Micro- and Mini-Dimensional Heat Transfer in Spacecraft & Aircraft Technologies

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Industry Panel — Current and Future Trends in Liquid Cooling of Electronics

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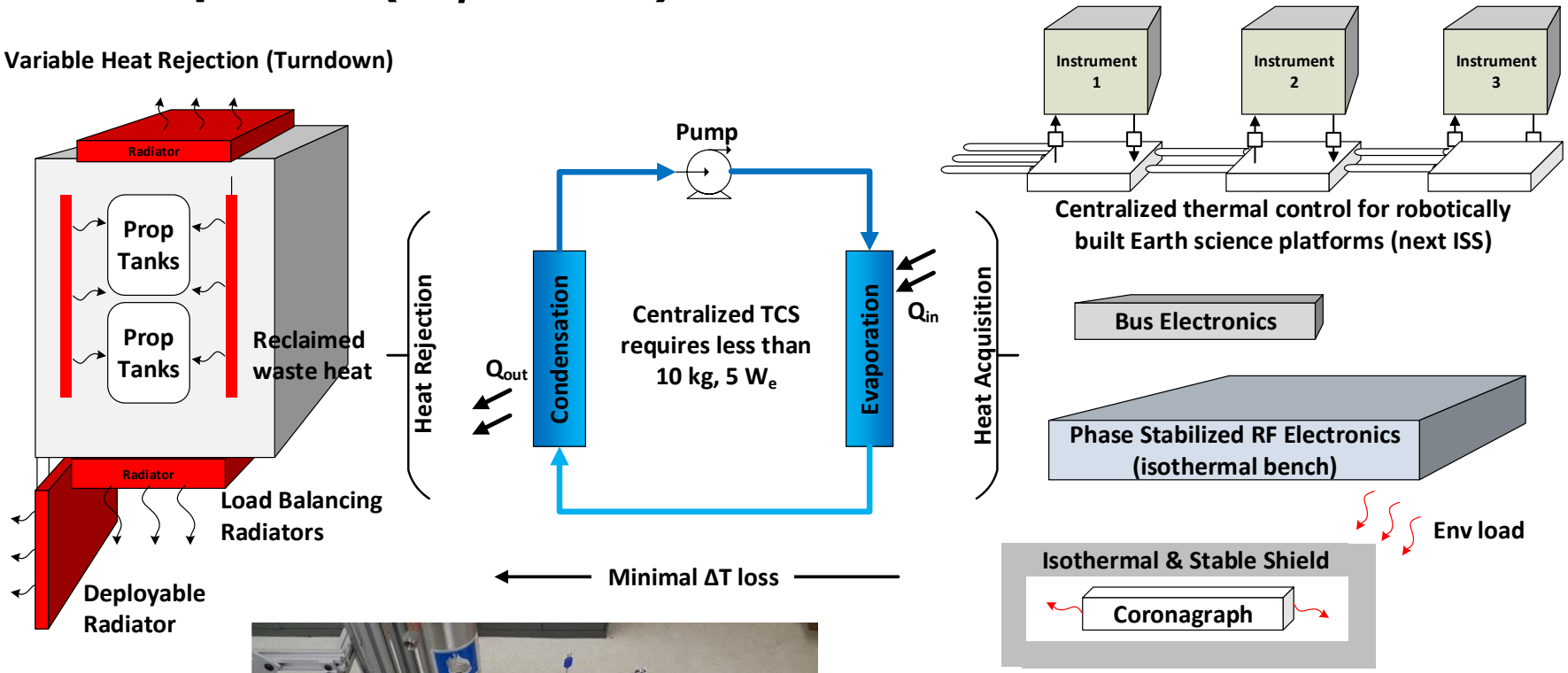
Challenge: Thermal Control for Deep Space Small Spacecraft

- Objective: Develop a thermal bus system (spanning both the bus and payload interfaces) that enables deep space exploration to 10 AU at low cost
- Needs
  - Order of magnitude reduction in TCS power and 50% reduction in mass over current state-of-the-art.
  - Accommodates high heat fluxes up to 5 W/cm2; isothermalization of < 3 ^{o}C over a 1-m payload bench; temporal stability of < 0.05 ^{o}C/minute.
  - Modular, scalable, configurable to enable integration flexibility and at reduced costs.
  - High degree of control authority to reduce uncertainty and thermal testing costs.

Performance Parameter	SOP Large Sat	SOP CubeSat	Proposed Small S/C (~ 250 kg dry)
Cooling Load (W_t)	500	30-50	> 500
Thermal - Mass (Kg)	75 - 100	< 0.5 kg	10
Thermal - Power (W_e)	100 - 300	< 5 W	5
TRL	9	9	3

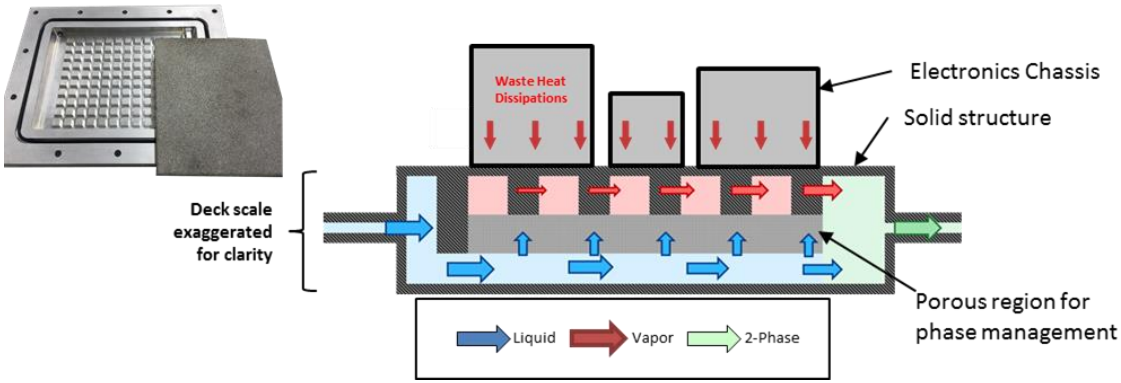
Thermal Control for Deep Space Small Spacecraft—Two-Phase Mechanically Pumped Fluid Loop Development (2-ϕ MPFL)



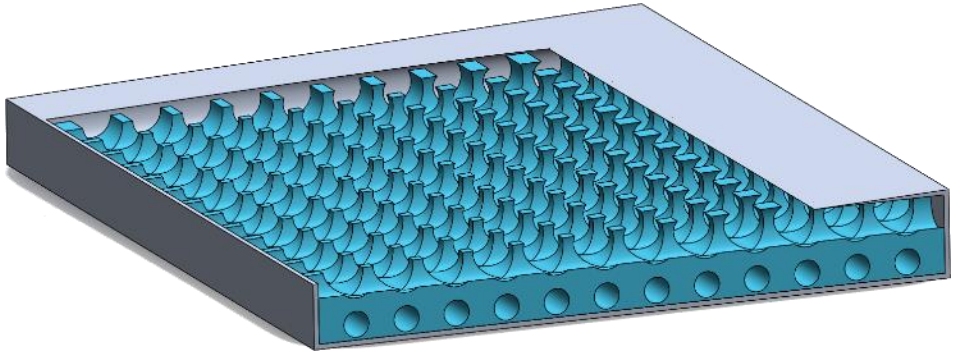
Sub-scale testing at JPL

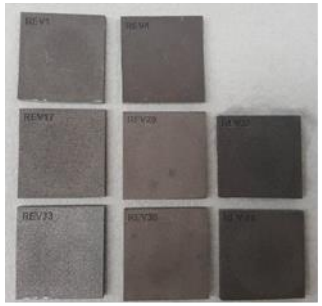
Multifunctional Thermal Structure – Innovative Two-Phase Cold Plate

Traditional 2ϕ heat exchangers require lengthy and separate materials procurements, fabrication, and assembly.

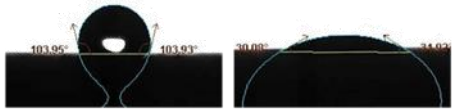


An AM fabricated aluminum wick absorbing water.



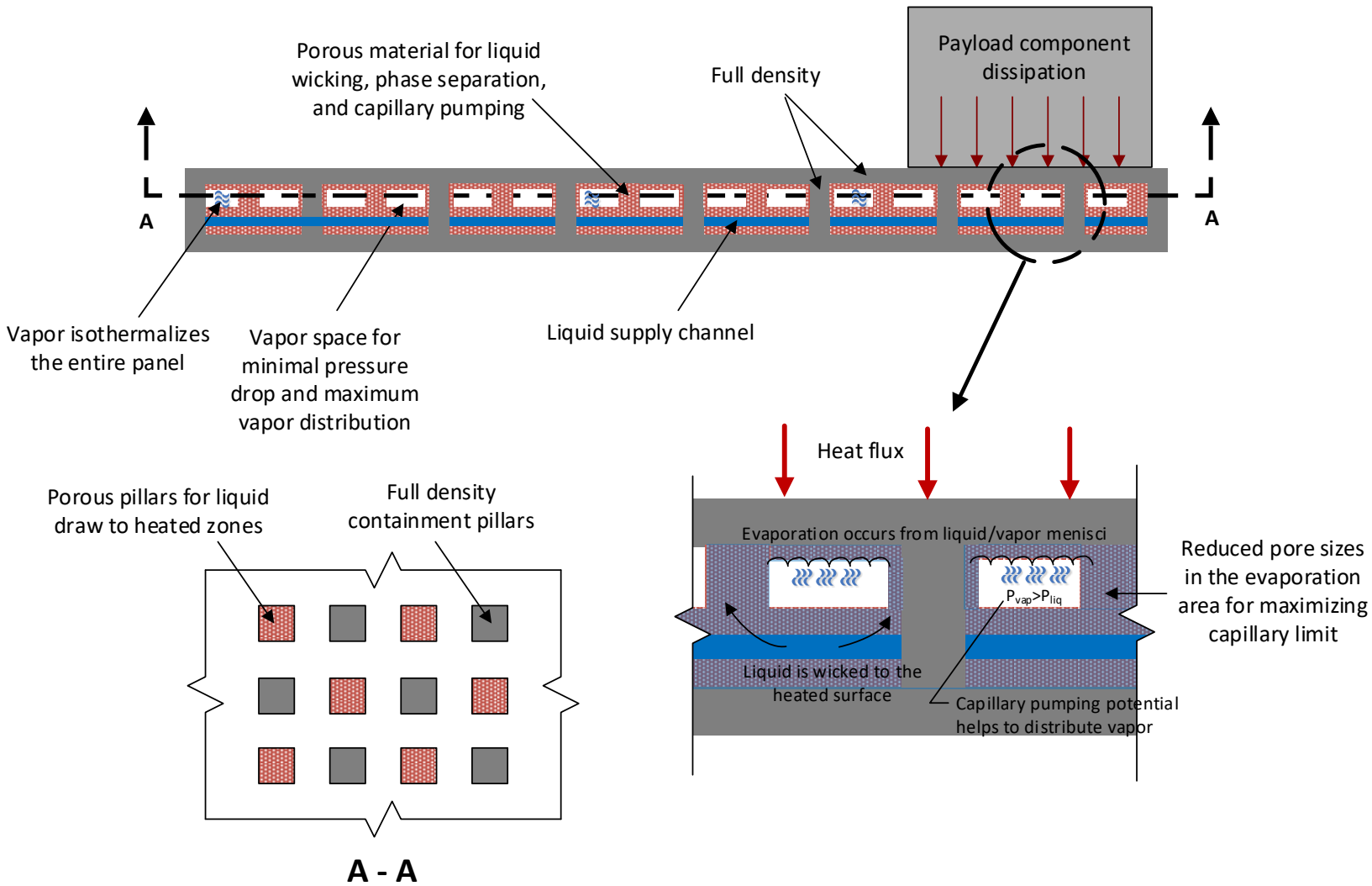


Additively manufactured porous media



Novel cold plate designs can be created with variable porosity structural elements and open liquid passage ways to decrease mass and improve performance

Multifunctional Thermal Structure – Innovative Two-Phase Cold Plate (cont'd)

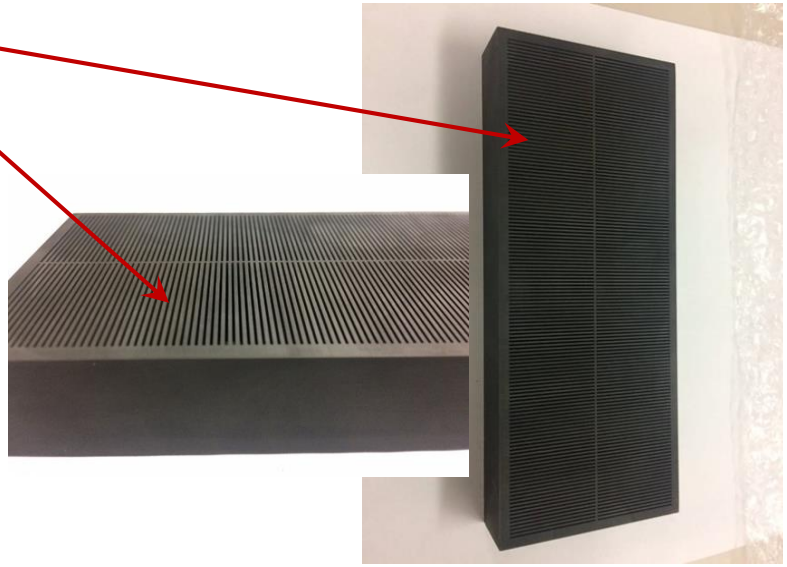


The ability to additively build variable porosity structures opens a new domain space for two-phase heat transfer devices

Graphite Heat Exchanger Technology

Challenge: High Performance Heat Exchange Technology for Terrestrial and Planetary Energy Recovery and Thermal Management

- **Demonstrated Minichannel Graphite Heat Exchange Technology @ JPL**
  - **Minichannels shown to right**
  - **Could be gas or liquid HEX**
- **High Temperature Heat Exchange**
  - **500 μm channel widths**
  - **4.8 W_{th}/cm^3**
  - **Low Density, Light weight - 128 grams**
  - **High Thermal Conductivity**
  - **Low CTE**
  - **Reasonably good strength**
  - **Good manufacturability**



Looking to additively manufacture this unique structure
This represents the innovative focus that is required to move micro- and mini-scale heat transfer technology into main stream

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