



CHANGING WHAT'S POSSIBLE



FLEXNODE



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## PREFAB MODULAR LIQUID-COOLED MICRO DATA CENTER

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With:

- University of Maryland
- Boeing
- Iceotope
- Shop Architects
- Arup
- Boyce Technologies



CHANGING WHAT'S  
POSSIBLE



COOLERCHIPS

TECHNICAL CATEGORY B

COOLERCHIPS  
Kickoff Meeting  
*October 18 & 19, 2023*

Total Project Cost:	\$3.5M
Length	36 mo.



# FLEXNODE



CHANGING WHAT'S  
POSSIBLE

## PROJECT VISION

Design & develop a high-performance ultra-compact & highly efficient computing micro data center featuring an unprecedented combination of performance & sustainability parameters, including:

- Elimination of the primary cooling loop (facility supply); heat rejected directly to ambient.
- Zero reliance on, and use of, external water supply.
- Negligible (<10) coolant global warming potential (GWP).
- Zero coolant ozone depletion potential (ODP).



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# TEAM OVERVIEW

Prime & Sub-Recipients	Location	Role in project, core competencies
Flexnode	Bethesda, MD	Prefab modular liquid-cooled HPC micro data center
University of Maryland	College Park, MD	Thermal management, environmental energy engineering
Boeing	Auburn, WA	Reliability & availability analysis + thermal management
Iceotope	Raleigh, NC	Chassis-based precision immersion liquid cooling
Shop Architects	New York, NY	Global reach cutting-edge architecture & design
Arup	New York, NY	Global engineering & sustainability design

The team comprises design & engineering innovators currently collaborating on commercial projects + world class additive manufacturing, thermal management, heat transfer and reliability/availability/maintainability experts. We are:

- Re-creating data centers as configurable, relocatable products rather than as “built in place” buildings.
- Easing the challenge of leveraging advanced technology via flexible data management infrastructure.
- Optimizing for speed of deployment and ease of assembly using a combination of forward-thinking engineering, industrial design, prefabrication, green componentry, and logistics / supply chain strategies.

# MICRO DATA CENTER STRUCTURE

## INTERIOR & EXTERIOR FLEXHUBS



- Interior data center components fit into an elevator & can be assembled with two people in 8 hours.
- Exterior grade DC built to withstand CAT 5 hurricanes.
- Needs only external power source and fiber.

# KEY INNOVATIONS: HIGHLY EFFICIENT MANIFOLD MICROCHANNEL HEAT SINK

- Novel force-fed manifold microchannel heat sink (FFMM).
- Approx. 3X the heat transfer of a typical microchannel heat sink.
- Novel optimal fluid FEED system synched with FFMM enables high heat removal with very low pressure drops.



Fig. Forced fed Manifold Microchannel heat sinks

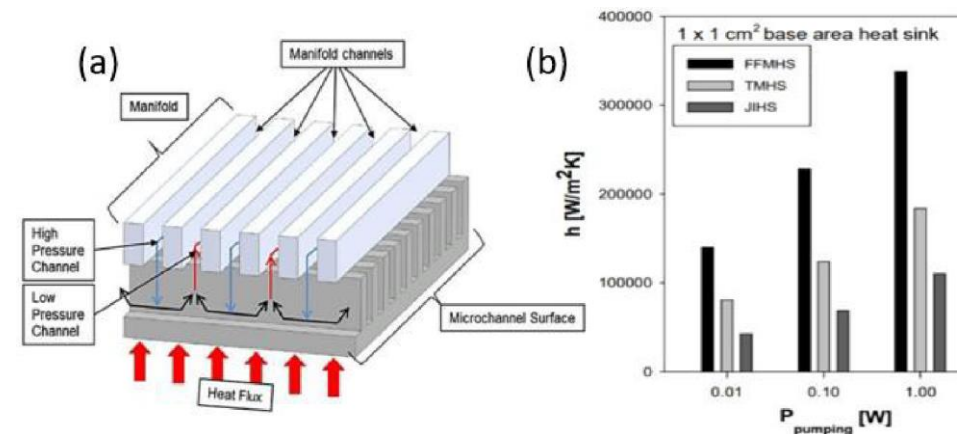
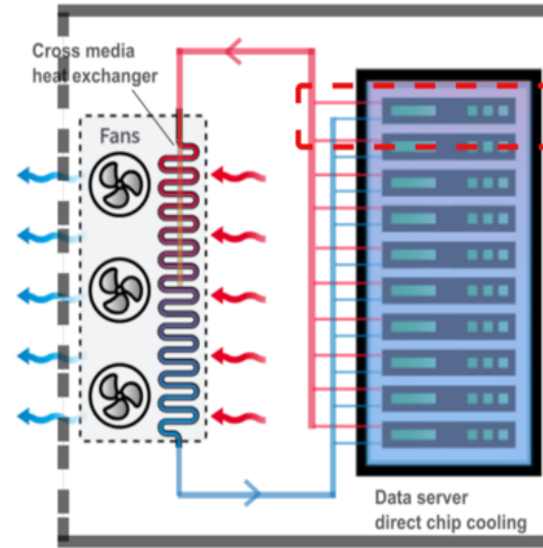


Fig. Forced fed Manifold Microchannel heat sink concept

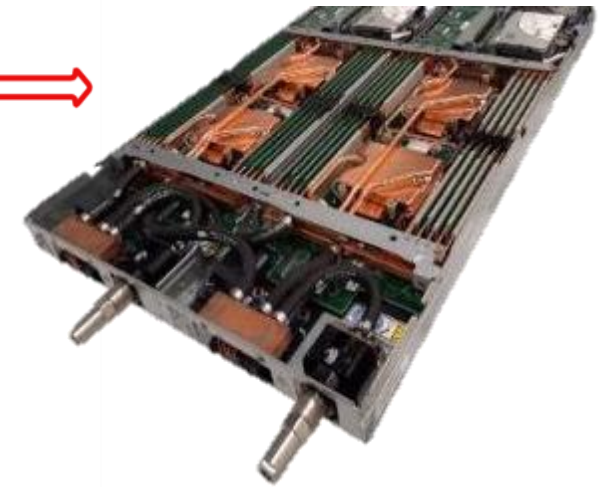
# KEY INNOVATIONS:

## ADDITIVELY MANUFACTURED POLYMER COMPOSITE DRY COOLING SYSTEM

- Requires huge HX surface area.
- Novel heat exchanger approach to reduce the cost of heat exchangers.
- Highly compact.
- Metal and polymer are printed together.



A) Schematic



B) Chassis Cooling

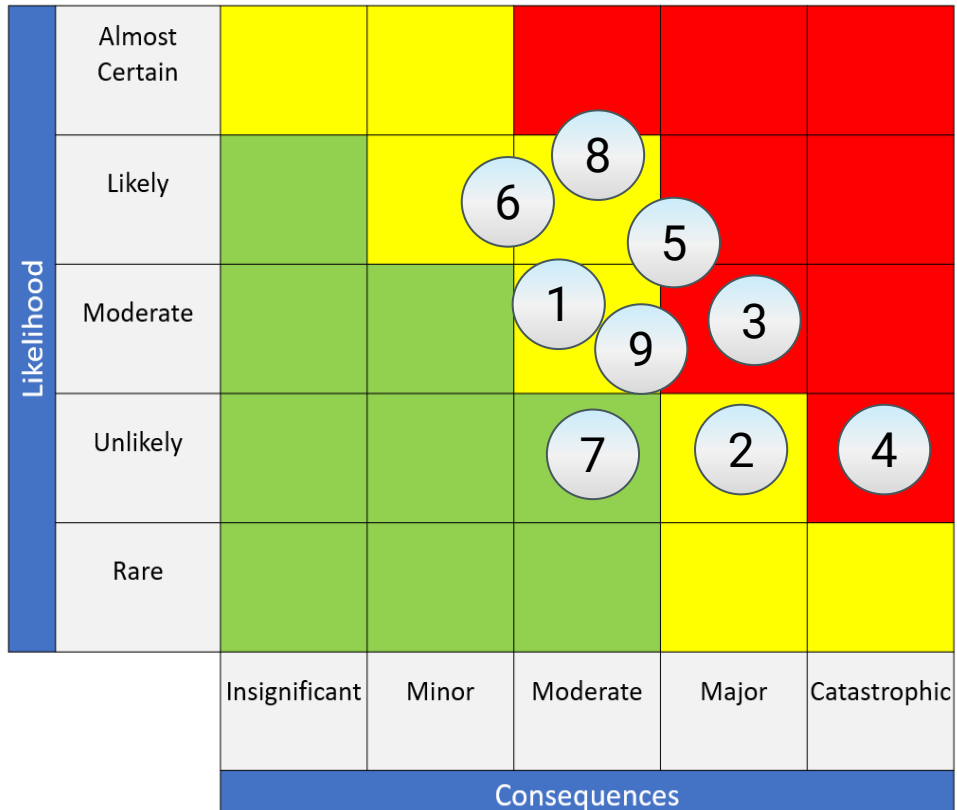


C) Dry cooler printer



D) Low-cost Dry cooler heat exchanger

# CHALLENGES AND RISKS



## Risk Status

Risk	#
Suitable fluids and compatible materials to meet the reliability and cost requirements	1
The heat removal rate from the back of the chip falls short	2
High system pressure drop and hence power consumption	3
Leak risk: Deionized water within server chassis	4
Technology does not meet the FOA target for cooling power as a percentage of IT load	5
Volume of ISO 40-dimensional limitation is exceeded	6
Tier III reliability is not achievable	7
Component degradation within a specified life span	8
Temperature thresholds for components exceed the recommended level	9



# KEY INNOVATIONS

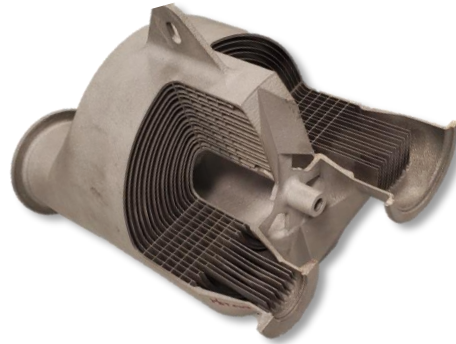
## HEAT TRANSFER ENHANCEMENT IN ADDITIVELY MANUFACTURED DEVICES

### ▶ **Heat Transfer Enhancements**

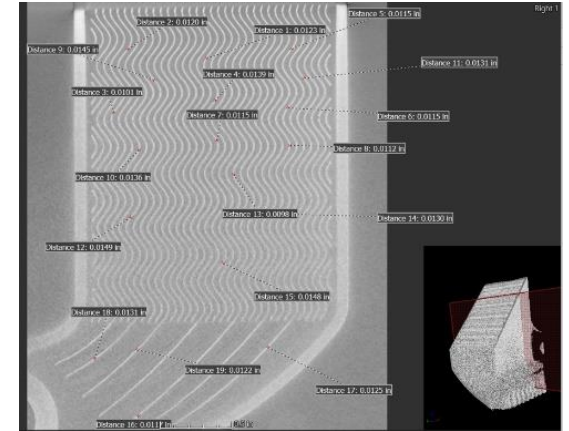
- ▶ *Current aviation approaches*
- ▶ *Topology optimized flow passages and manifolds*

### ▶ **Enabling Capabilities**

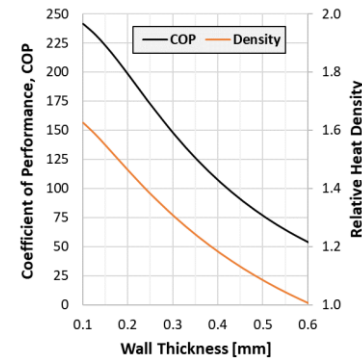
- ▶ *Thin-walled AM fabrication in metals and polymers*
- ▶ *Powder removal from complex flow passages*
- ▶ *Topology optimization toolsets*



3D printing of topology optimized heat exchangers



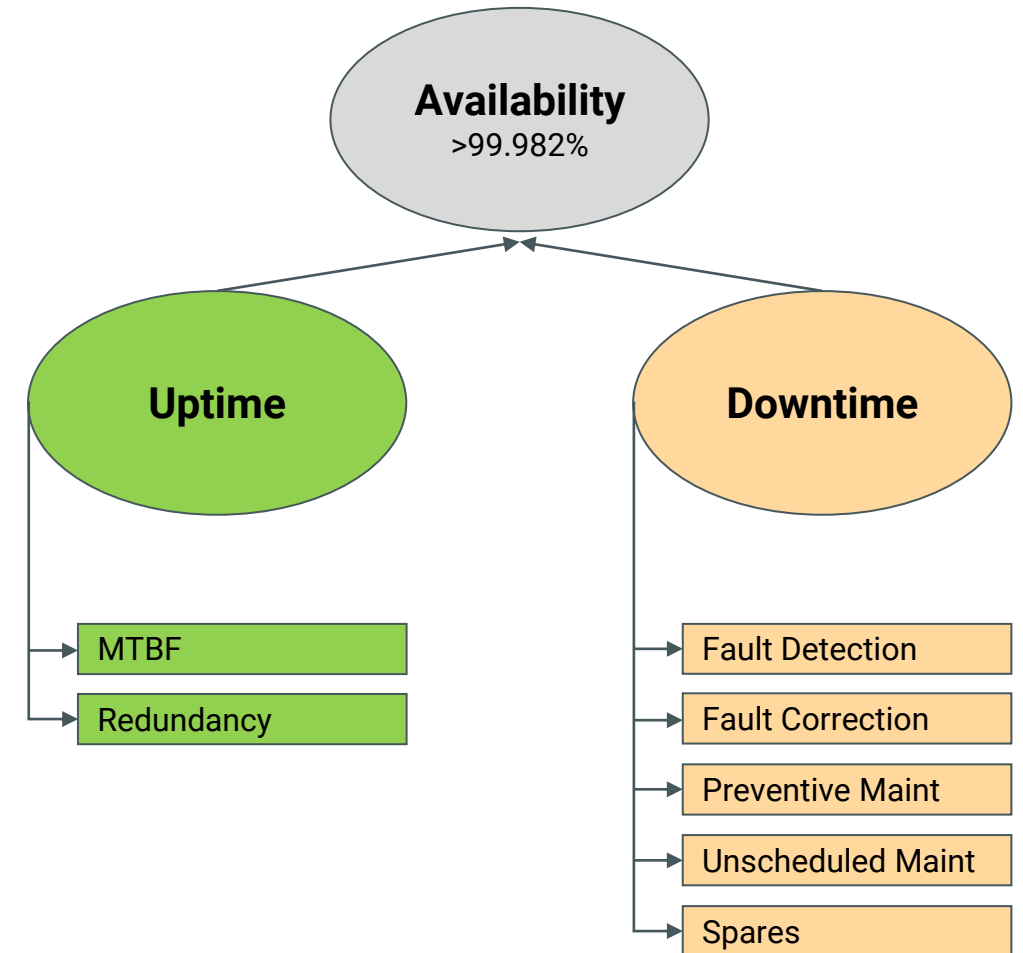
Printing and powder removal from complex flow passages



Polymer Composite Heat Exchangers

# RELIABILITY PROCESSES

- ▶ **Reliability, Availability & Maintainability (RAM) Plan**
  - ▶ *Leverages Boeing's System Engineering processes and expertise*
- ▶ **Failure Mode and Effects Analysis (FMEA)**
  - ▶ *Identify failure modes*
  - ▶ *Minimize impacts to overall system*



# TECHNOLOGY-TO-MARKET APPROACH

- ▶ In parallel with developing the technology for COOLERCHIPS, Flexnode has launched a commercial business around deploying and managing IT infrastructure in modular micro data centers. We are deploying this technology in our own product line, which includes micro data center solutions for both interior and exterior applications.
- ▶ The credibility attached to the COOLERCHIPS grant will help the business to further advance the sustainability benefits of our platform and will catalyze new private sector investments by way of a Series A and B capital raise to expand our business globally.
- ▶ Early demand is concentrated in markets with extraordinary requirements for high density compute, storage and networking, including research and academia, data intensive enterprise and government. Additional long term market opportunities include smart cities, transportation and cellular networks with heavy distributed data management needs.



# Q & A



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**ENERGY**

<https://arpa-e.energy.gov>