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Oscillating Heat Pipe Enabled Radiators

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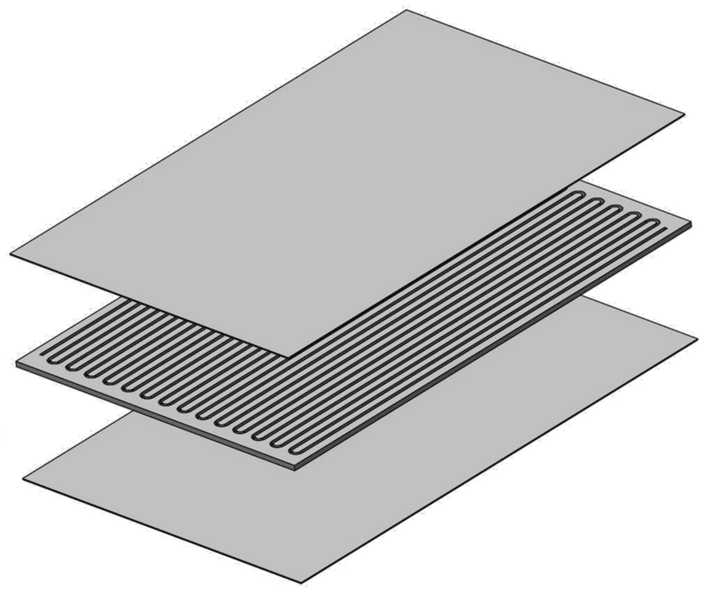
What is an Oscillating Heat Pipe (OHP)?

A passive high performance heat transfer device that can be manufactured in thin (<4 mm) and structural members (aluminum, copper). A radiator effective thermal conductivity can be >10,000 W/mK.

How is an OHP Constructed?

A meandering channel path machined into a plate with a lid brazed on top to form a hermetic capillary channel.

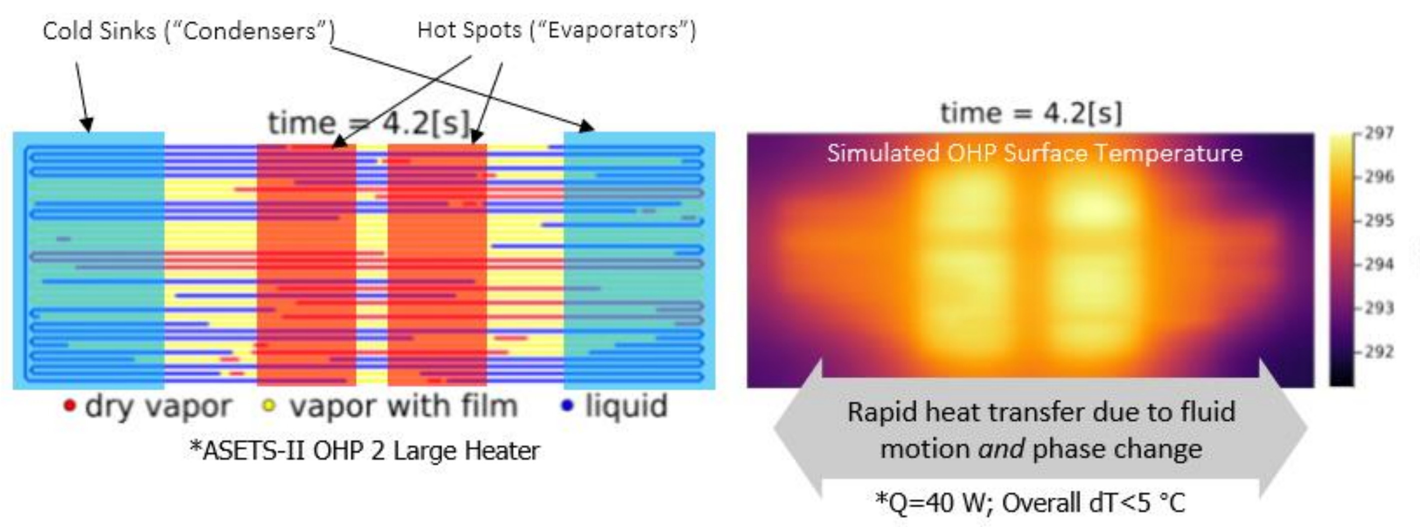
The OHP channel is sized to maintain capillary flow with a chain of liquid slugs and vapor bubbles. The working fluid is sealed inside in a saturated state.



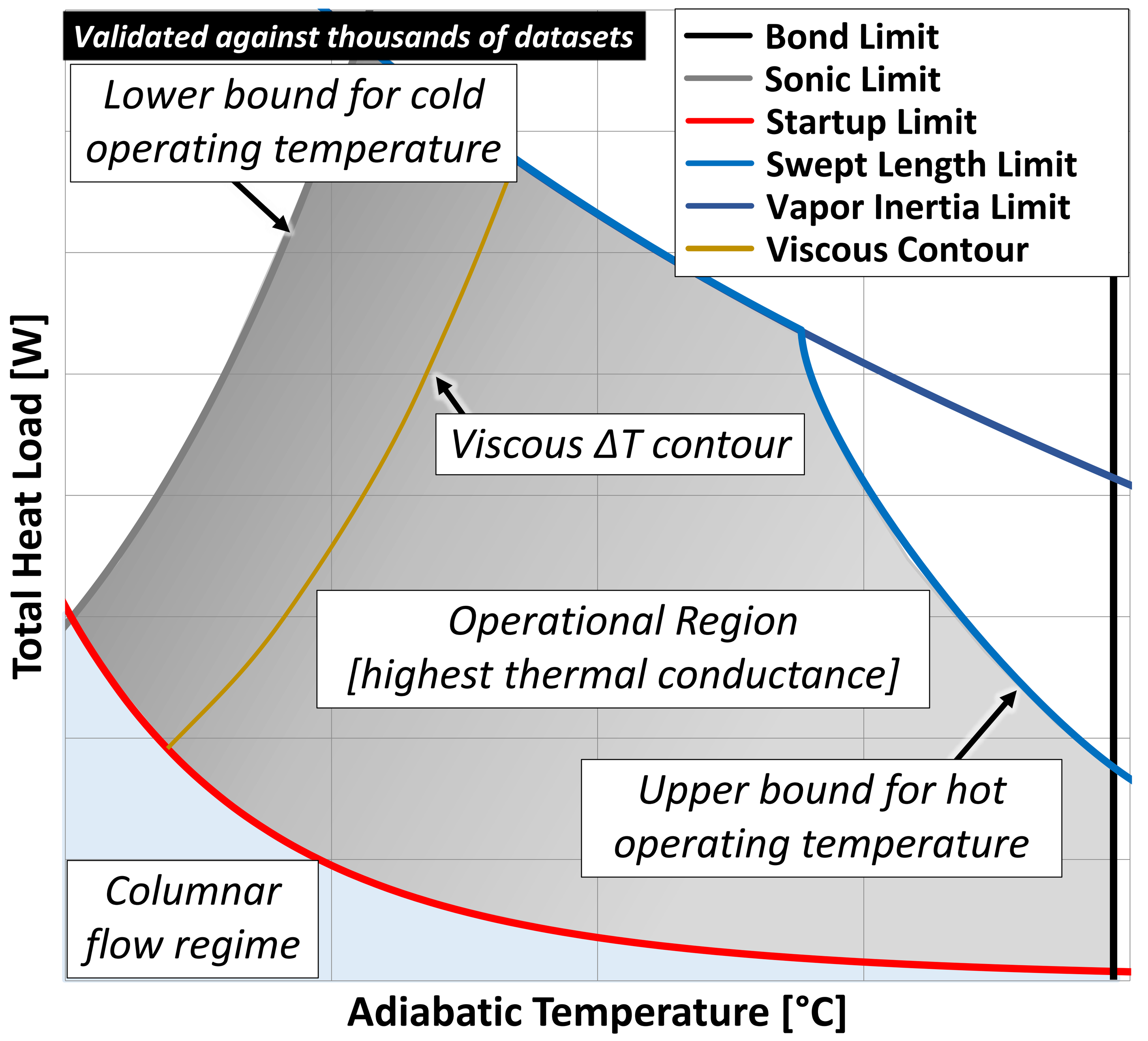
This form factor is highly configurable for a wide range of geometries and can be a structural member.

How Does an OHP Work?

The OHP operates by using boiling to pump fluid through a capillary channel between the heat source and heat sink. The resulting rapid fluid motion transports heat via sensible heat from the liquid and vapor movement and latent heat from evaporation and condensation. The OHP operates within a set of defined limits shown below.



OHP Limits of Operation



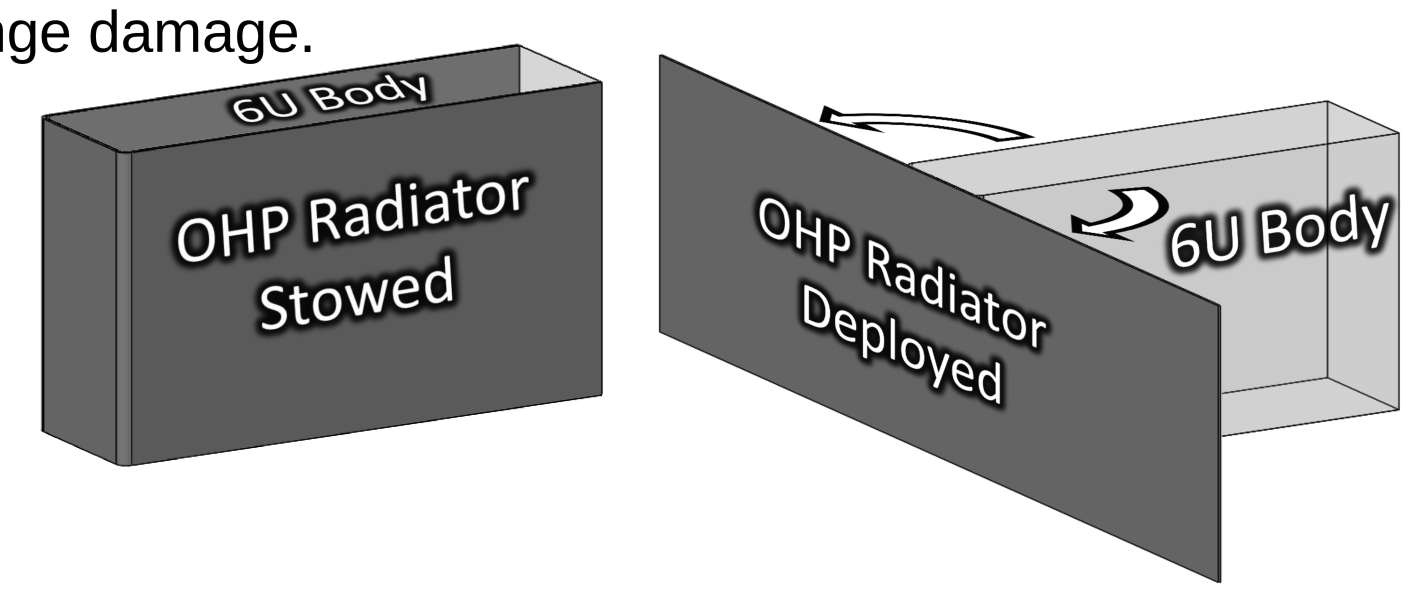
B.L. Drolen and C.D. Smoot, "The Performance Limits of Oscillating Heat Pipes: Theory and Validation," Journal of Thermophysics and Heat Transfer, 31, 4, pp. 920-936 (2017); Start up minimum presented at Spacecraft Thermal Control Workshop (2018)

Deployable OHP Radiator Design

This OHP deployable radiator was designed to reject an asymmetric heat load of 75 W from a 6U smallsat.

The OHP radiator was constructed out of aluminum with a thickness of 3.2 mm resulting in a mass of 1060 g. This version was tested thermally and deployed. A lightweighted version using an isogrid to provide structural integrity was also designed with a predicted mass of <740 g showing room for mass minimization without loss of thermal performance.

The OHP was deployed by plastically deforming the aluminum structure at hinge location. Three deployments were viable before hinge damage.

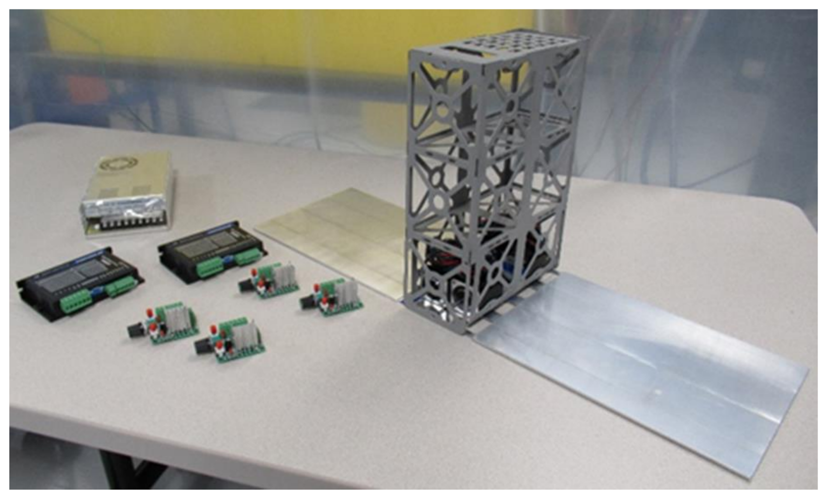


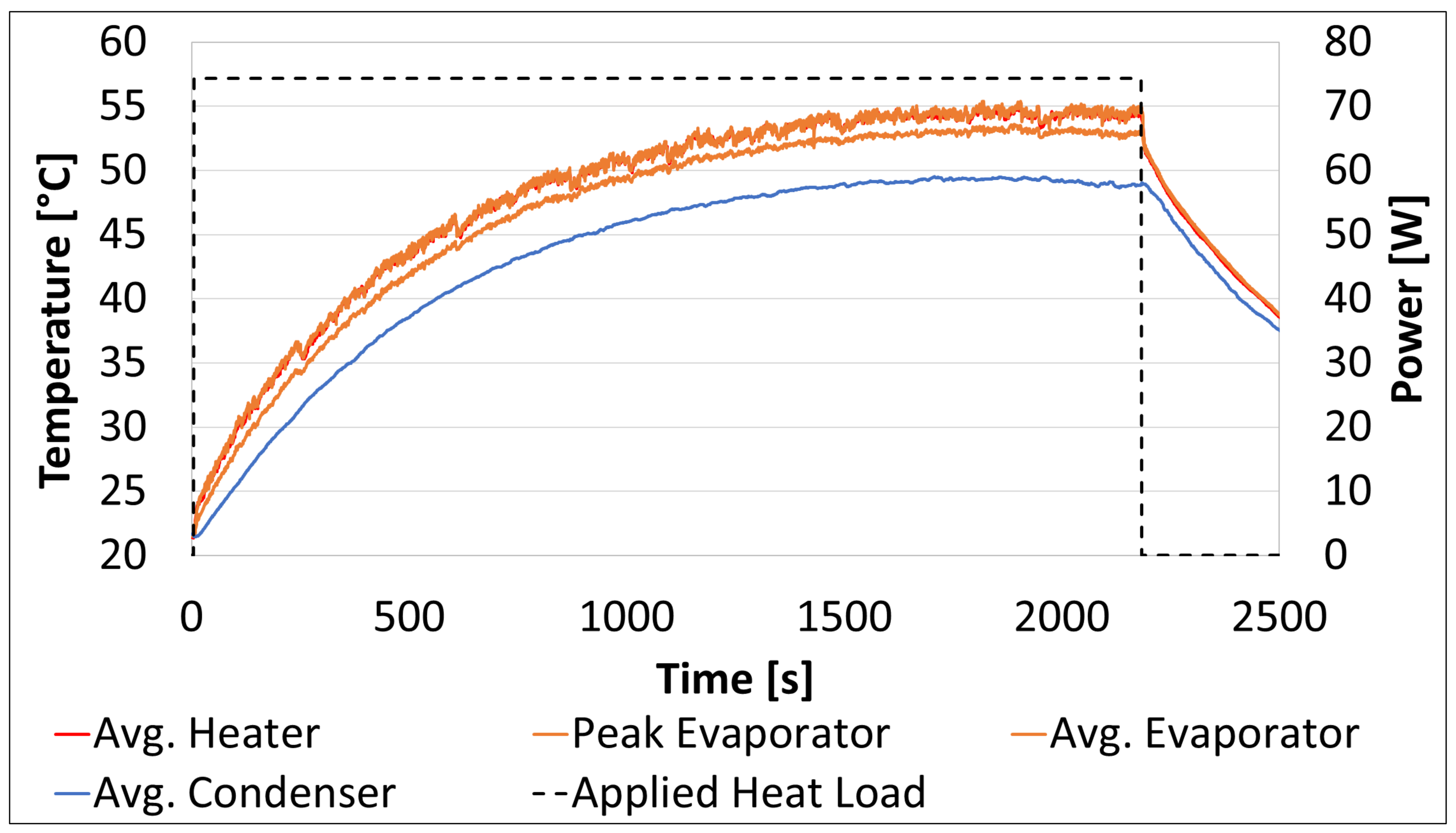
Thermal Testing

The deployed OHP radiator was tested with an asymmetric applied heat load of 75 W and heat was rejected at 25 W/m^{2}K via convection and radiation; a thermal resistance matching a 4 K radiant boundary with an emissivity of 0.8. The OHP was instrumented with thermocouples to measure the temperature distribution. Testing orientation gravity effects resulted in higher performance than on orbit.

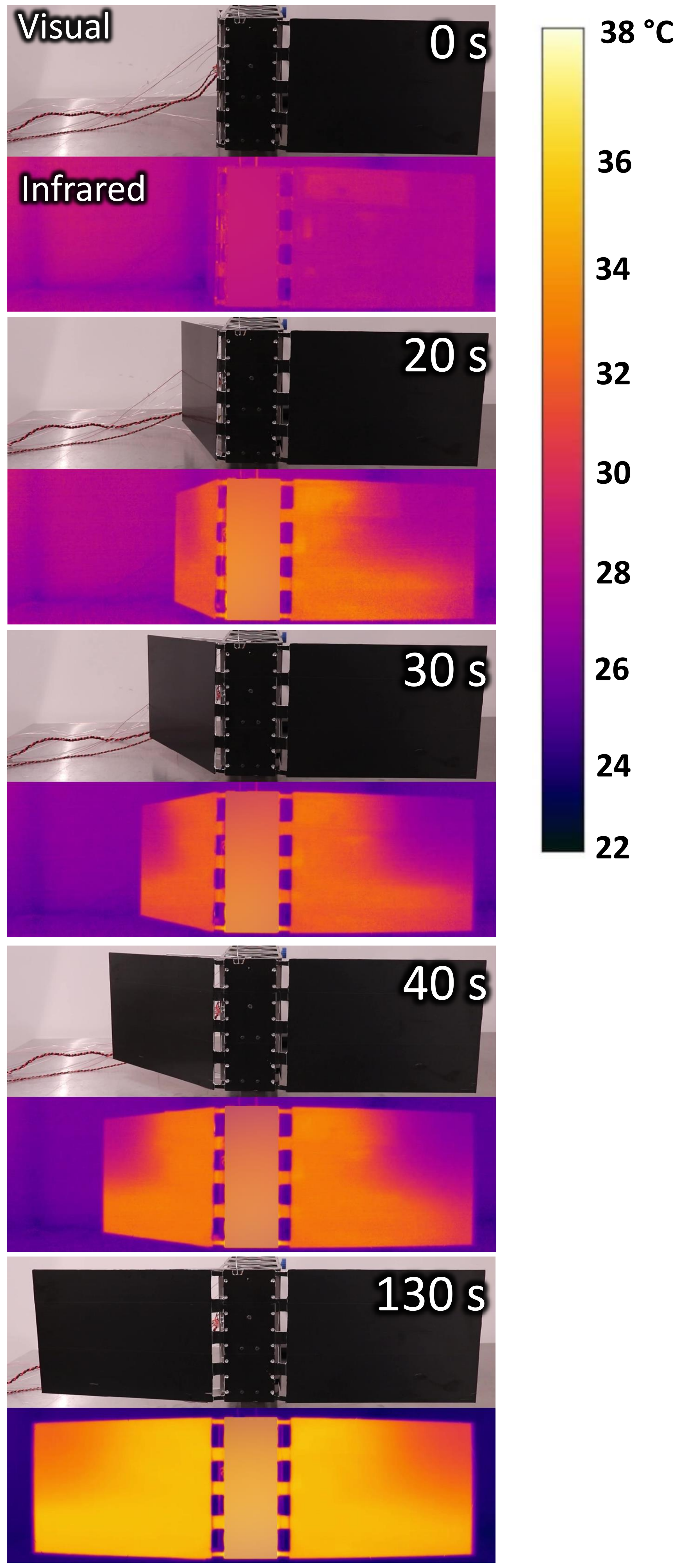
The maximum steady-state temperature at the heat source was 55 °C and the overall ΔT 5.7 °C.

Additional tests were conducted in TVAC with similar performance.





Deployment and Thermal Imaging



Conclusions

Successful demonstration of:

- OHP based 6U smallsat deployable radiator
- Number of deployments: 3
- Thickness: 3.2 mm
- Mass: 1060 g (<740 g light weighted)
- Heat load: 75 W
- Heater temperature: 55 °C
- Performance: ΔT 5.7 °C (>13 W/K)
- Ambient and TVAC evaluation

Future Development

- Reduce thickness to ≤1 mm
- Reduce mass via light weighting
- Increase rejection area

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