COOLING ENVIRONMENTS

Rack-Scale Weight Reduction for Liquid-Cooled Server Systems Using Lightweight Materials

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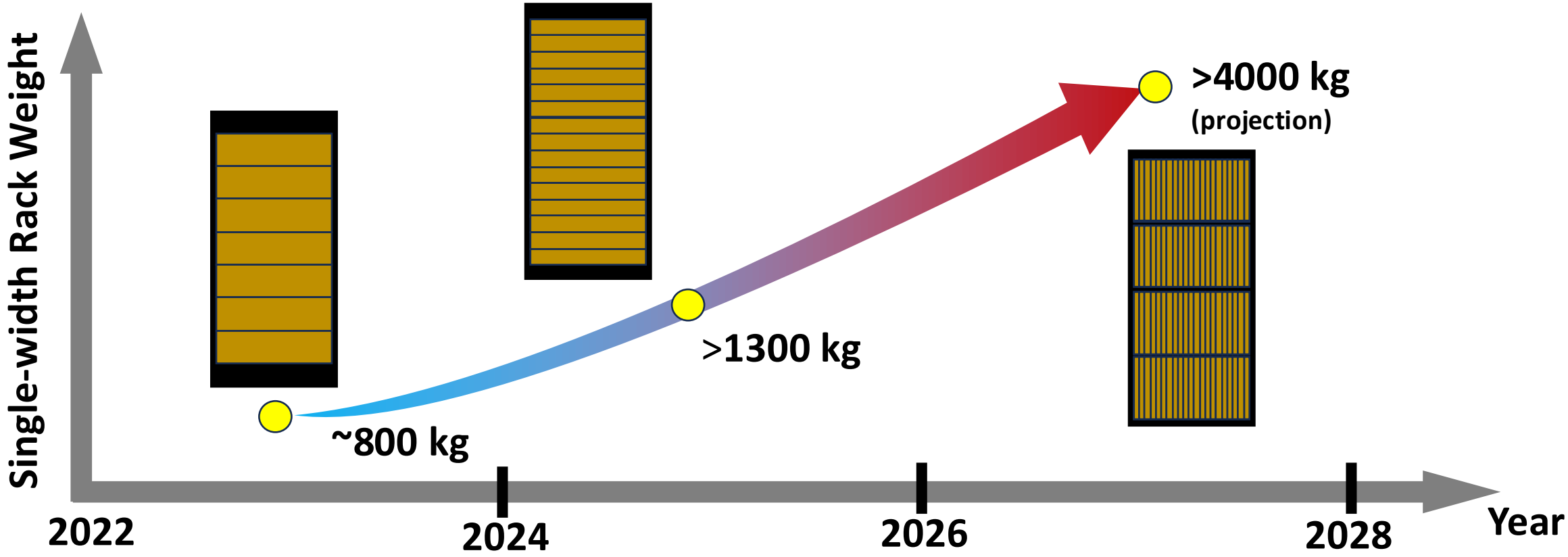
OCP PLATINUM Member

Outline

1. AI Rack Weight Growth Driving Lightweighting
2. Identifying Liquid Cooling Component Candidates for Lightweighting
3. Material Selection for Lightweight Liquid Cooling Components
4. PPS+GF Component Design for Liquid Cooling
5. PPS+GF Component Reliability Validation Items

AI Rack Weight Growth Driving Lightweighting

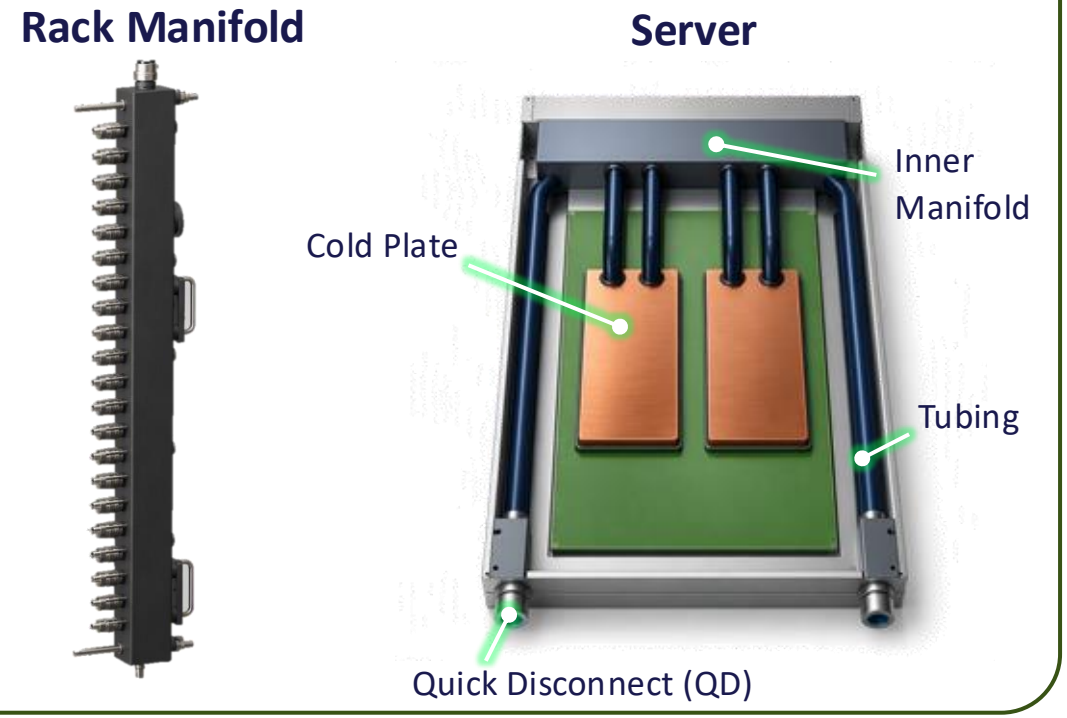
- Growing AI rack weight is challenging data center floor-loading limits
- Lightweighting helps reduce floor-loading demands, material usage, and deployment costs



Identifying Liquid Cooling Component Candidates for Lightweighting

- Cold plates, inner manifolds, and tubing account for over 70% of total liquid cooling component weight in a rack

Liquid Cooling Components



Components	Weight-Reduction Potential
Rack Manifold	Low (Constrained by high mating force)
QD	Low (Limited design flexibility)
Cold Plate	High
Inner Manifold	High
Tubing	High

>70% of total liquid cooling component weight

Material Selection for Lightweight Liquid Cooling Components

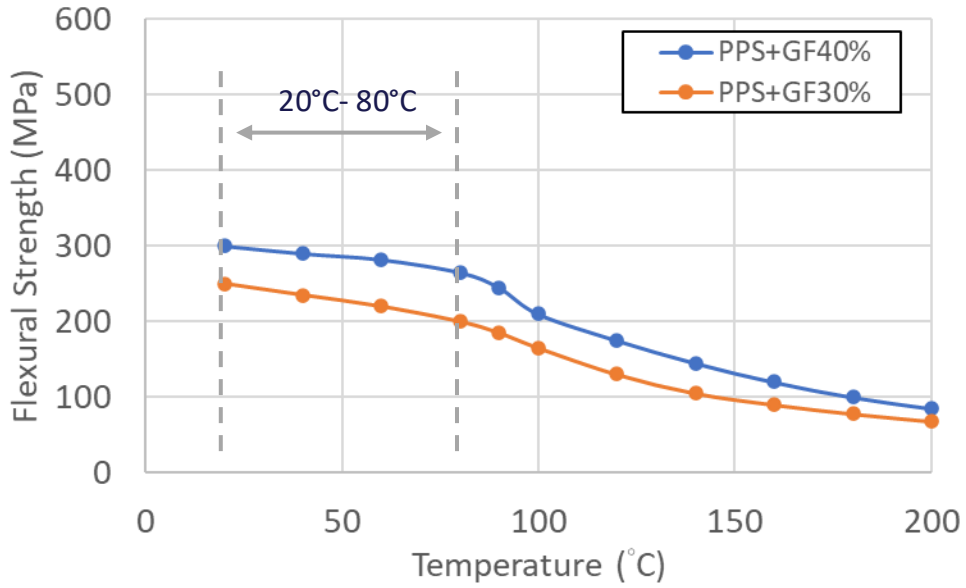
- Material selection requires balancing weight, compatibility, and structural strength
  - Aluminum reduces weight by ~70% vs. copper while retaining sufficient thermal and structural performance
  - PPS+GF offers the lowest density with good PG25 compatibility

Property	Copper	Aluminum	Plastic (PPS+GF)
Density	High (~8.9 g/cm³)	Moderate (~2.7 g/cm³)	Low (~1.66 g/cm³)
Compatibility with PG25	Compatible	Compatible	Compatible
Thermal Conductivity	High (~400 W/m·K)	Moderate (150~200 W/m·K)	Low (<1 W/m·K)
Structural Strength	High	Moderate to High	Moderate

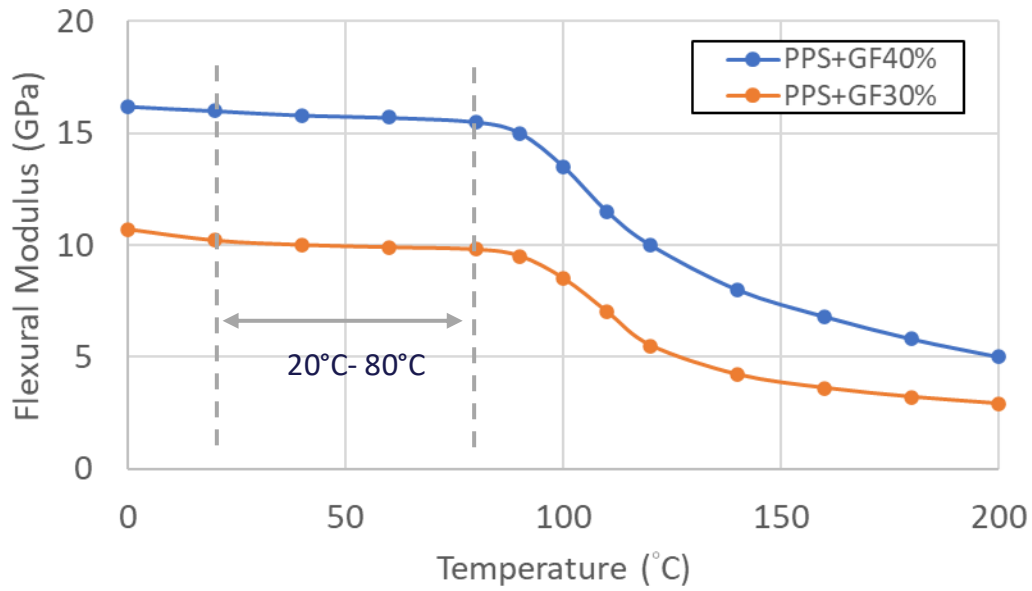
PPS: Polyphenylene Sulfide
GF: Glass Fiber

PPS+GF Maintains Strength and Stiffness from 20°C to 80°C

Flexural Strength of PPS+GF



Flexural Modulus of PPS+GF

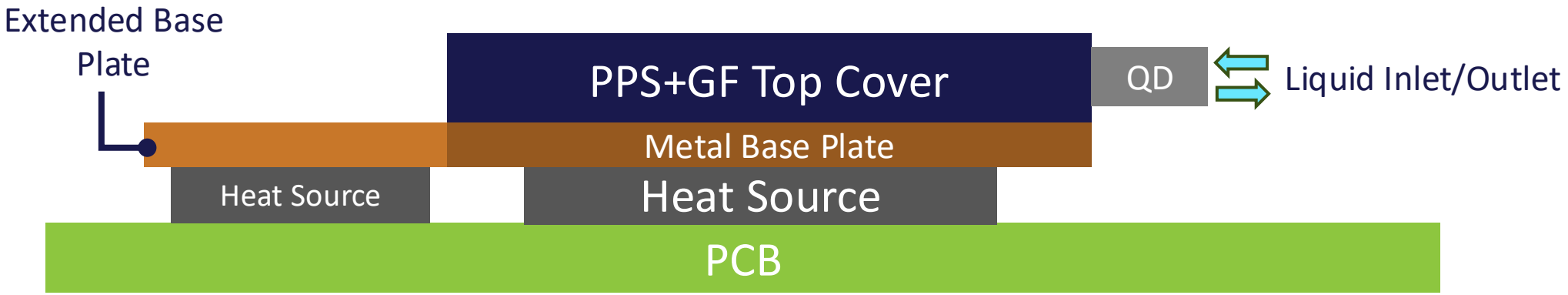


Both flexural strength and flexural modulus retain at least 80% of their room-temperature values up to 80°C

Reference: PPS+GF material property data from the DIC PPS Product Guide

Lightweight Cold Plate without Compromising Thermal Performance

- A cold plate typically consists of a top cover and a metal base plate
  - Replacing the top cover with PPS+GF reduces weight
  - The metal base plate is retained to preserve heat transfer performance
  - The base plate can be extended to cool adjacent components simultaneously

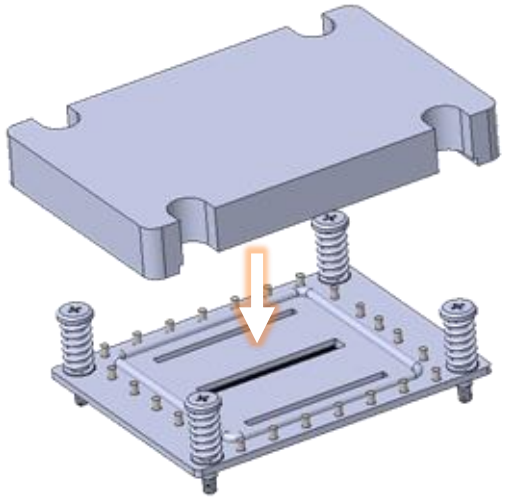


Lightweight Cold Plate Architecture

Joining Methods for Plastic-Metal and Plastic-Plastic Interfaces

- Multiple joining methods were evaluated for manufacturability, structural strength, and sealing

Cold Plate



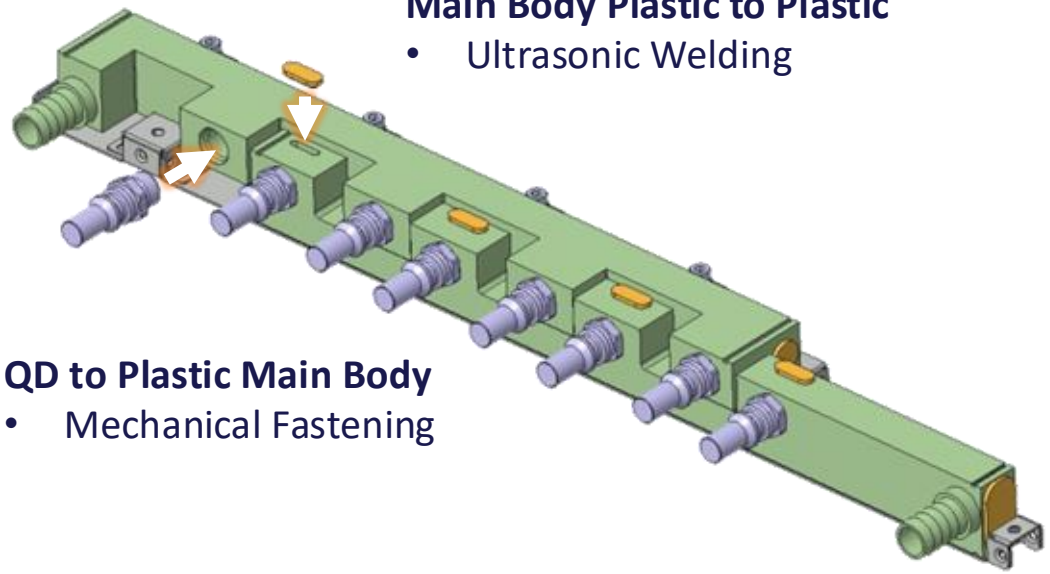
Plastic Top Cover to Metal Base Plate

- Mechanical Fastening
- Overmolding
- Others

Inner Manifold

Main Body Plastic to Plastic

- Ultrasonic Welding



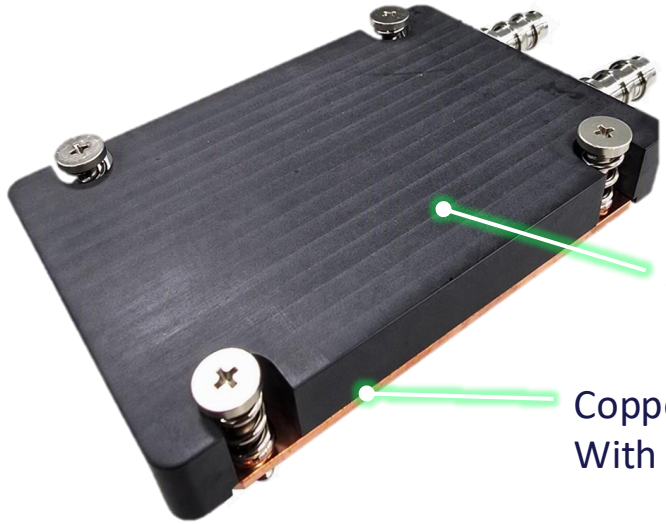
QD to Plastic Main Body

- Mechanical Fastening

PPS-Based Designs Achieve >50% Weight Reduction

Cold Plate

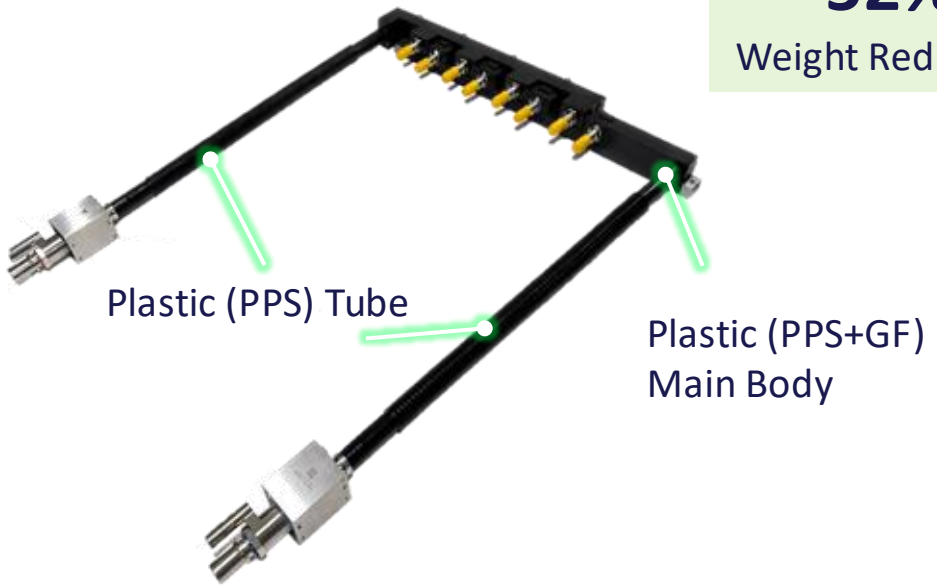
66%
Weight Reduction



- Top Cover Replaced with PPS+GF
- Metal Base Retained for Thermal Performance

Inner Manifold

52%
Weight Reduction



- Metal Main Body Replaced with PPS+GF
- Plastic Tubing Implementation

Reliability Validation for Plastic Components

- Plastic Cold Plates and Inner Manifolds are validated against thermal, pressure, and environmental stresses to ensure long-term reliability in liquid-cooling applications
- Both the cold plate top cover and inner manifold showed no leakage at 100 psi. The cold plate top cover exhibited only 0.0018 mm of flatness change, within specification

- **Thermal Reliability**
  - Thermal Cycling Test
  - 2,000-hour Accelerated Life Test
  - MTBF Verification
- **Pressure Reliability**
  - Pressure Cycling Test
  - Burst Pressure Test
- **Environmental Reliability**
  - Storage Test
  - High Humidity Test (85°C / 85%RH)

Plastic Cold Plate



Plastic Inner Manifold



Pass Criteria:

- No Leakage
- No Cracks, Deformation, or Bulging
- No Change in Thermal Resistance
- No Change in Pressure Drop
- Full Functionality Retained After Reliability Testing

Conclusions

- Effective lightweighting requires both material selection and structural design, while balancing weight, structural integrity, performance, coolant compatibility, and reliability
- PPS+GF enables significant weight reduction without compromising functionality. A PPS+GF top cover with a metal base plate maintains cold plate performance, while reducing inner manifold weight
- Comprehensive reliability validation is planned to assess the long-term feasibility of PPS+GF liquid-cooling components, including thermal, pressure, and environmental reliability under representative operating conditions

Call for Action

- Future Work
  - **Validate Long-Term Reliability of PPS+GF:**

    Continue evaluating PPS+GF components through extended reliability testing to confirm their long-term feasibility in liquid-cooling applications
  - **Explore Additional Cold Plate Joining Methods:**

    Continue evaluating alternative joining technologies for cold plate assemblies to improve reliability, manufacturability, and design flexibility
  - **Expand Lightweight Material Applications:**

    Continue investigating alternative lightweight materials and exploring additional liquid-cooling components for implementation, maximizing system-level weight reduction while maintaining performance and reliability
- Get involved in Cooling Environments – Cold Plate Sub-project
  - Every 2nd Wednesday of the Month from 8am-9am PT
  - https://www.opencompute.org/w/index.php?title=Cooling_Environments/Cold_Plate

Thank You!

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