Solving the Thermal Challenge in Power-Dense CubeSats with Water heat Pipes

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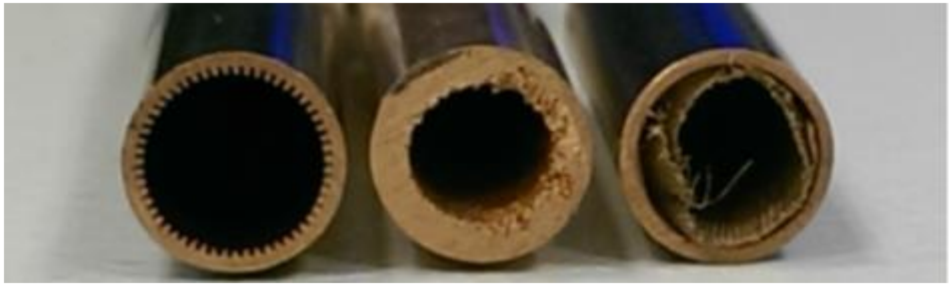
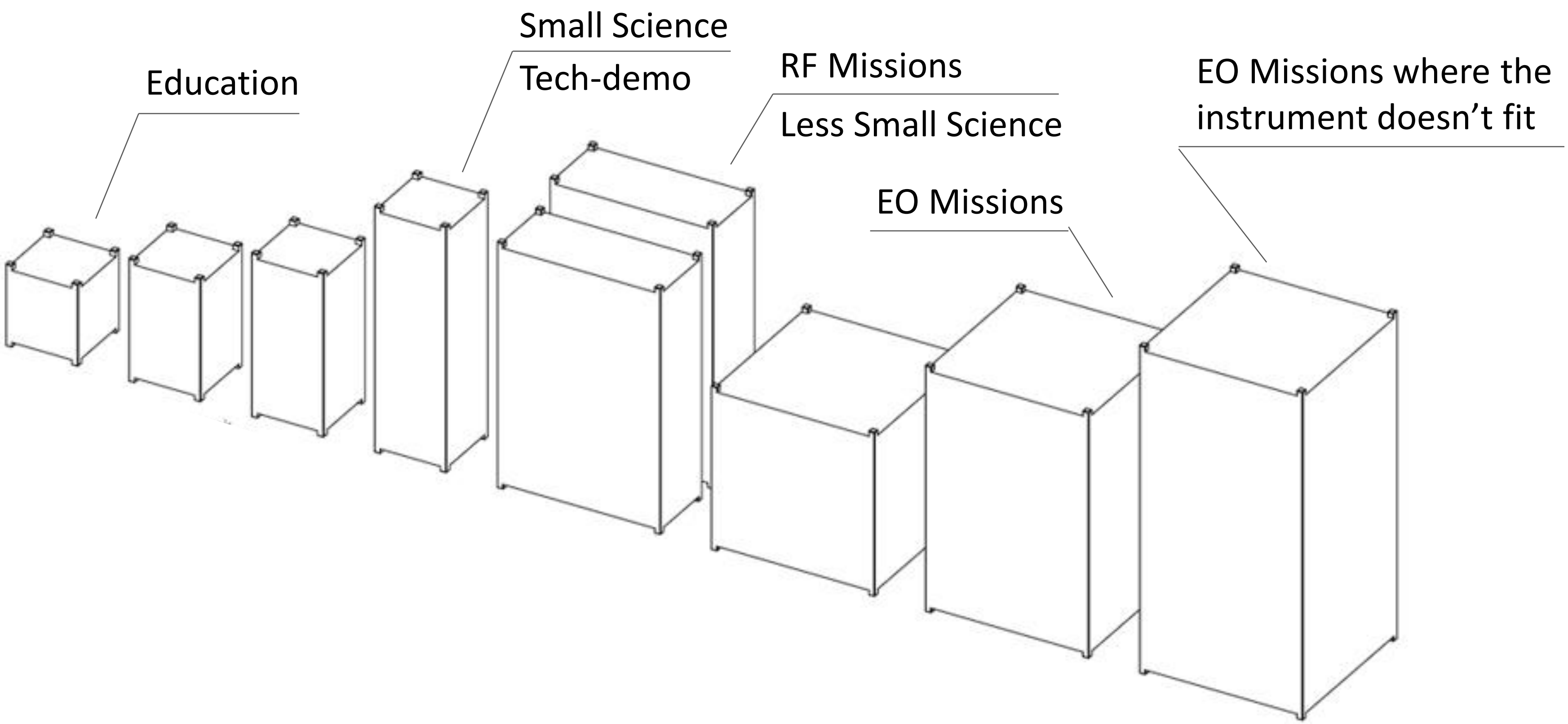
Contents

- Power-Dense CubeSats
- The Thermal Challenge
- Water Heat Pipes as Solution
- Solving the Challenge



Power-Dense CubeSats - Trends



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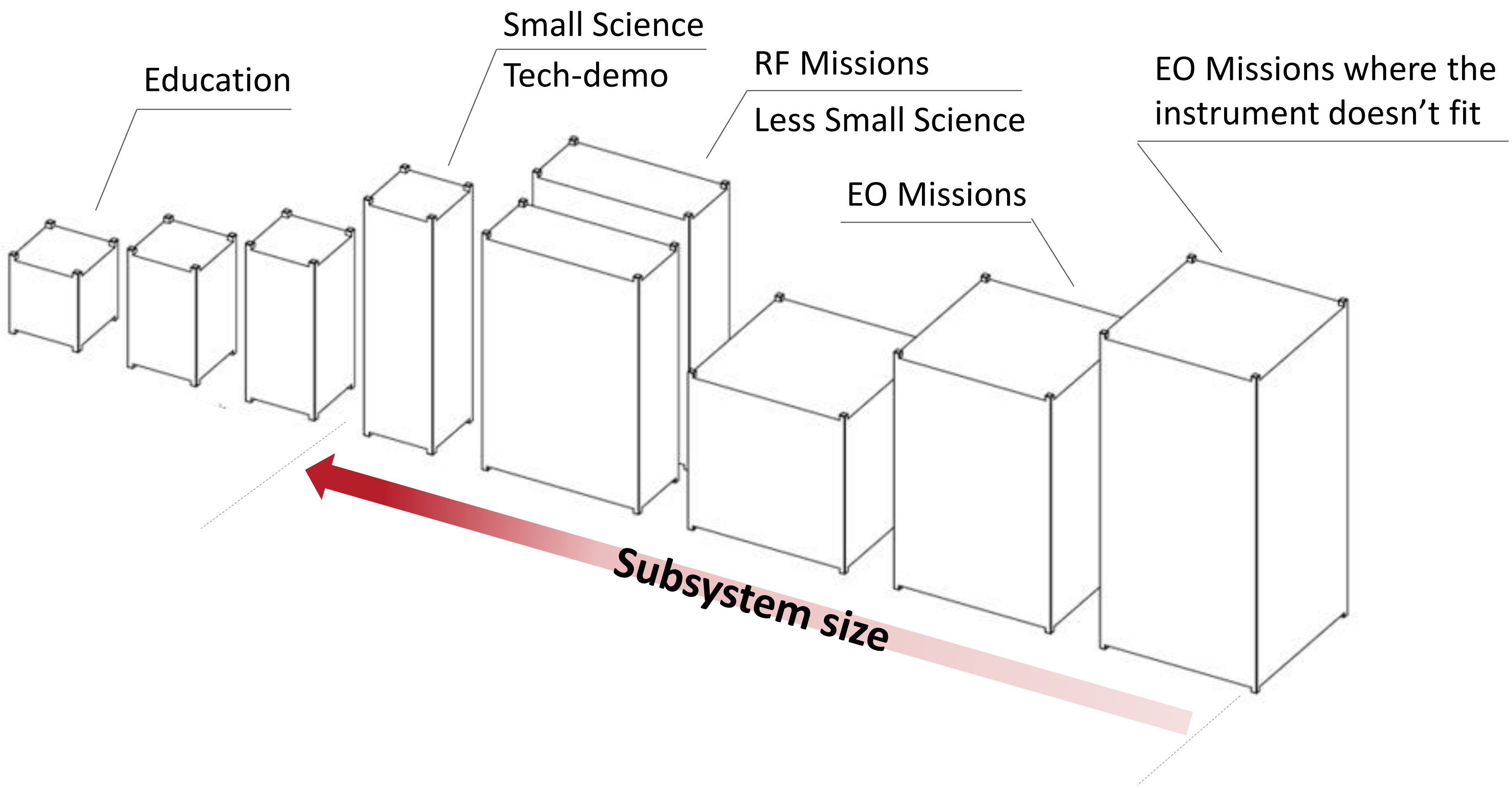

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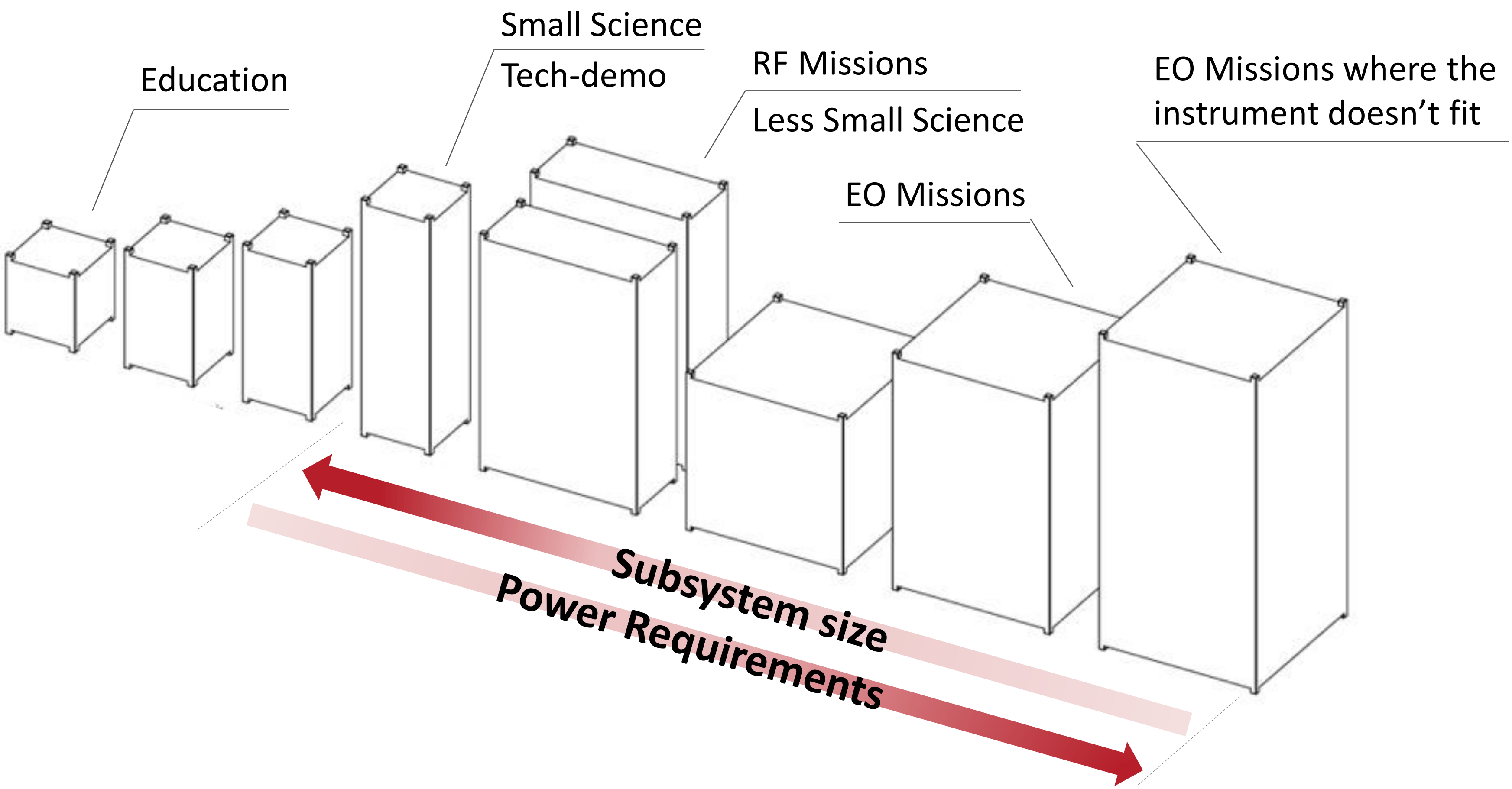

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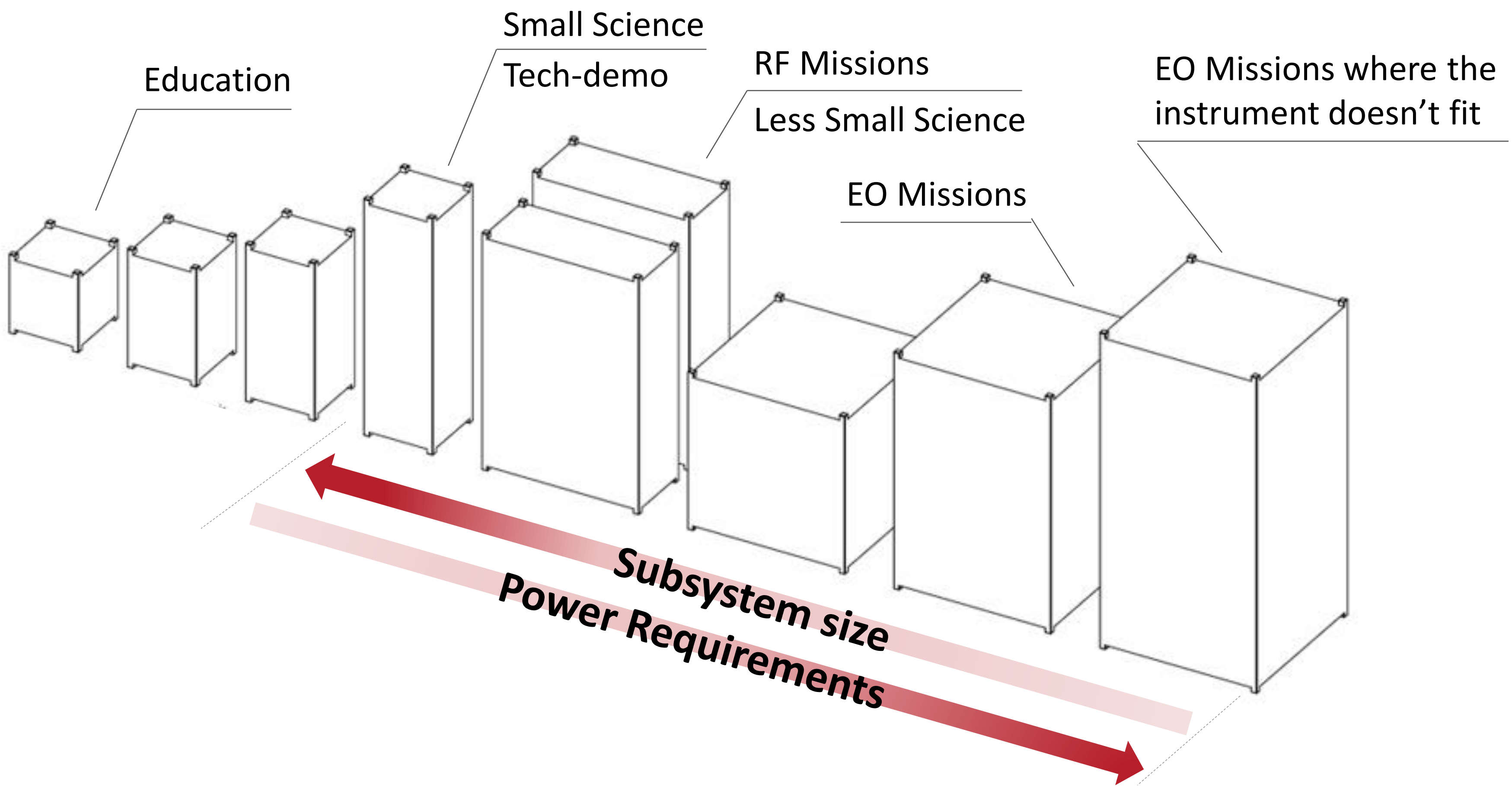
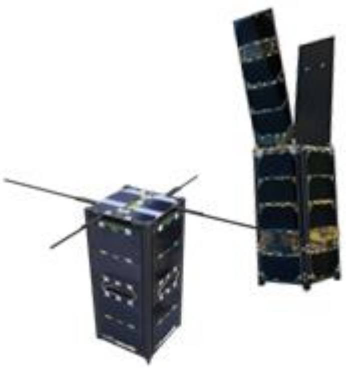


Shift towards high-performance missions lead to stricter thermal requirements

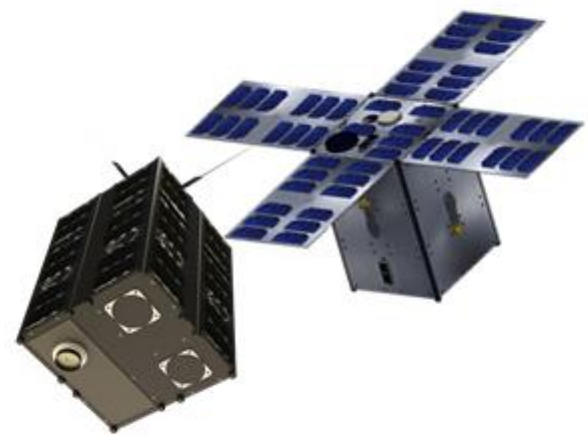
Power-Dense CubeSats - Trends

The hunger for more power is being answered:



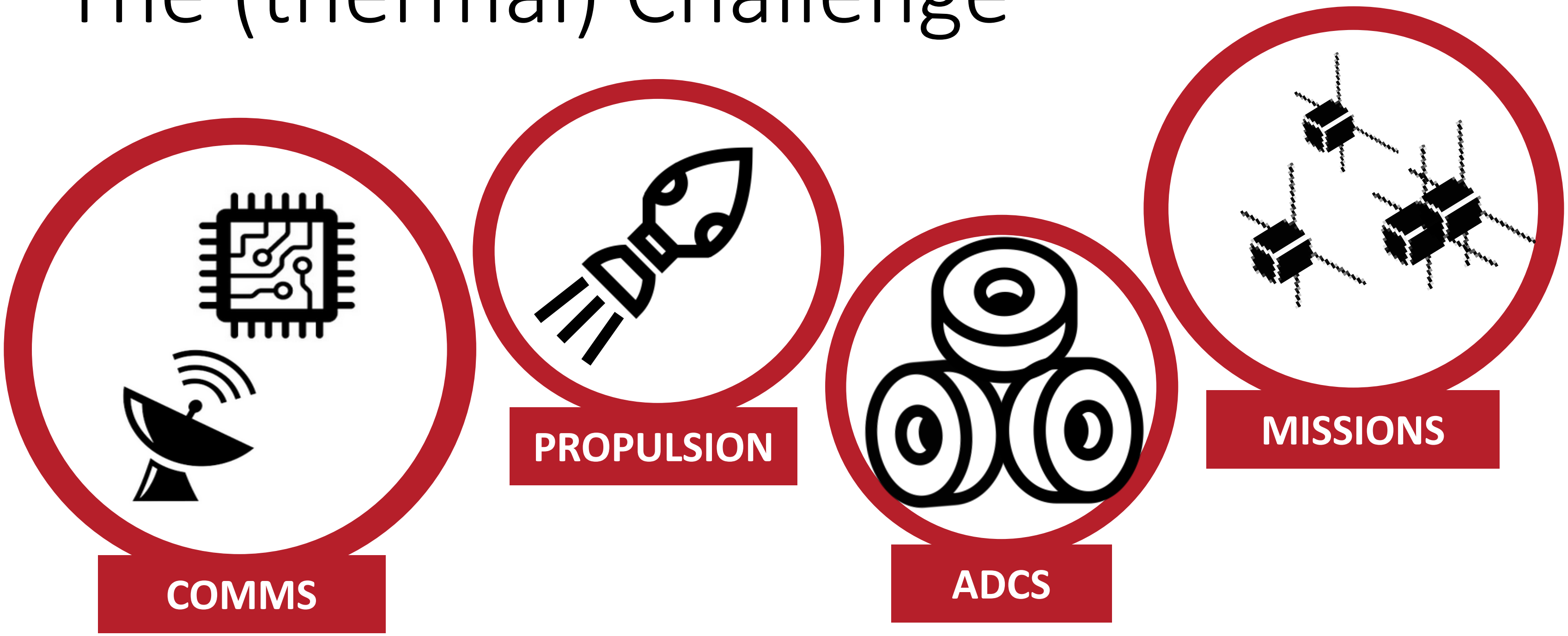
3W to 8W

7W to 15W

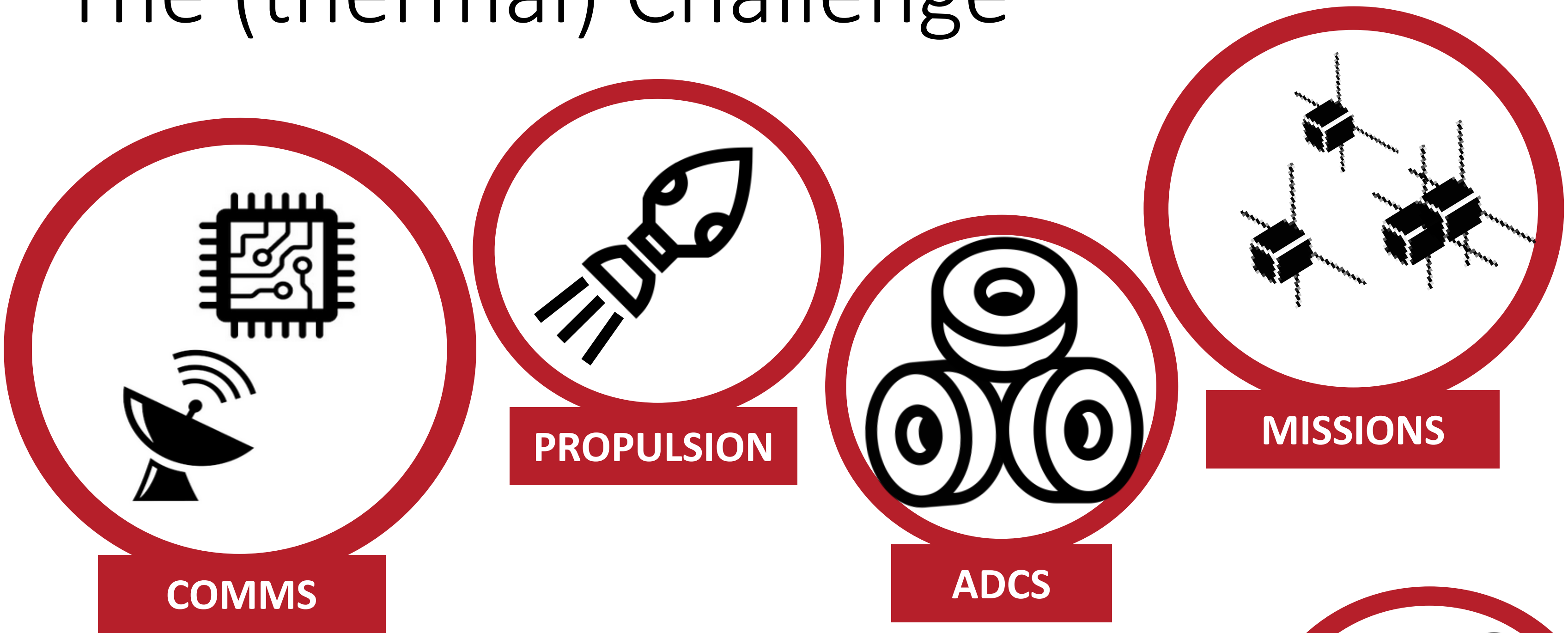


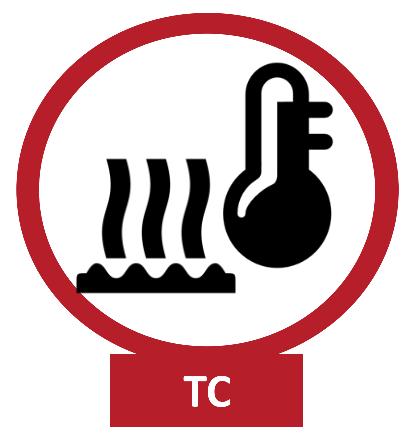
15W to 25W

The (thermal) Challenge



The (thermal) Challenge





Putting the attention to thermal control...

# Presentations at SmallSat 2017:		125

# Presentations on thermal control:		2

The Thermal Challenge

Power density goes up and...

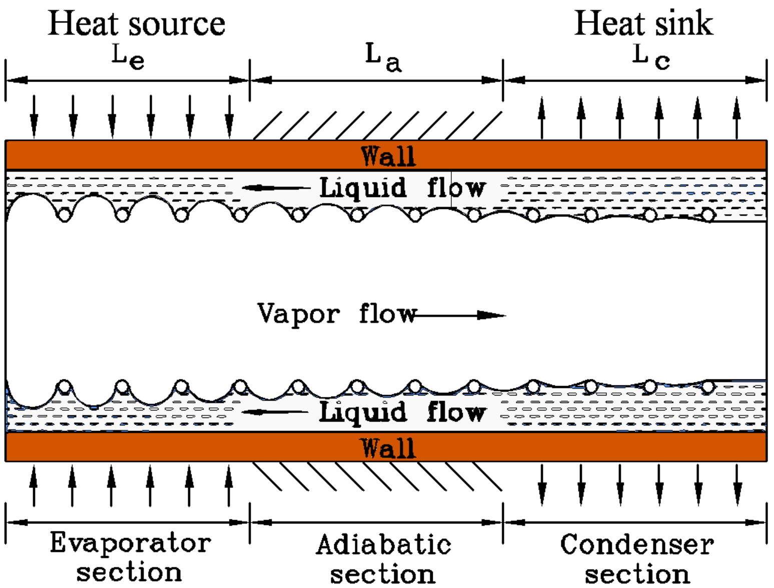
... Local hotspots appear

- Densily packed stacks driven by the CubeSat Standard
- Subsystem PCBs low conductivity
- Difficult to apply dedicated thermal control solutions

Heat Pipes to the Rescue

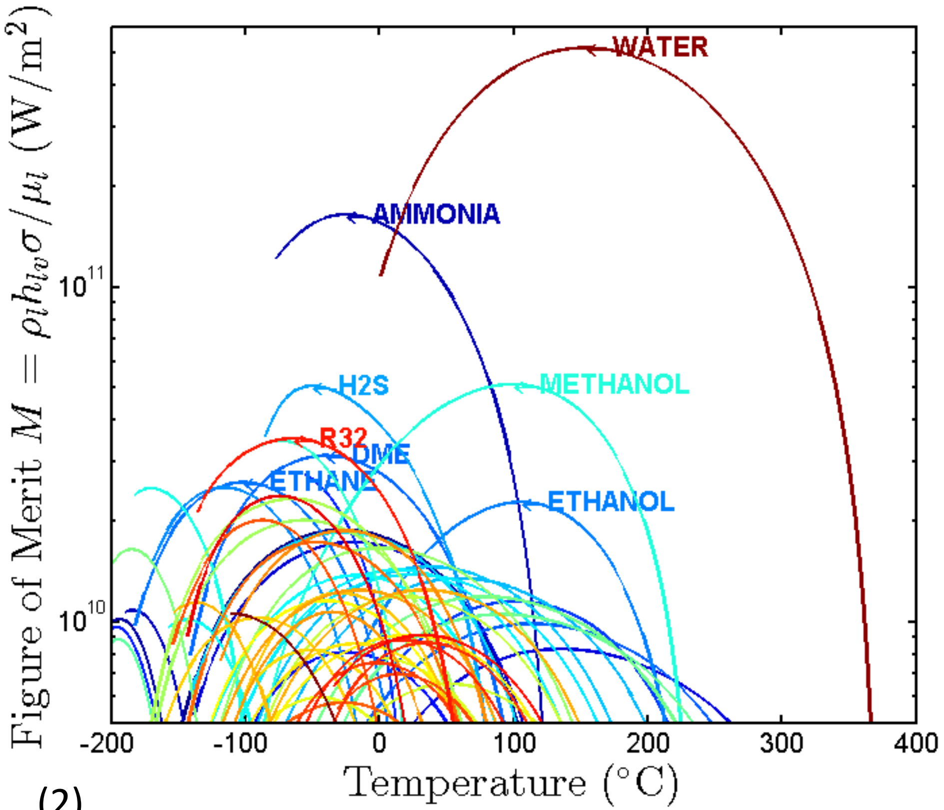
- Heat pipes extensively used on Earth and in Space
- Passive thermal control method
- Bending and heat input flexibility
- (Potentially) low thermal gradients
- COTS and cheap!

$$\Delta p_c = \Delta p_l + \Delta p_v + \Delta p_g$$



(1)

The Solution: Water Heat Pipes



(2)

Water as working fluid

- Unmatched performance
- Non-hazardous fluid
- Abundant availability

$$\dot{Q} = \left(\frac{N A_w r_{h,l}^2}{l_{eff}}\right)\boxed{\left(\frac{\sigma_l \rho_l h_{lv}}{\mu_l}\right)}\left(\frac{2}{r_c} - \frac{\rho_l g\, l_{eff} \sin(\phi)}{\sigma_l}\right)$$

Solving the Thermal Challenge

Requirements

- Remove a representative continuous heat dissipation
- Survive LEO environment

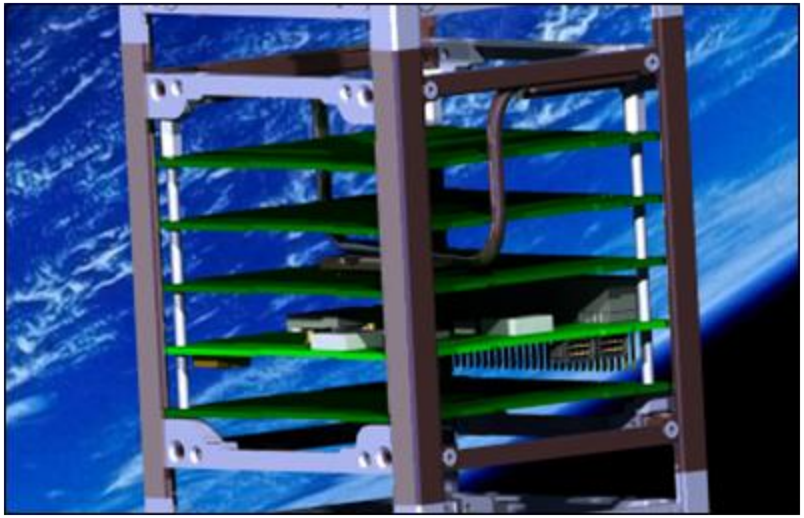
Challenges

- Integration into the CubeSat structure
- Repetitive freeze-thaw cycling
- Transient start-up from frozen state

Challenge: Heat Pipe Integration

Proposed design

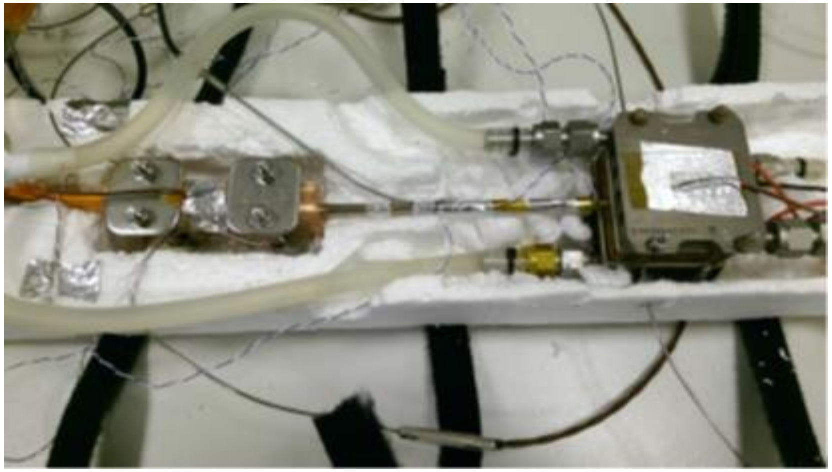
- No or little impact on other subsystem PCBs
- Interfaces similar to Earth-based applications
- Direct coupling with external frame to quickly remove the waste heat

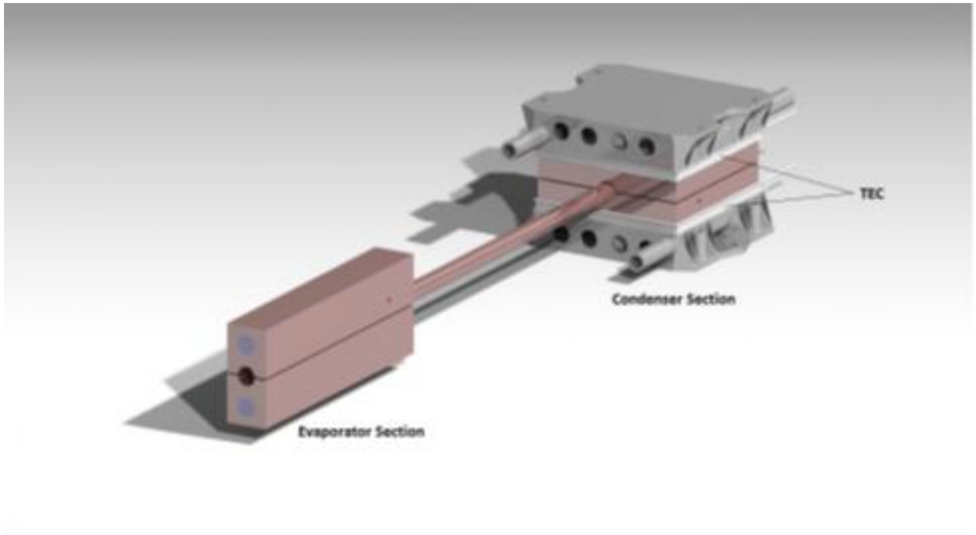


Challenge: Freeze-Thaw Cycling

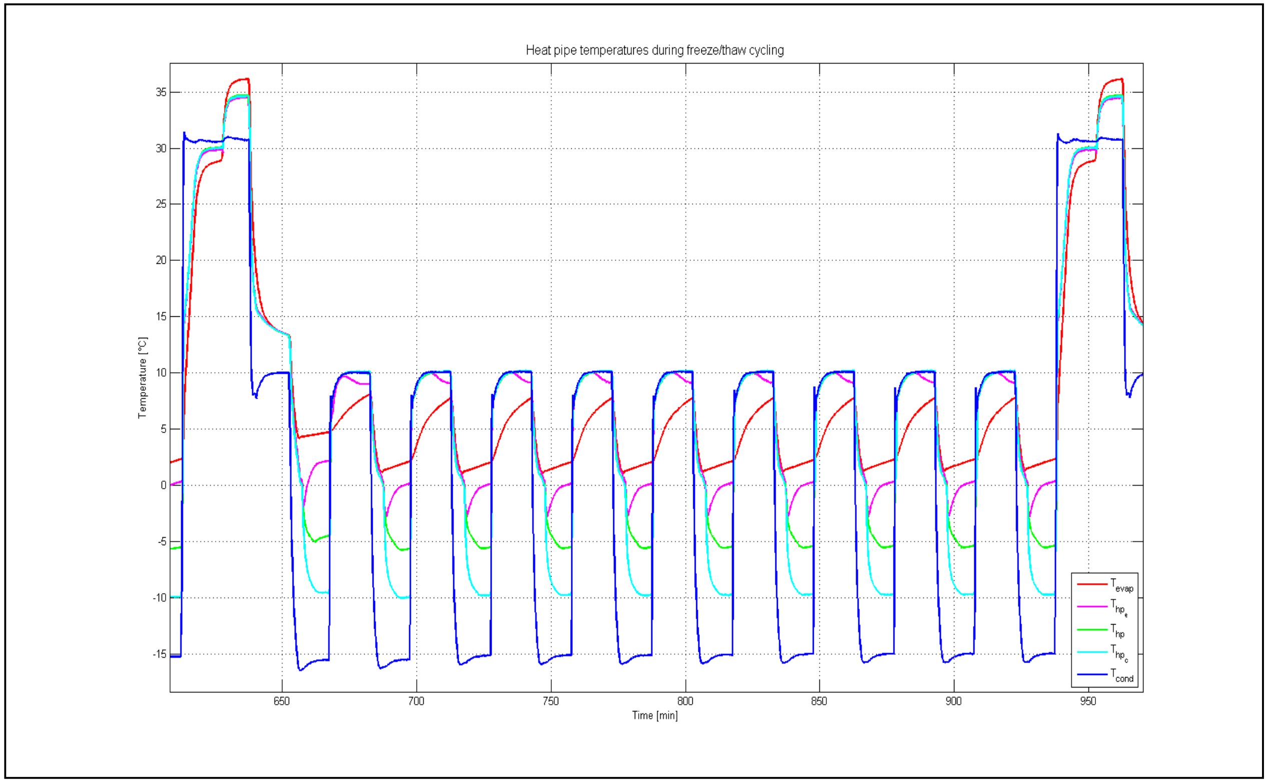
Test Set Up

- Heat pipe temperature from -15 to +10 degC
- Functional test after every 10 cycles
- 100 cycles in total





Challenge: Freeze-Thaw Cycling



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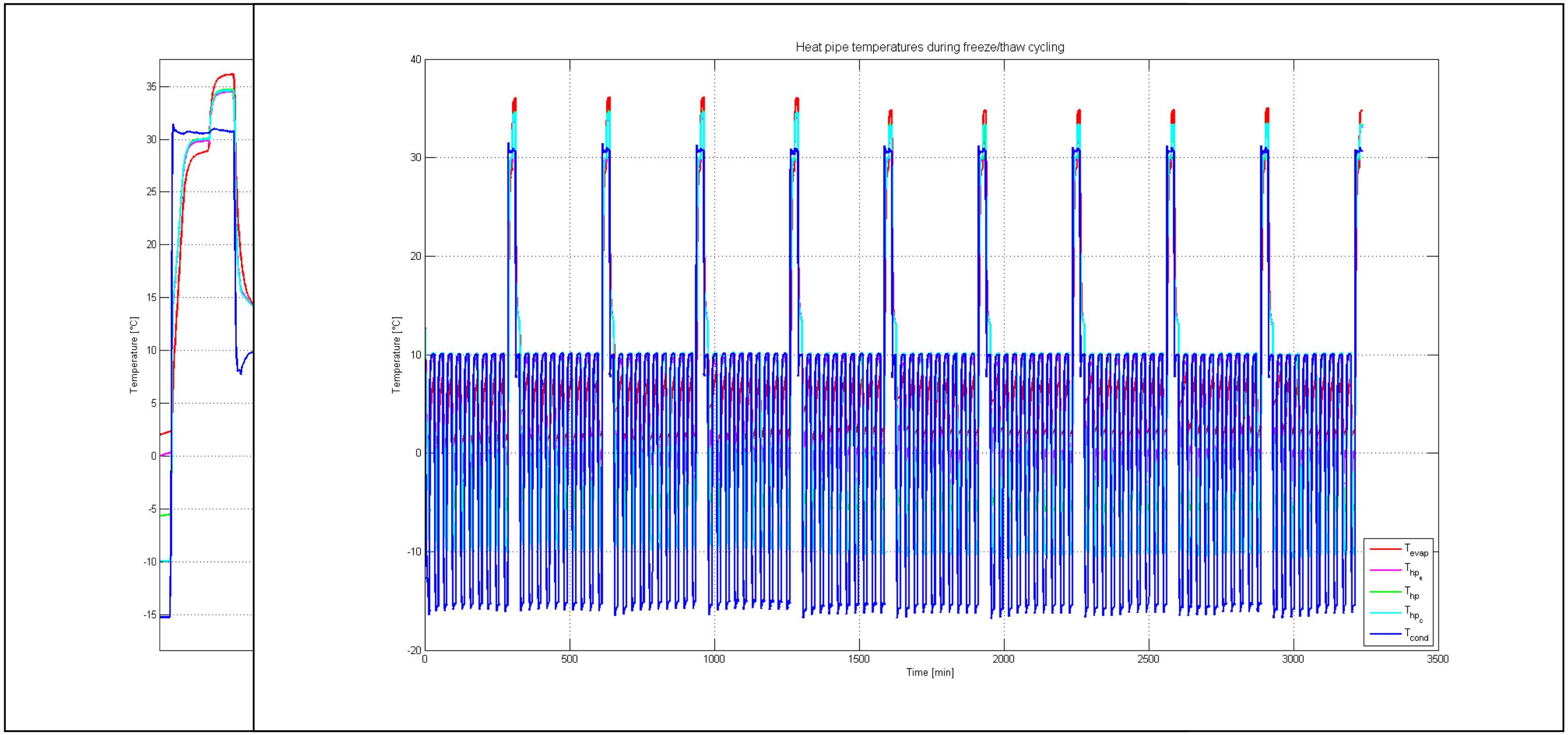
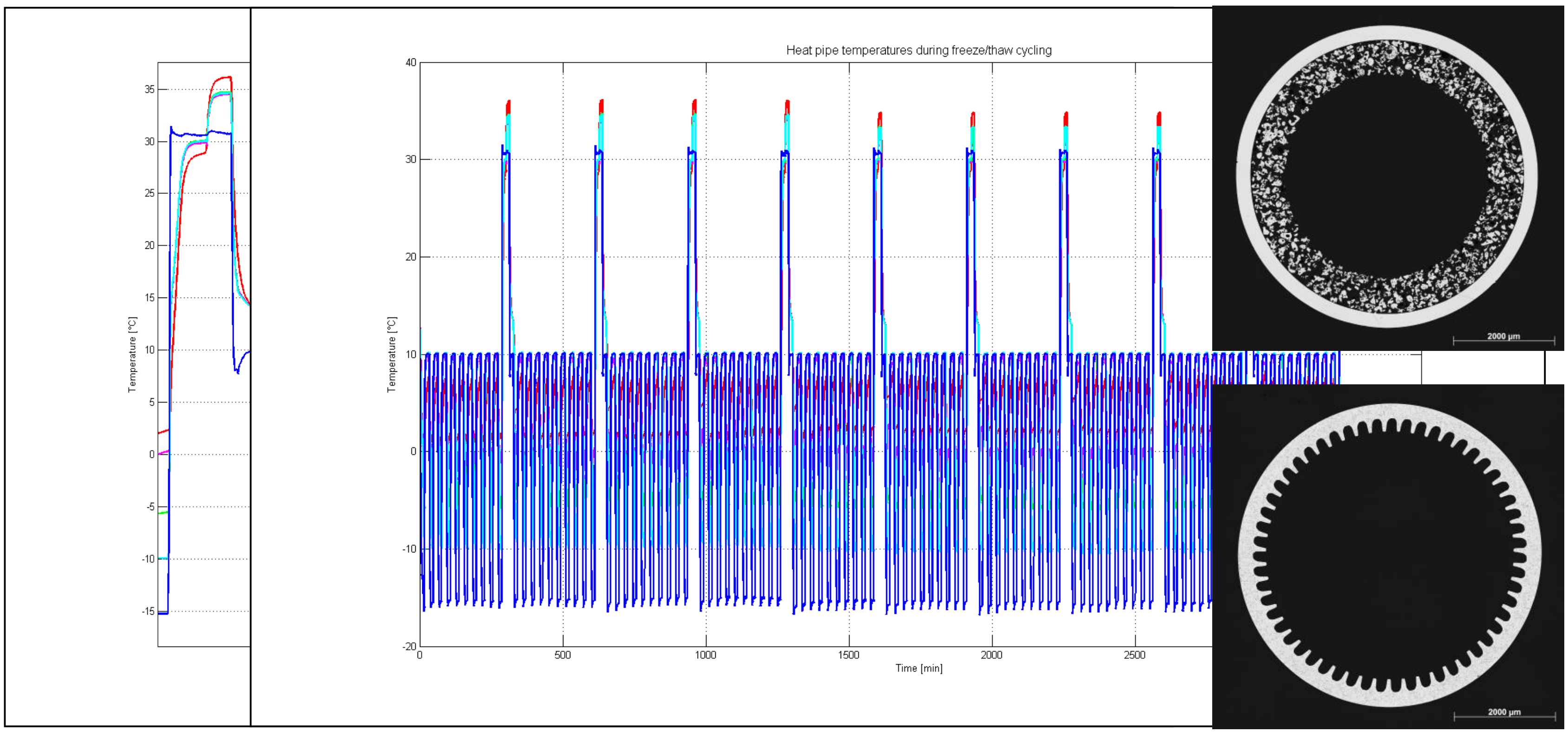


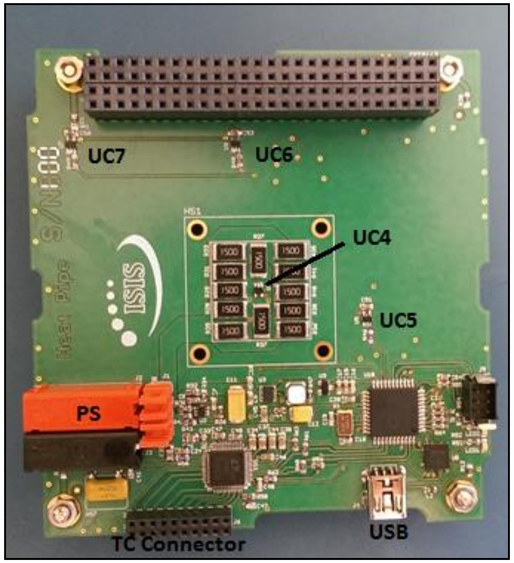
Challenge: Freeze-Thaw Cycling

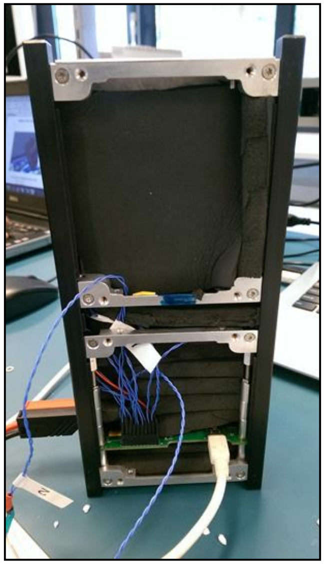
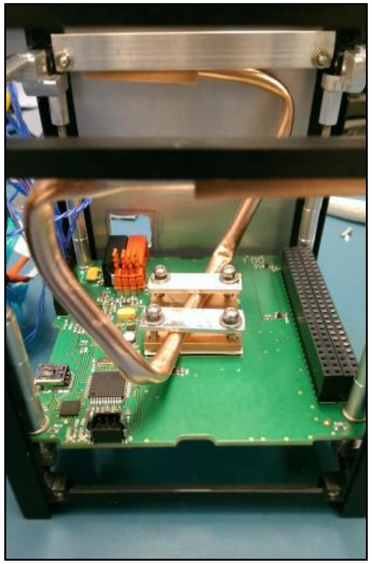


Challenge: Transient Start-up

Test Set Up

- Custom designed PCB able to generate heat
- Dissipating resistors footprint similar to MCUs or PAs
- Isolating foam to only allow conductive heat transfer

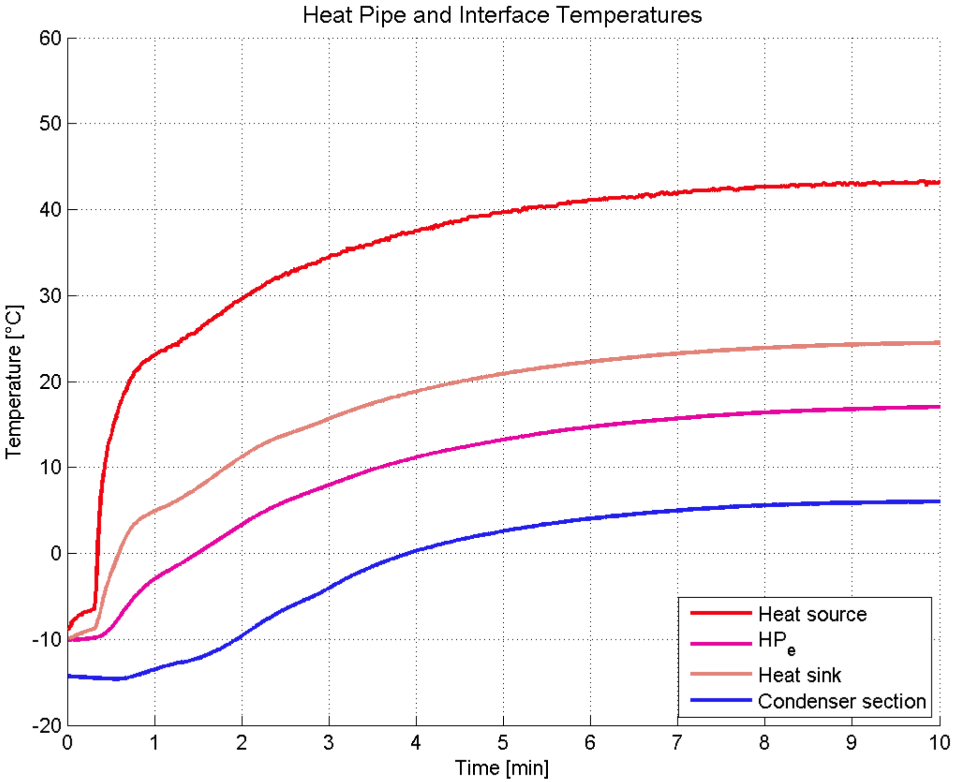


Challenge: Transient Start-up

Cold-case scenario in LEO

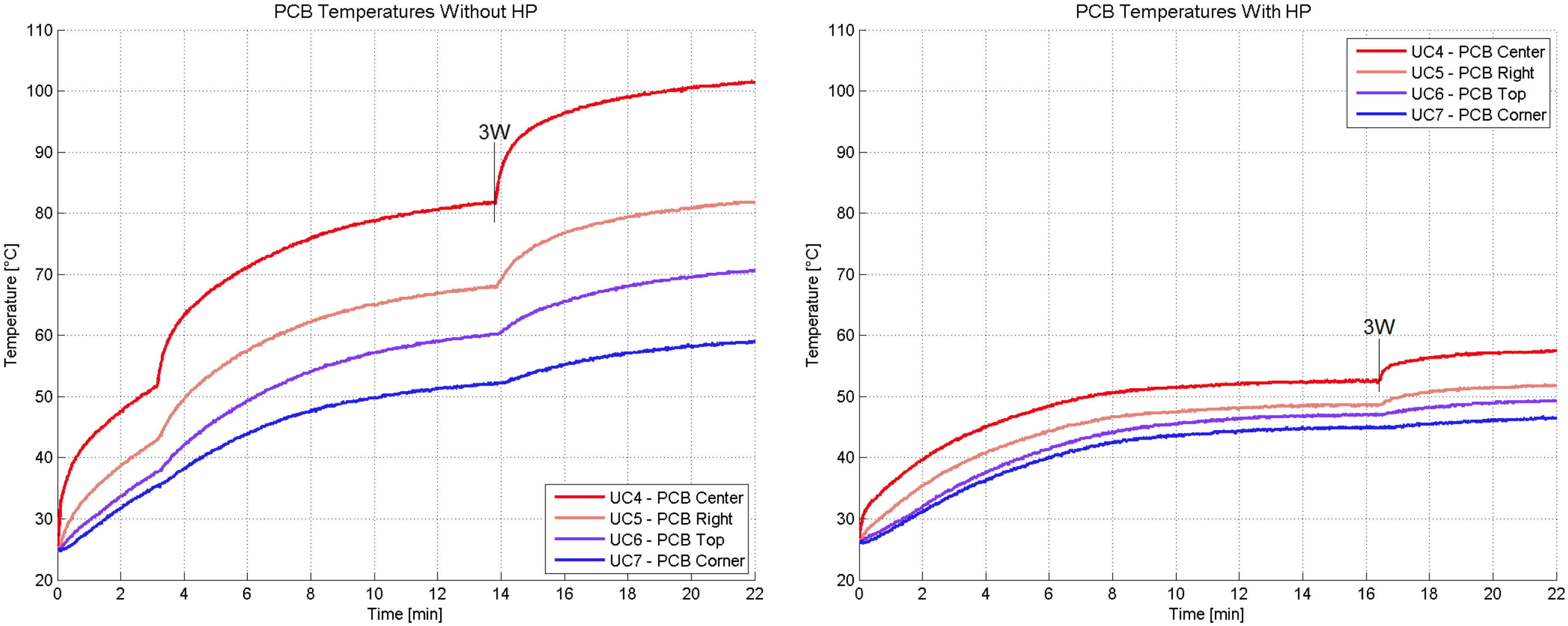
- Panel sink temperature -20 °C
- Internal temperature of -10°C
- Heat input of 10W



- Pure copper conduction main heat mechanism until heat pipe starts to thaw
- Freezing only occurs when subsystem is fully switched off

Solving the Challenge

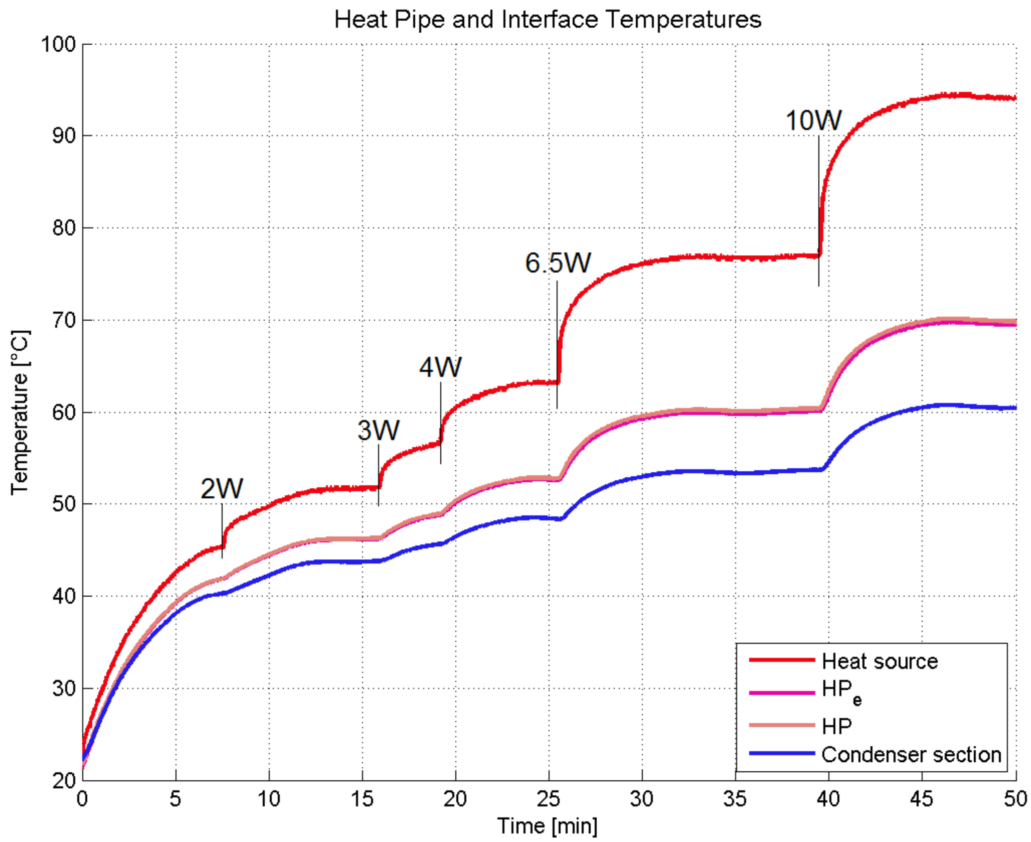
Continous heat load - Temperature distribution over the PCB



Solving the Challenge

Increasing the heat load

- 10W continuous heat load
- Sink panel temperature 40°C
- Max temperature 94°C



ΔT of 24°C between heat sink interface and the heat pipe

Conclusions & Recommendations

- Improve design to increase heat transfer coefficient
- Qualify for a large number of freeze-thaw cycles
- Vibrational analysis

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- Improve design to increase heat transfer coefficient
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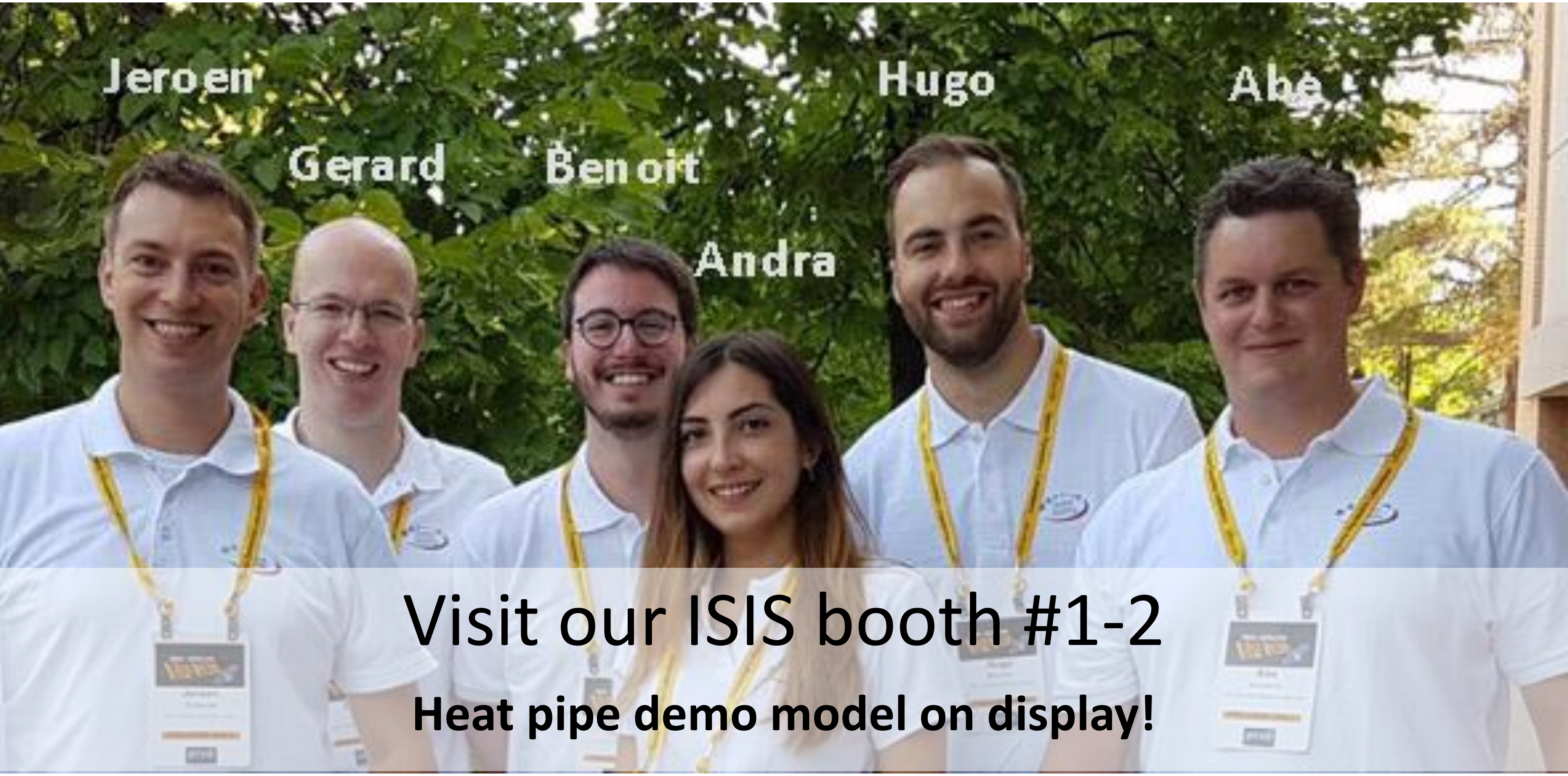
- Vibrational analysis

Fly!

Questions?



Visit our ISIS booth #1-2

Heat pipe demo model on display!

References

1 H. J. V. Gerner, R. C. V. Benthem, and J. V. Es, *Fluid selection for space thermal control systems,* in *44th `International Conference on Environmental Systems*, July (Tucson, Arizona, 2014) pp. 1–7.

2 Thermal-Fluids Central, *Operation Principles of Heat Pipes,* https://www.thermalfluidscentral.org/encyclopedia/index.php/Operation_Principles_of_Heat_Pipes, Date Accessed 16-09-2015 (2014).

Heat pipe picture (slide 11)

https://www.conrad.nl/nl/quickcool-qg-shp-d6-200g-heatpipe-01-kw-o-x-l-6-mm-x-200-mm-189178.html

BACKUP

The Solution: Water Heat Pipes

Stand-alone performance test with water heat pipes

- Different wick structures
  - Sintered
  - Mesh
  - Axial grooved

- 6 mm diameter