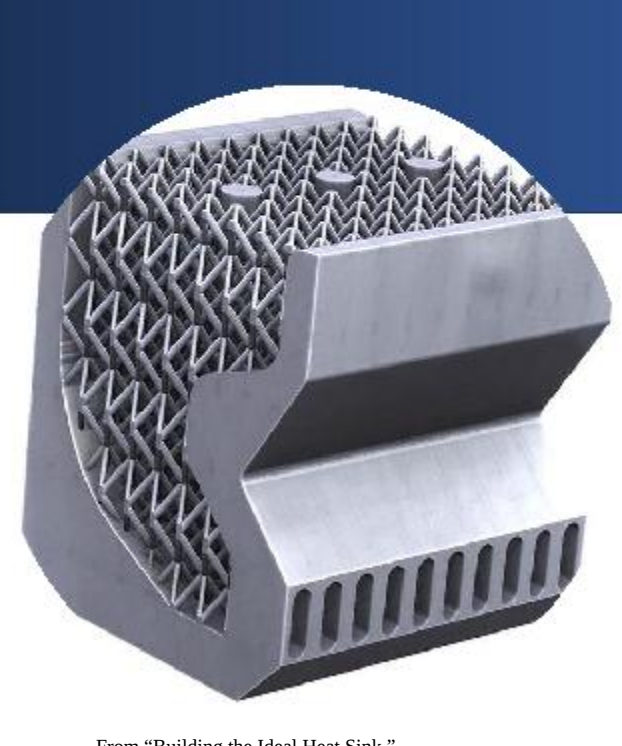
Heat Sink Optimization

John Glista

This HTML is created from PDF at https://www.pdfonline.com/convert-pdf-to-html/

The Problem

From “Understanding Heat Sinks,” (https://www.arrow.com/en/research-and-events/articles/understanding-heat-sinks-functions-types-and-more).

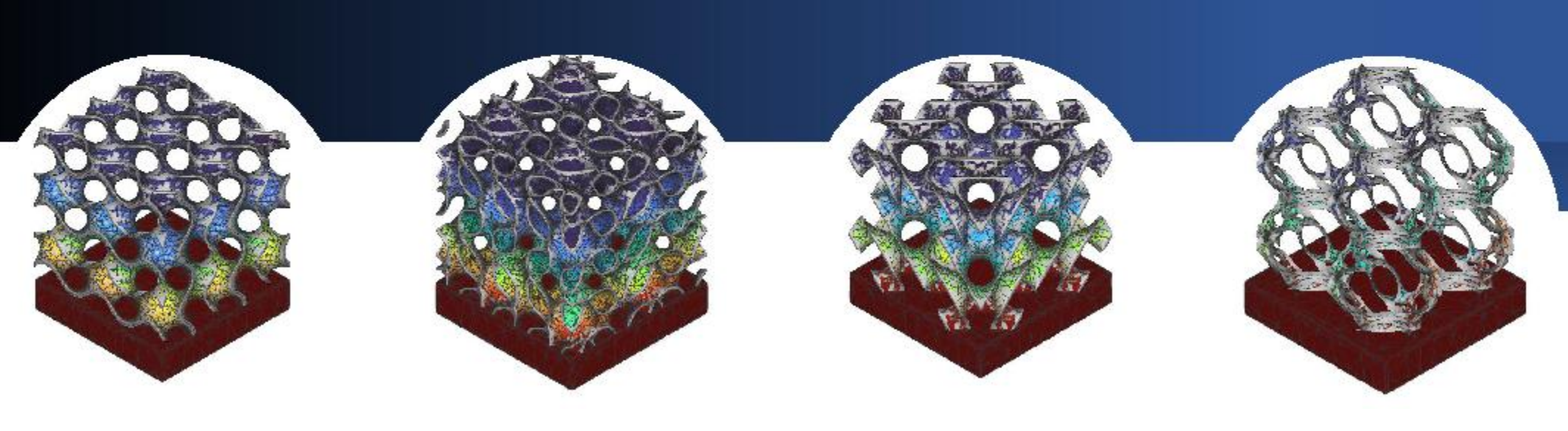


From “Building the Ideal Heat Sink,” (https://engineering.purdue.edu/ME/News/2019/building-the-ideal-heat-sink).

- Heat sinks are commonly used to dissipate heat in electronic devices.
- While simple geometries can be easier to manufacture, complex geometries can yield better dissipation.

This HTML is created from PDF at https://www.pdfonline.com/convert-pdf-to-html/

The Solution

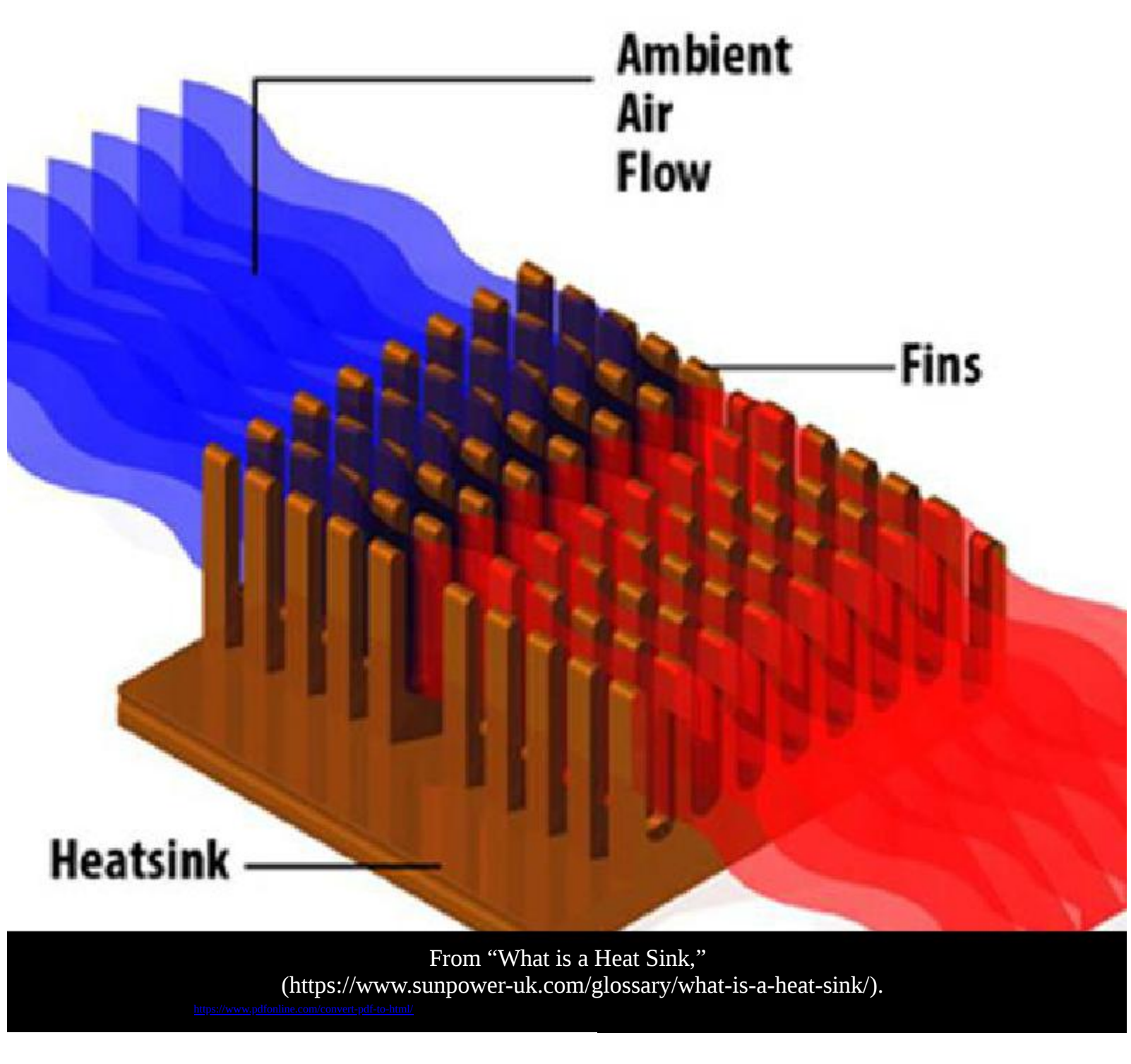


Use automated design to optimize a heat sink connected to a heat-generating plate

This HTML is created from PDF at https://www.pdfonline.com/convert-pdf-to-html/

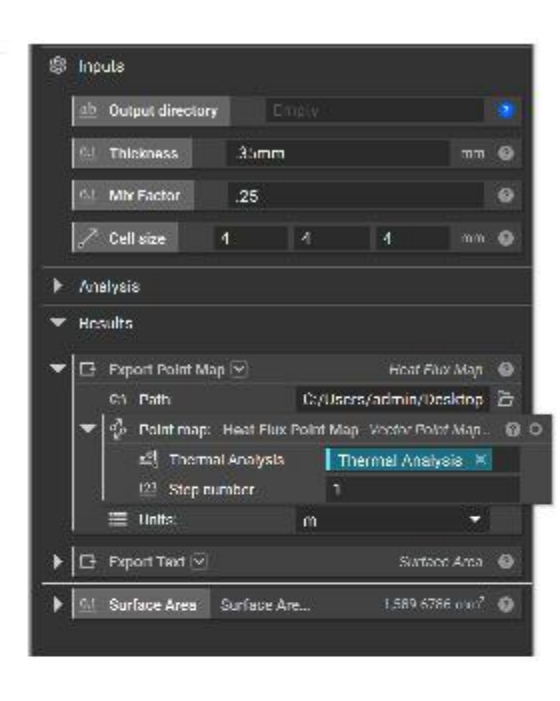
The Physics

- Heat sinks dissipate energy through convection and radiation
- The most efficient heat sink is the one that has the greatest heat flow rate [Watts]



From “What is a Heat Sink,” (https://www.sunpower-uk.com/glossary/what-is-a-heat-sink/).

Methodology



```
[totalFlux, SurfaceArea] = evaluateDesign(lattice1, lattice2, mix, thickness, cellSize);
```

- Each design is created and evaluated through nTopCL (nTopology Command Line API)
- nTopCL receives inputs stored in .json file and can return results in .csv
- Optimize in MATLAB by using nTopCL to return objective function

nTopology Steps

Finite Element Model Creation

- Create implicit model
- Infill with lattice
- Create surface mesh from implicit body with voxels
- Create volume mesh from surface mesh

Thermal Analysis

- Define Material (Al 6061-T6)
- Define Boundary Conditions
- Generate heat flux point map

This HTML is created from PDF at https://www.pdfonline.com/convert-pdf-to-html/

Automation Steps (nTopCL)

Pre-processing

- Define nTopology input variables (thickness, mix factor, cell size)
- Set up results to be exported to .csv file
- Copy .ntop files and manually change block types

Each Design Iteration

- Write input.json file
- Execute nTopCL through system command line
- Parse results from output files

This HTML is created from PDF at https://www.pdfonline.com/convert-pdf-to-html/

Defining an Optimization Problem

- nTopology can calculate total surface area (A) and nodal heat flux (q_n)
- Heat flow rate is the product of area and flux
- $\sigma\, q_e A_e \neq A\, \sigma\, q_n$
- Two-objective optimization of a large, unknown search space → NSGA-II

This HTML is created from PDF at https://www.pdfonline.com/convert-pdf-to-html/

NSGA-II

(Non-dominated Sorting Genetic Algorithm II)

Objective Functions:

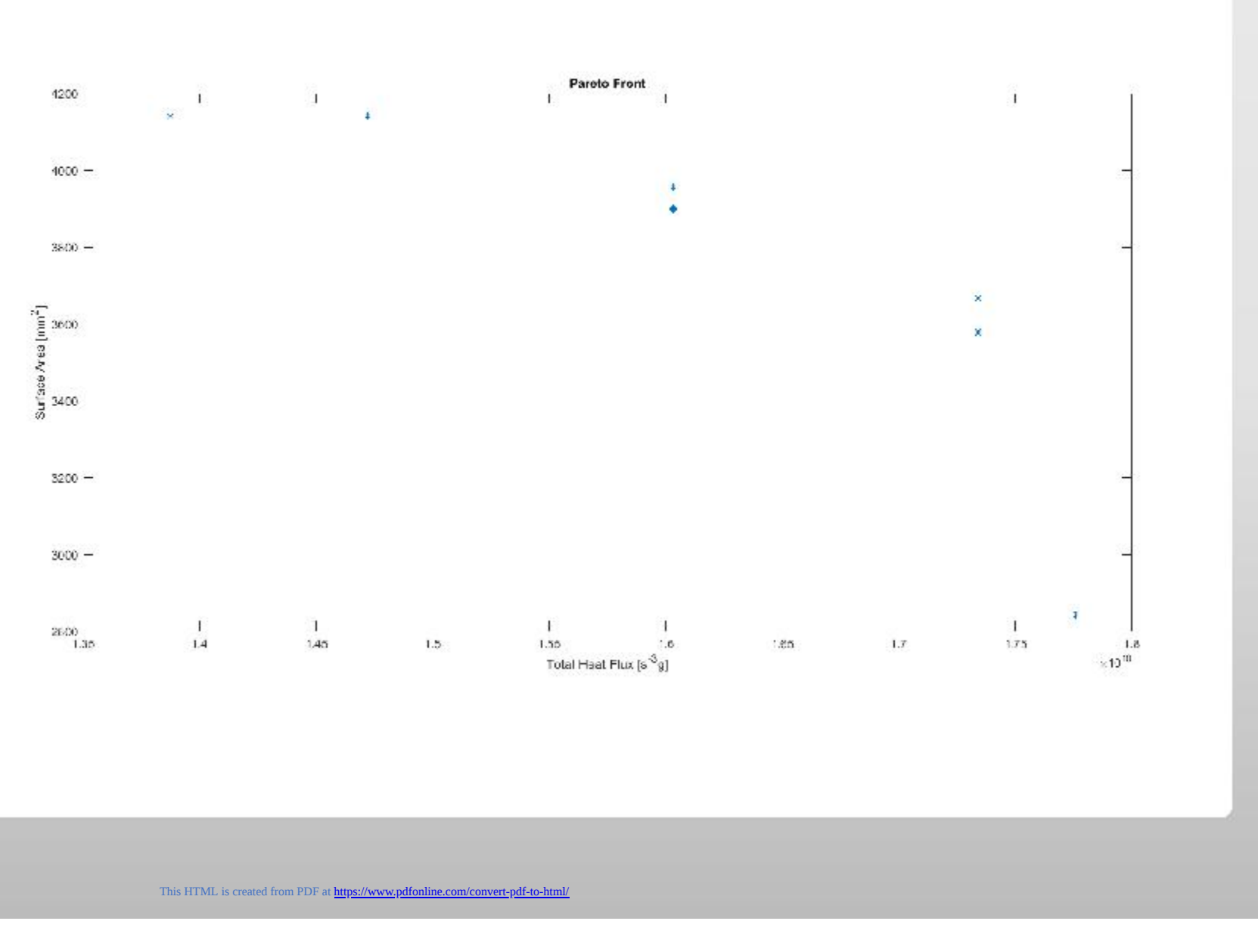
- [totalFlux, SurfaceArea] = evaluateDesign(lattice1, lattice2, mix, thickness, cellSize);

Decision Variables:

- Lattice 1 type (Gyroid, Schwarz, Diamond, Lidinoid , SplitP, Neovious) ∊ [1…6]
- Lattice 2 type (Gyroid, Schwarz, Diamond, Lidinoid , SplitP, Neovious) ∊ [1…6]
- Mix Factor ∊ [0,1]
- Thickness ∊ [.2mm, .5mm]
- Cell Size ∊ [3mm, 5mm]

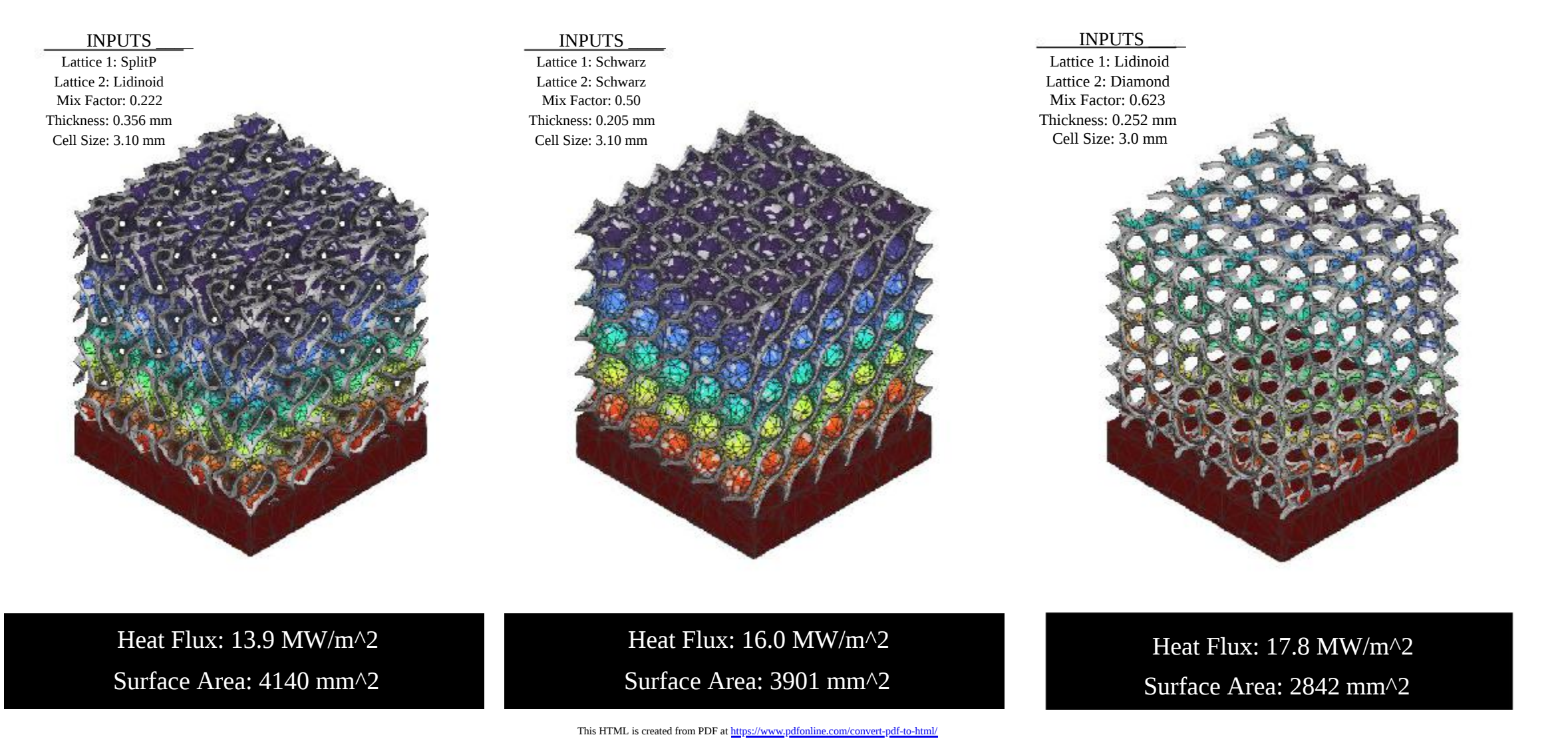
This HTML is created from PDF at https://www.pdfonline.com/convert-pdf-to-html/

Optimization Result



This HTML is created from PDF at https://www.pdfonline.com/convert-pdf-to-html/

Sample Designs



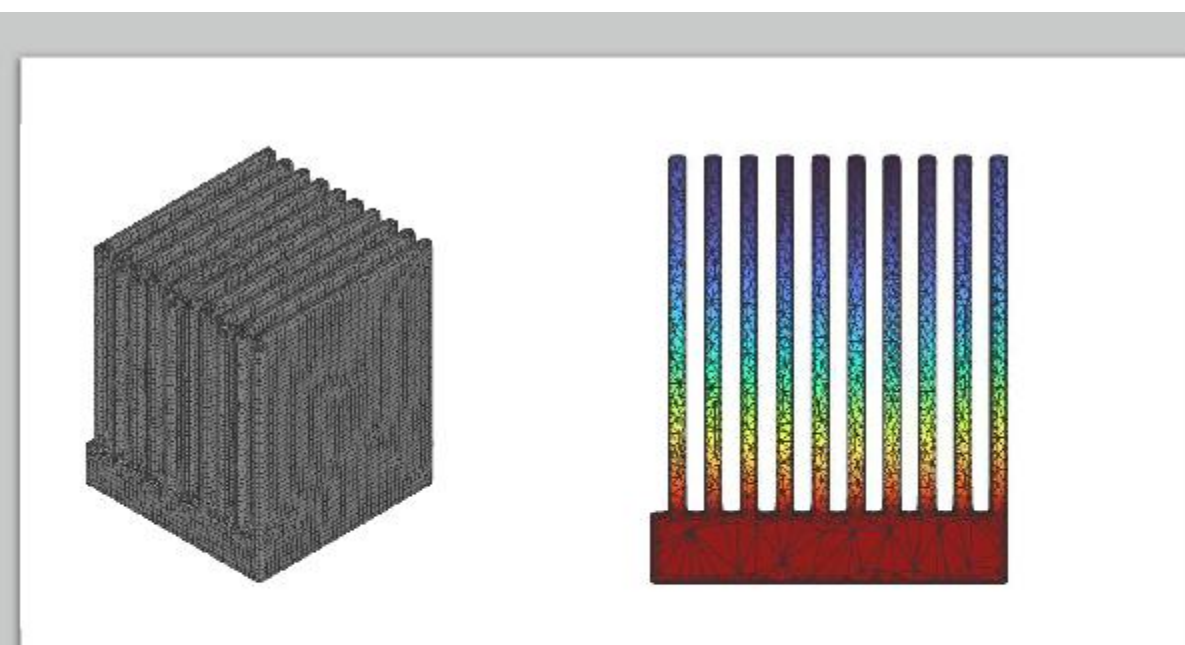
Heat Flux: 13.9 MW/m^2
Surface Area: 4140 mm^2

Heat Flux: 16.0 MW/m^2
Surface Area: 3901 mm^2

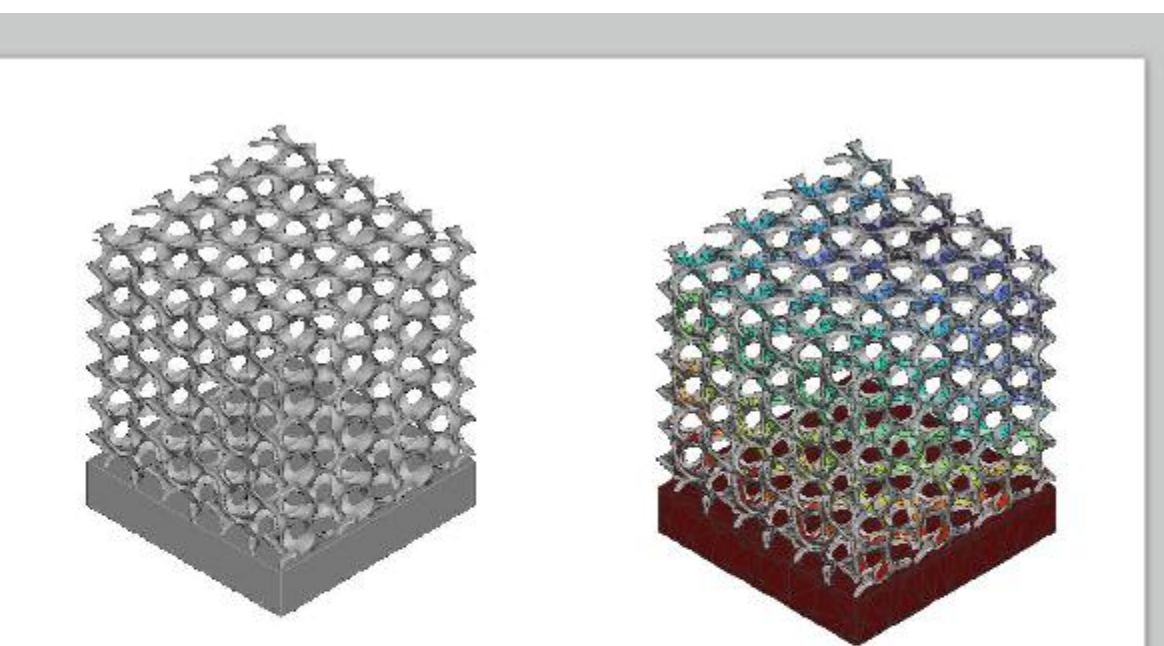
Heat Flux: 17.8 MW/m^2
Surface Area: 2842 mm^2

This HTML is created from PDF at https://www.pdfonline.com/convert-pdf-to-html/

Comparison to a Standard Sink Design



Heat Flux: 7.09 MW/m^2
Surface Area: 584 mm^2



Heat Flux: 17.8 MW/m^2
Surface Area: 2842 mm^2

This HTML is created from PDF at https://www.pdfonline.com/convert-pdf-to-html/

Further Improvements

- Convection is largely a fluid problem, so using a CFD solver would provide more realistic results than the FE solver
- Optimize mesh generation so that less failures occur and meshes are not needlessly large

This HTML is created from PDF at https://www.pdfonline.com/convert-pdf-to-html/

Full Code and Files

- https://github.com/jglista1/heatsinkoptimization

This HTML is created from PDF at https://www.pdfonline.com/convert-pdf-to-html/