**
- **Deliverables**

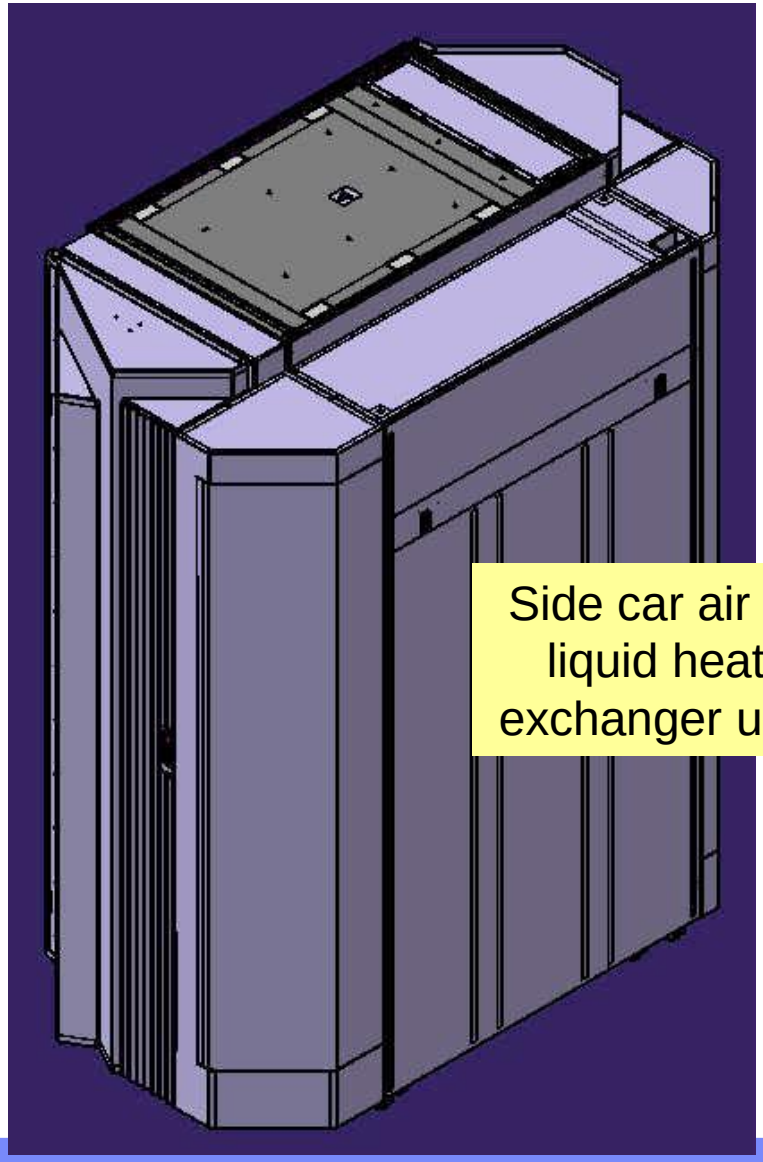
Project Approach

- Utilize “free” cooling from the ambient, outdoor environment
- Eliminate refrigeration based cooling components
- Enabled by high efficiency thermal designs, targeted for volume servers
- Smart controller to minimize cooling power

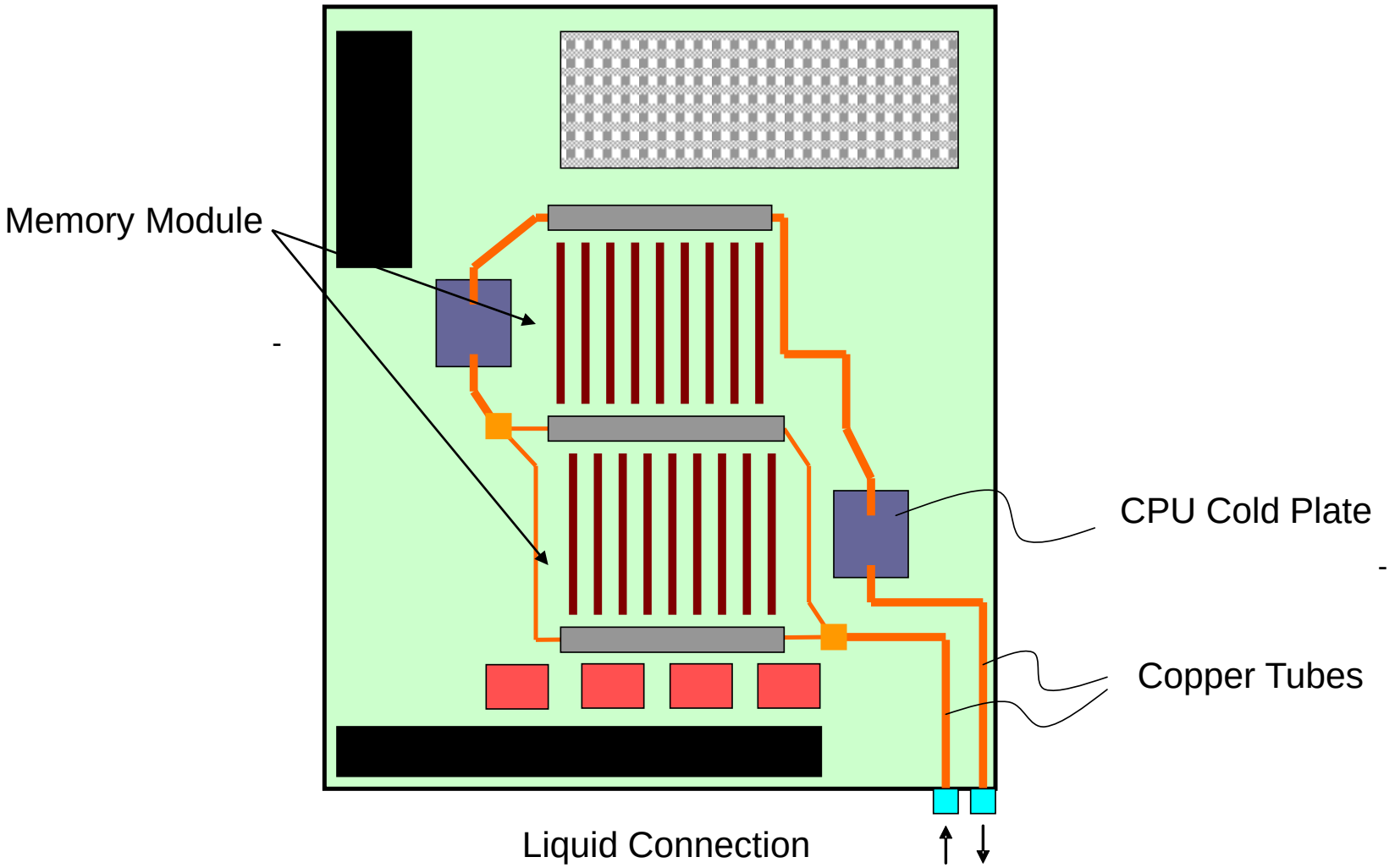


Dual Enclosure Liquid Cooling System

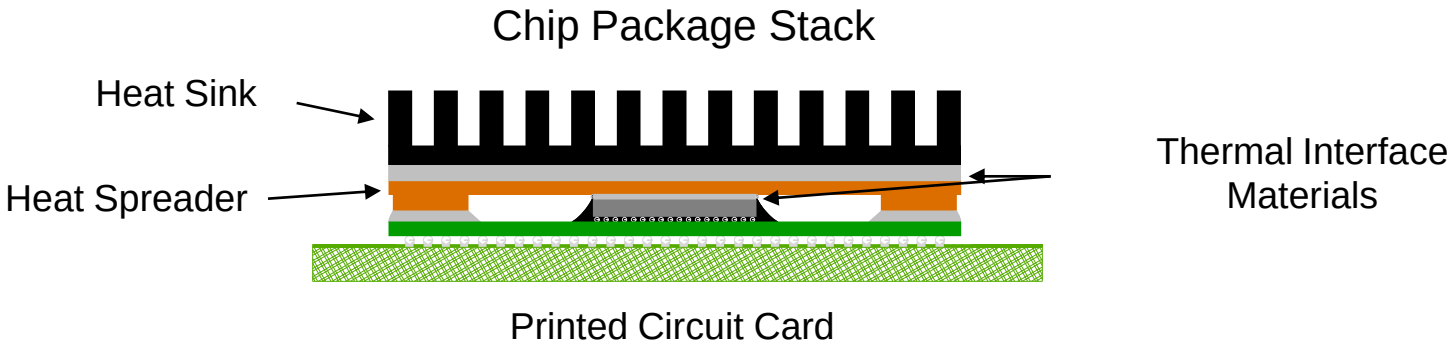


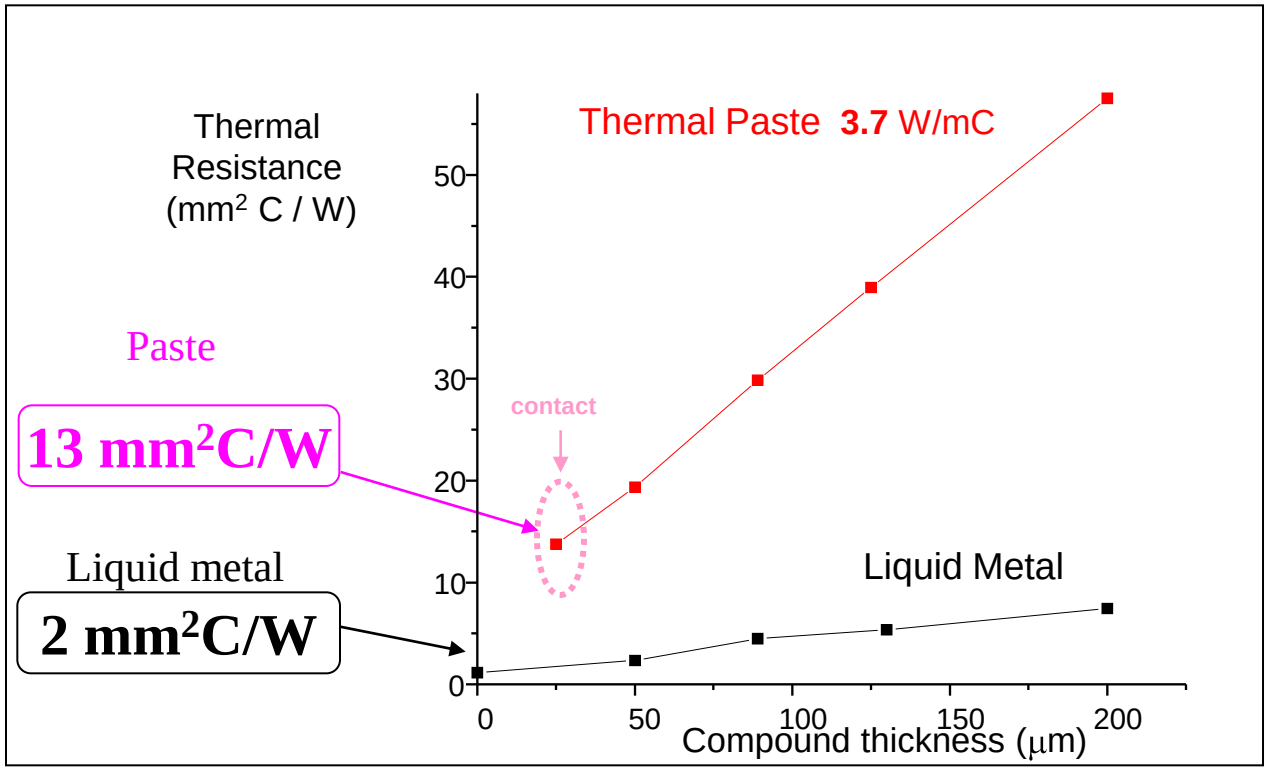


Server Node Processor and Memory Liquid Cooling

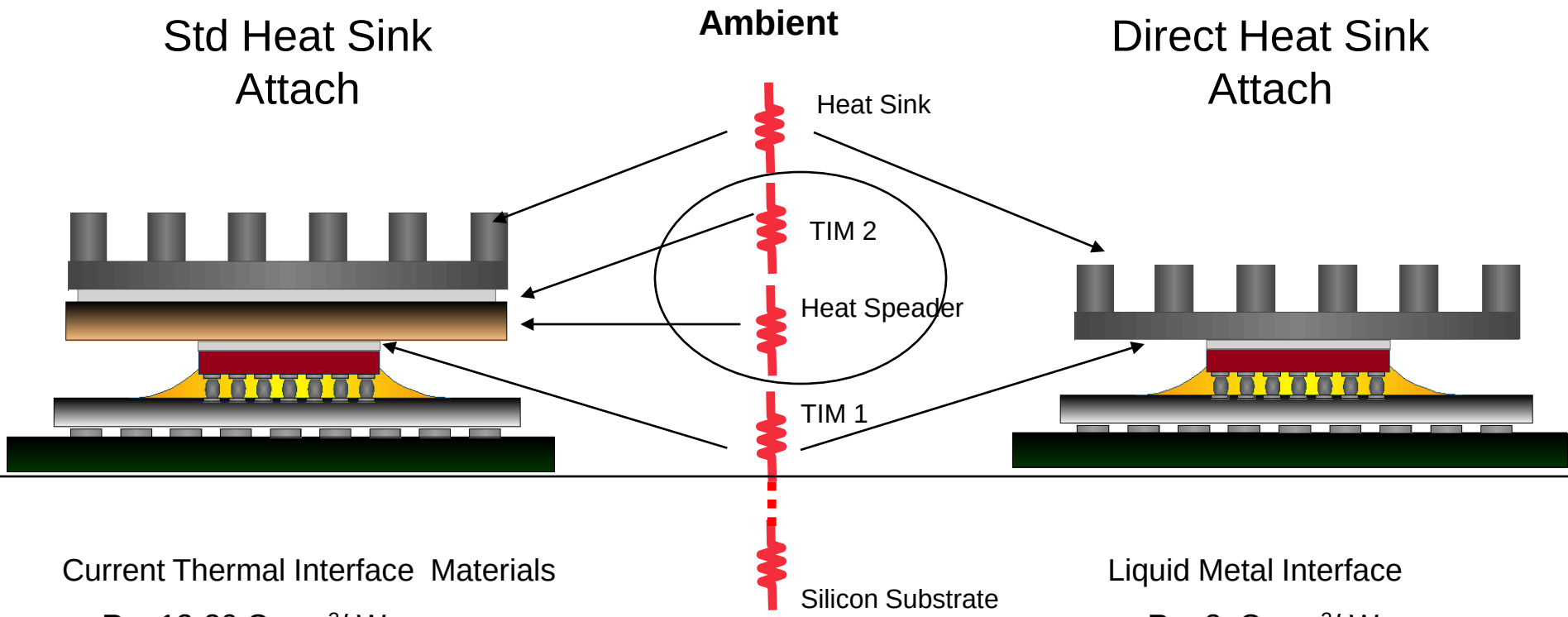


Advanced Liquid Metal Thermal Interfaces





Direct Heat Sink Attach with Liquid Metal Thermal Interface



Current Thermal Interface Materials

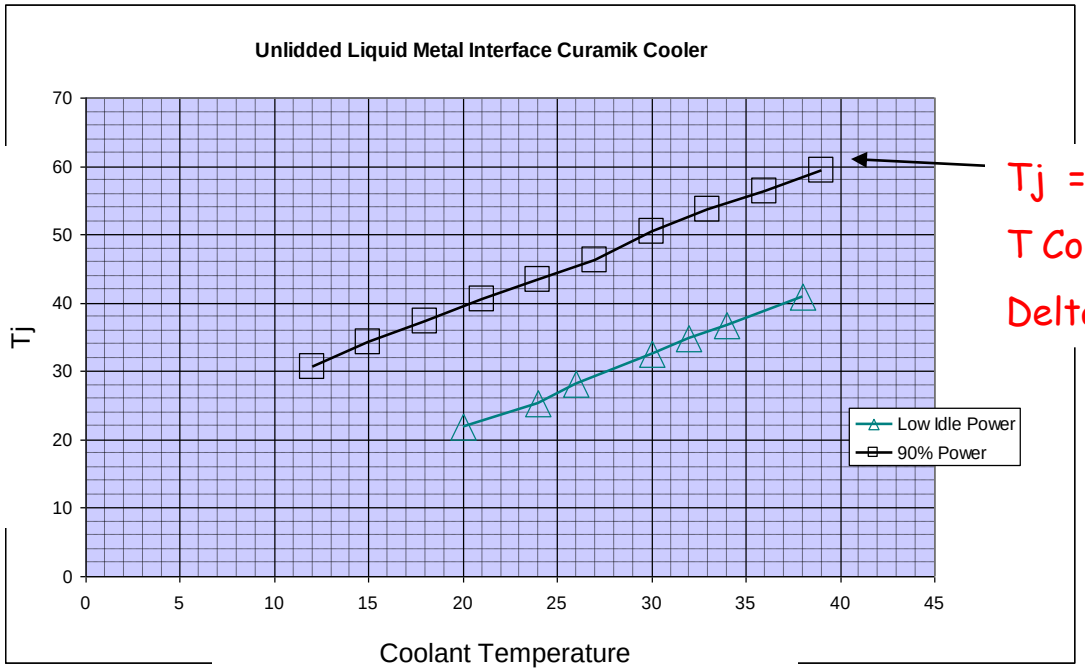
- R = 12-30 C mm^2/ W
- k = 4.2 W/m C

Liquid Metal Interface

- R = 2 C mm^2/ W
- k = ~ 40 W/m C

Reducing Thermal Resistance Allows Higher Ambient Temperature for same Chip Junction Temperature

Demonstration of Direct Heat Sink Attach/Liquid Metal



Tj =59 C

T Coolant = 38 C

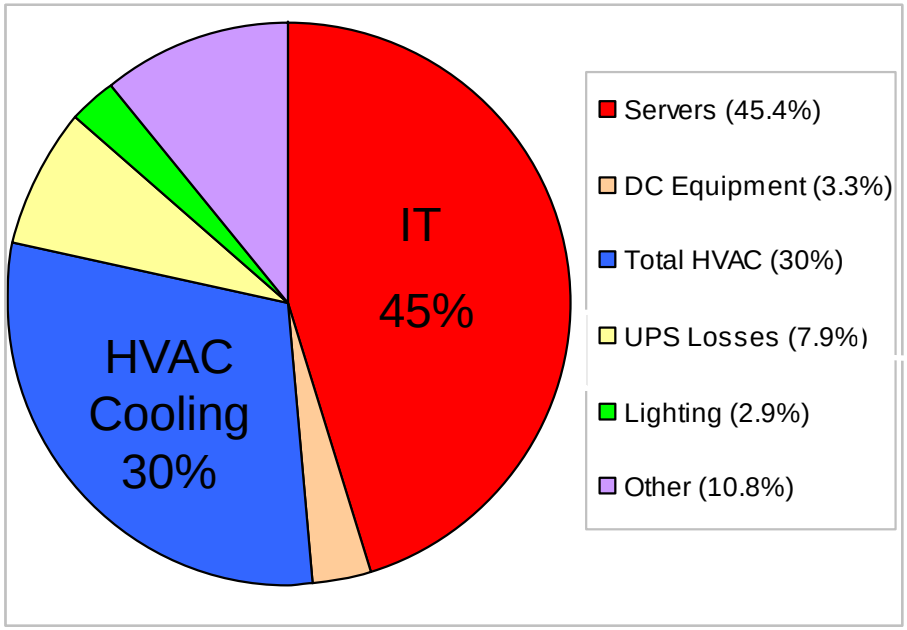
Delta = 21 C

DRAFT

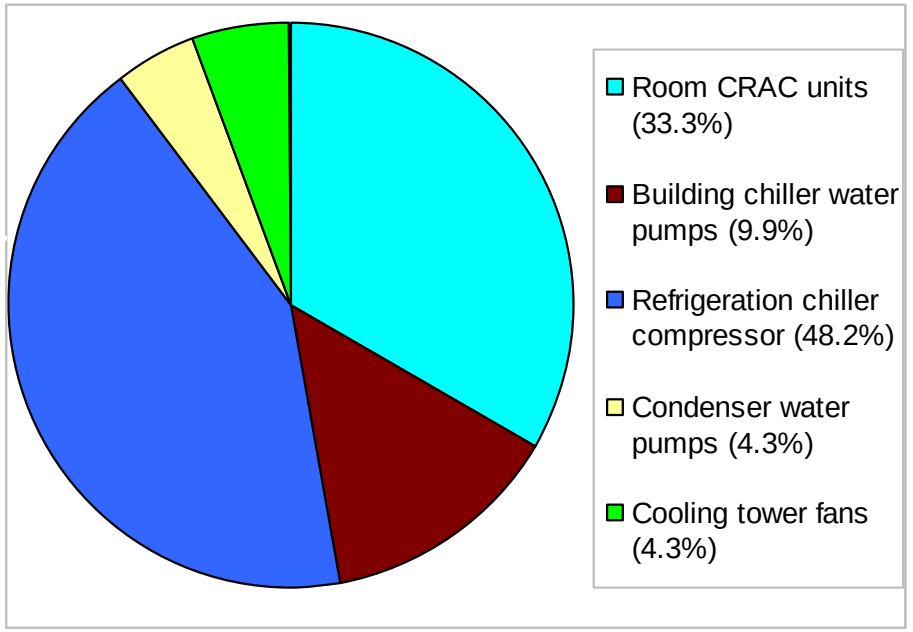
Anticipated Results

HVAC cooling accounts for 25-40% of current data center energy consumption

Achieve cooling of 5% of current data center energy, by reducing HVAC cooling



(a) Typical total data center energy breakdown



(b) Typical data center cooling energy breakdown

Deliverables

- Design and develop a Dual Enclosure Liquid Cooling System (DELC)
- Design and develop a Liquid Metal Thermal Interface
- Characterize System cooling performance under varying operating conditions
- Program summary of System Design and Operation
- Commercialization Analysis

PROJECT MILESTONES	Plan	Status
Rack Heat Exchanger CAD Design	10/2010	**100%**
Liquid Metal Module Integration with Volume Server	4/2011	
DELC Integration with Volume Server	5/2011	
Program Summary Report	3/2012	
DELC/LMTI Commercial Analysis	3/2012	

Transformation/ Game Changing

- **What is transformational/ game changing?**
  - Implementing a Data Center cooling system which eliminates refrigeration based cooling for year round operation and does not expose IT equipment to the outside environment.
  - Advancing the state of the art in liquid cooling by developing cost effective liquid cooling technology for volume servers.
  - Innovating advanced thermal solutions that improve thermal conduction of heat generating components and enable using higher temperature coolant to achieve the same device temperature.

Energy Savings

- **How will energy savings be achieved?**
  - Implementing a system which can operate year round using the outdoor air environment by using a liquid loop “free cooling system”
  - Eliminating refrigeration based cooling.
  - Improving the thermal resistance of server components to allow higher liquid cooling temperatures.
  - Deploying active control of cooling components

- **Estimates of Energy Savings**
  - National
    - 1.6 B kWh by 2015
    - 18.3 B kWh by 2020
    - 34.5 B kWh by 2025
  - Other impacts
    - Elimination of refrigerants in Data Center cooling systems
    - Elimination of water usage by removal of cooling towers

Jobs/ Employment

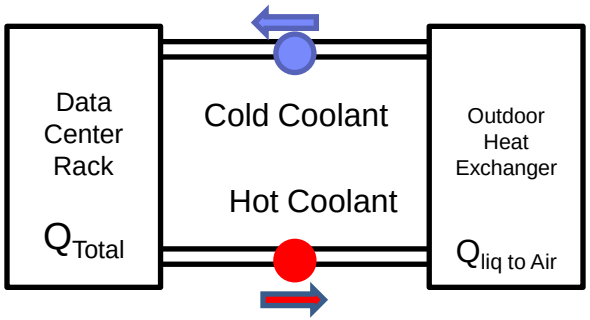
- **So far, what is the direct impact of your project on jobs/ employment?**
  - New Hires Post Doctoral Student 1 , Summer Intern 1
  - IBM Employees Full / Part Time 12
  - Data Center Test Facility Design & Construction Full/ Part Time 10
  - Prototyping components from US companies ~ $700k

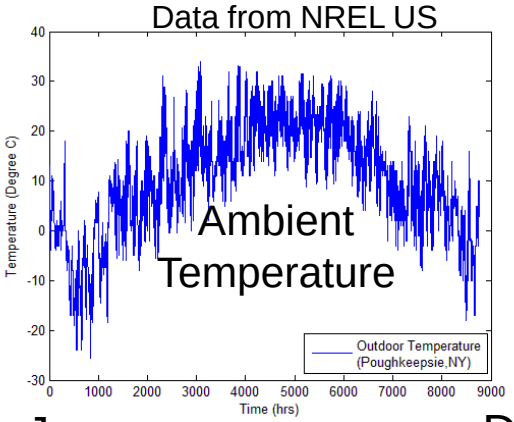
- **Nationally, if this technology is commercially successful, what is the potential or projected impact on jobs/ employment?**
  - We anticipate job creation in the following sectors with commercialization of economizer based liquid cooling technology
    - Engineering
    - Manufacturing
    - Assembly
    - Service and Support Personnel
    - Marketing and Sales Personnel

Project Status

- **Volume Servers**
  - Servers were configured and ordered
  - System software installed
  - Power / thermal characterization performed

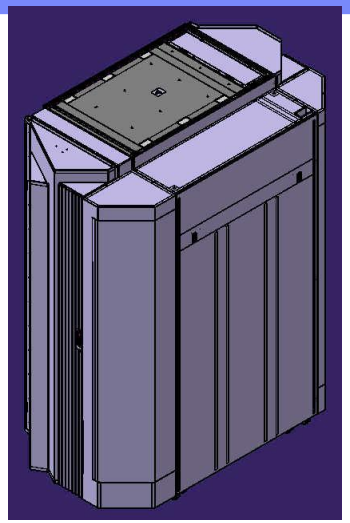
- **Data Center Test Facility**
  - Design completed including hydraulic, thermal and electrical subsystems.
  - System Model was developed to estimate the cooling performance and energy usage as a function of the workload and ambient temperature



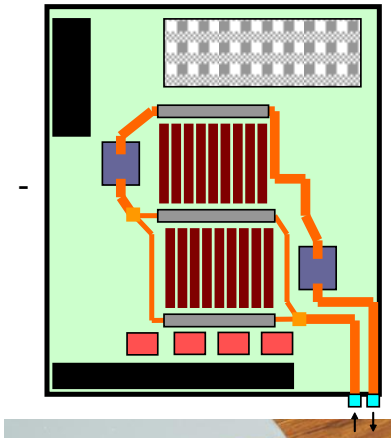


Project Status

- **DELC Rack Heat Extraction Exchanger**
  - CAD design was completed
  - Heat Exchanger built and received



- **DELC Node Heat Extraction Exchanger**
  - Node liquid cooling loop was designed, built and tested.
  - Thermal performance was measured on bench.
  - Characterization in operational Volume Server node



- **Liquid Metal Thermal Interface**
  - LMTI prototype was implemented into a Volume Server node
  - Thermal performance was measured

- **Memory Liquid Cooling**
  - Memory liquid cooling option was designed, built and tested

What's left?

- **What remains to be done on this project?**
  - LMTI Modules integration with Volume Server
  - DELC Integration with Volume Server
  - System Measurement and Characterization
  - Commercialization Analysis
  - Summary Report

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After ITP-Sponsorship

- **What happens after DOE sponsorship ends? What is your path forward? How will this reach and obtain broad distribution in the marketplace?**
  - This project will result in a prototype of DELC and LMTI technology.
  - IBM will evaluate how these developments may be incorporated into a portfolio of leading edge energy efficient technologies.
  - Data Center Test Facility will be deployed to showcase the technology to customers.
  - Data Center Test Facility would be an ideal platform for continued development
  - Publish and present findings at conferences and customer engagements.

Value Proposition for End User

- **If a product, what is the value proposition for the end user? Why would someone buy this product? What is in it for the end user?**
  - Elimination of capital intensive refrigeration based cooling components
  - Remove water usage by Data Center cooling towers
  - Reduction of Data Center cooling energy cost

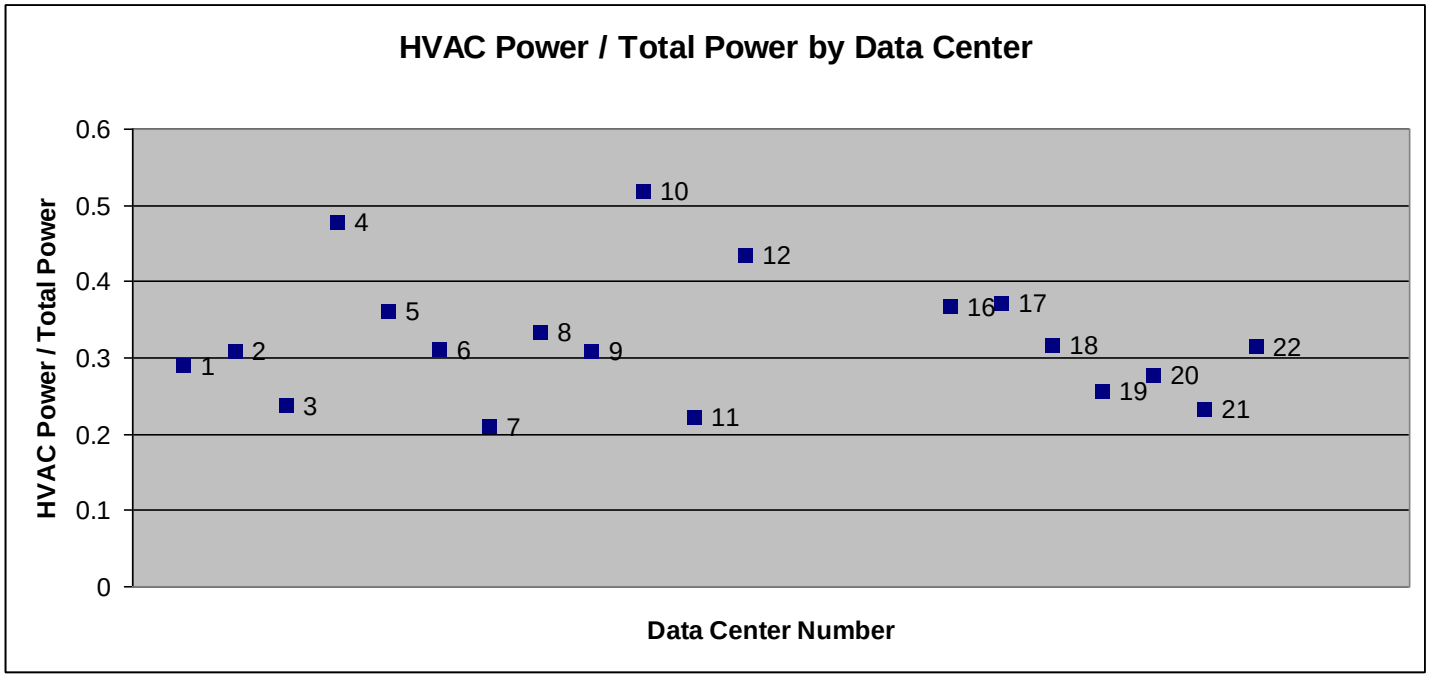

Halliburton Internet Image


King Sun Industries Website

Summary

- **Hardware design and build is nearing completion**
- **System bring up and measurement will be initiated**
- **Commercial interest in liquid cooled volume servers**
- **Acknowledgements**
  - IBM Team Members
    - Milnes David, Michael Gaynes, David Graybill, Brenda Horton, Madhu Iyengar Vinod Kamath Bejoy Kochuparambil, Yves Martin, Pritish Parida, Roger Schmidt, Mark Schultz , Robert Simons
  - DOE Contract DE-EE0002894 Team Members
    - Dibyajyoti Aichbhaumik, Darin Toronjo, Gideon Varga

Data Center Cooling Energy



Graph based on data published by: Greenberg, et. al " Best Practices for Data Centers: Lessons Learned from Benchmarking 22 Data Centers" , 2006 ACEEE Summer Study on Energy Efficiency in Buildings