ALTASIM TECHNOLOGIES
REALIZING TOMORROW'S TECHNOLOGY

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Convective Cooling of Electronic Components

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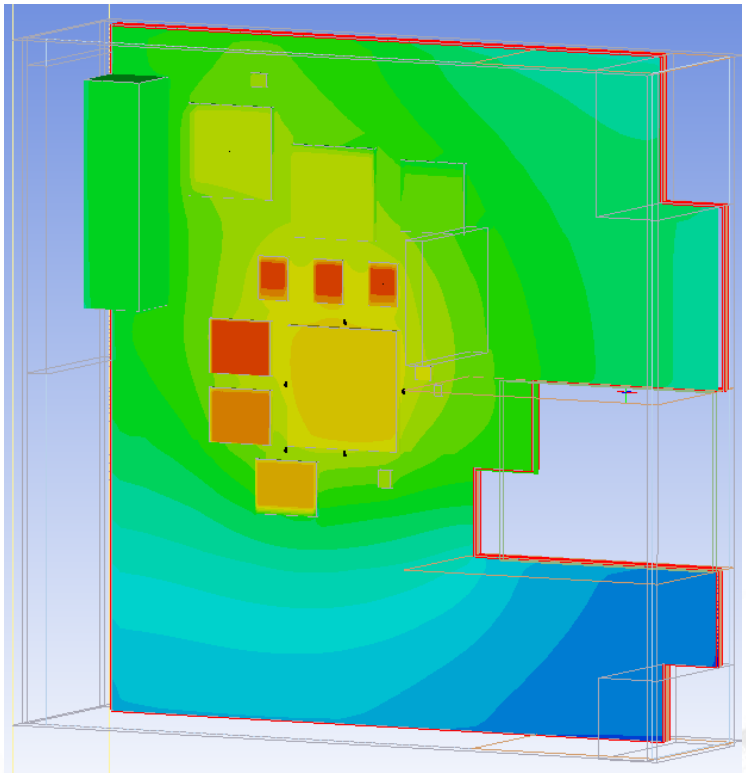
Motivation



- Smaller size
- Increased power density
- Higher operating temperature
- Decreased lifetime

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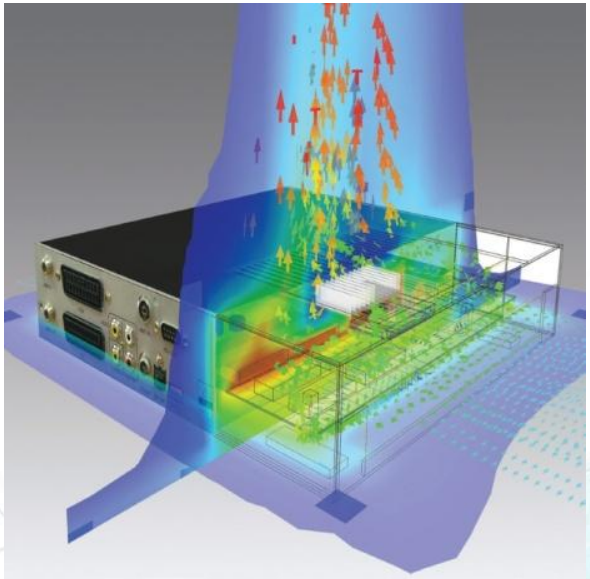
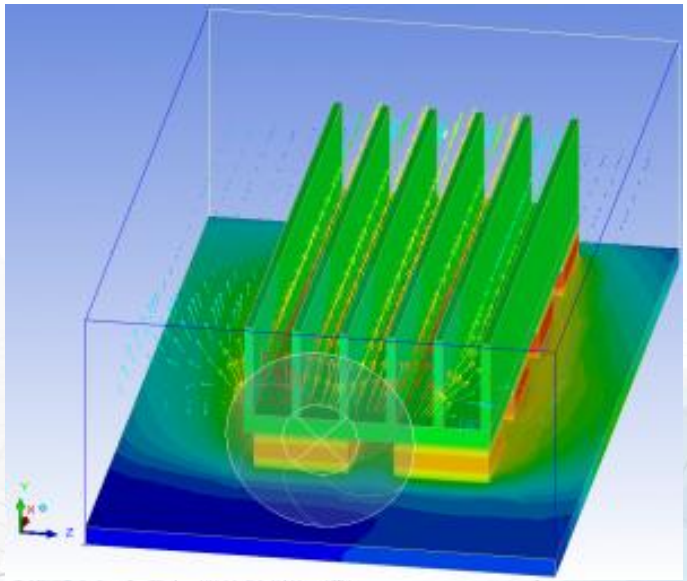
Solutions

- **Active cooling**
  - **Forced air flow**
  - **Pumped liquids**
- **Passive cooling**
  - **Natural convection**
  - **Board design**





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Problem description

- Heat sink design
  - Pin-Fin arrays
  - Staggered vs In-line
  - Size vs Spacing
  - Power
- Methodologies
  - Unit cell vs Full array
  - Steady state vs Transient
- Design guidelines

- Conjugate heat transfer
- Heat transfer in solid domain: $\rho\, c_p \frac{\partial T}{\partial t} = \nabla \cdot (\lambda \nabla T)$
- Heat transfer in fluid domain:
  - Mass $\nabla \cdot (\rho\, \mathbf{u}) = 0$
  - Momentum

$$\rho\, \mathbf{u} \cdot \nabla \mathbf{u} = -\nabla p + \nabla \cdot \left(\eta \left(\nabla \mathbf{u} + (\nabla \mathbf{u})^T \right) - \frac{2}{3} \eta (\nabla \cdot \mathbf{u}) \mathbf{I} \right) + \rho\, \mathbf{g}$$

  - Energy $\nabla \cdot (-k \nabla T) = Q - \rho\, c_p \mathbf{u}$

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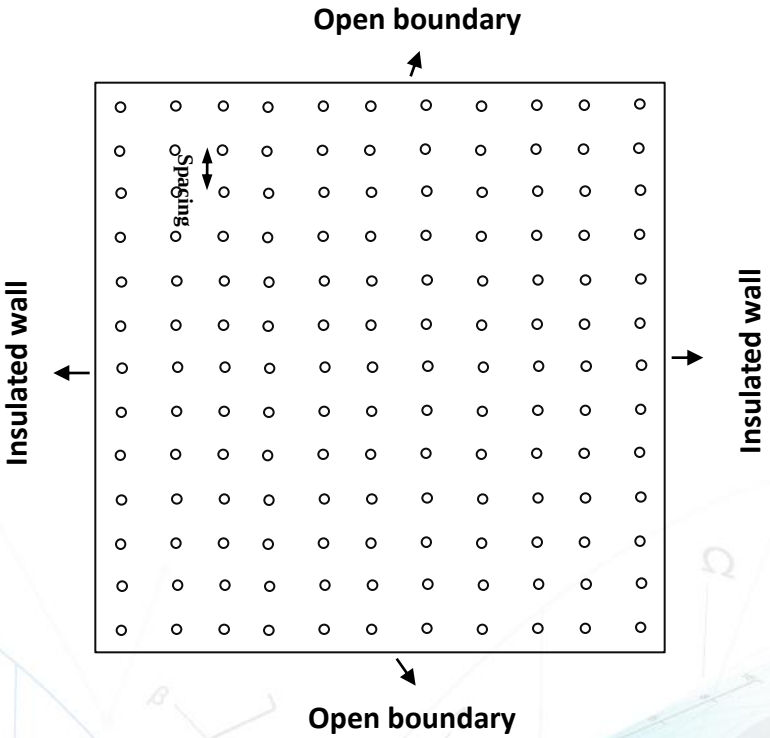
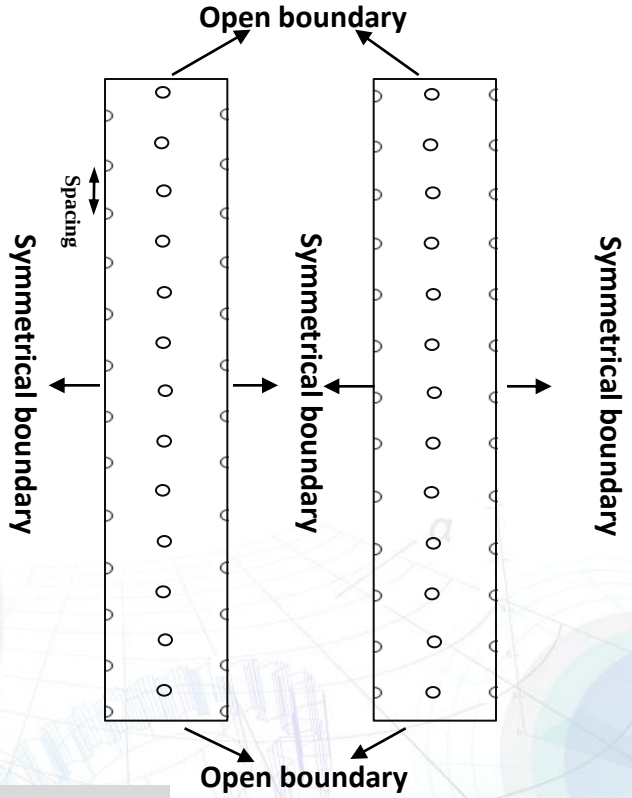
Pin-Fin heat sink

- **Full array**



- **Unit cell**



Front wall: Insulated
Back wall : Heat source

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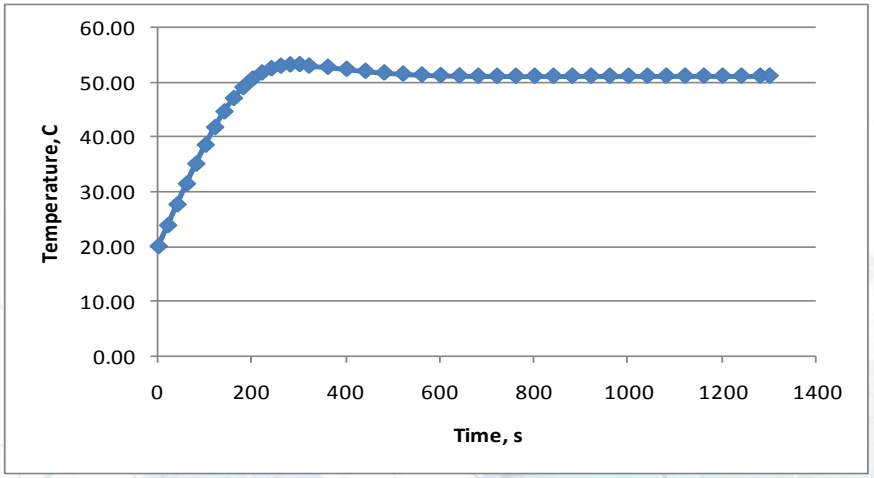
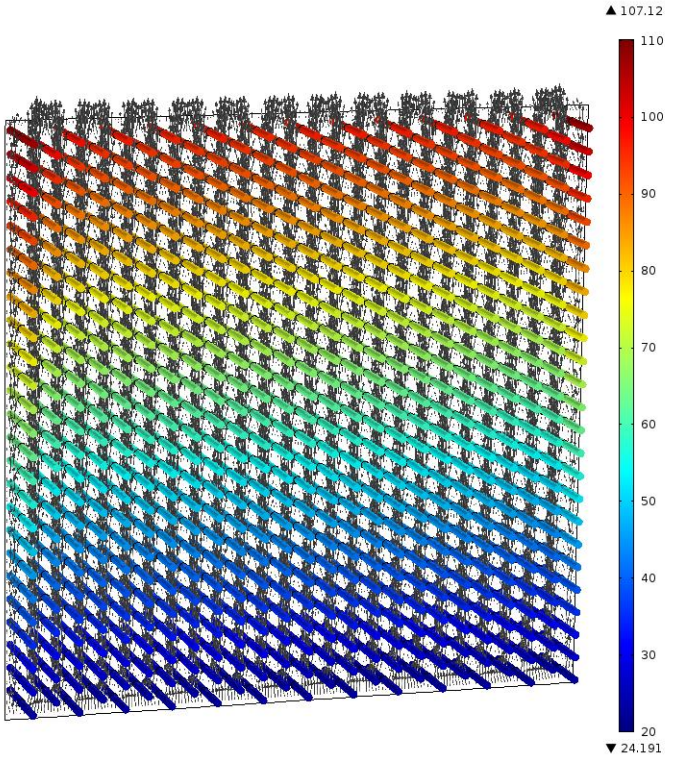
Transient analysis

Condition	RAM, GB	# Cores	Analysis time, h
Unit cell/Steady State	8	4	6
Full/Steady State	96	8	20
Full/Transient	384	96	34



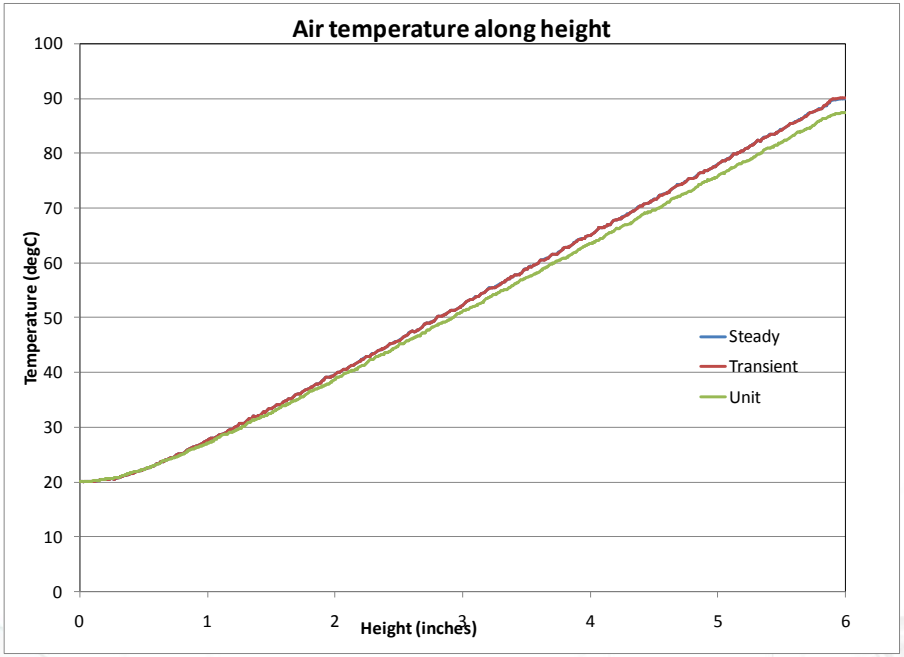
- **Temperature/Flow stabilizes after ~ 700s**

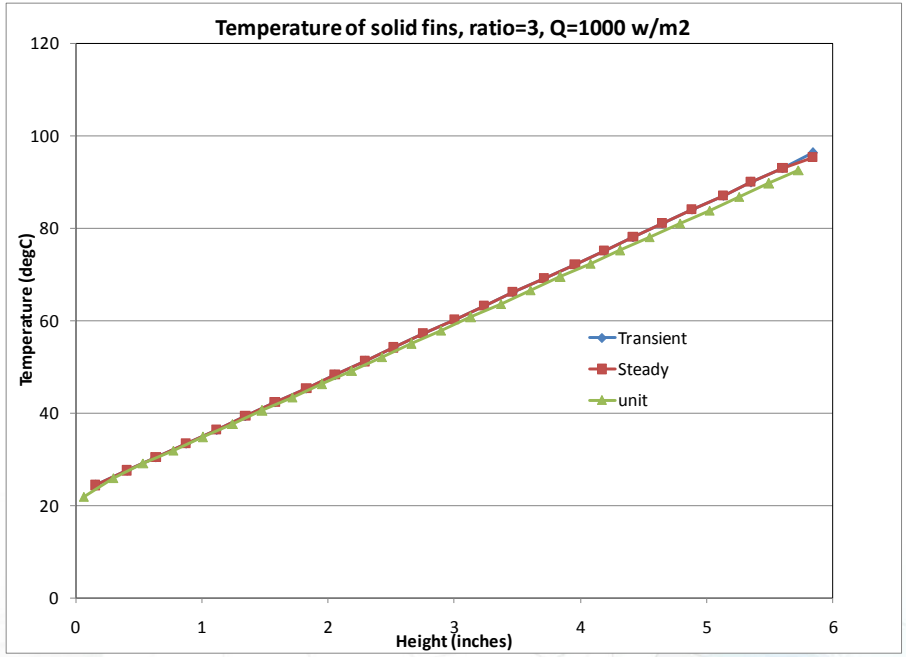


Transient animation

Transient vs Steady State

- Transient and Steady State provide identical results
- Unit cell slightly lower than full array analysis





Condition	Mass flow, kg/s	Ave.T 10th pin, °C	Mean wall T, °C	T_{max}, °C
Full/Steady	3.058 e-4	51.26	111.8	95.93
Full/Transient	3.06 e-4	51.24	111.7	96.89

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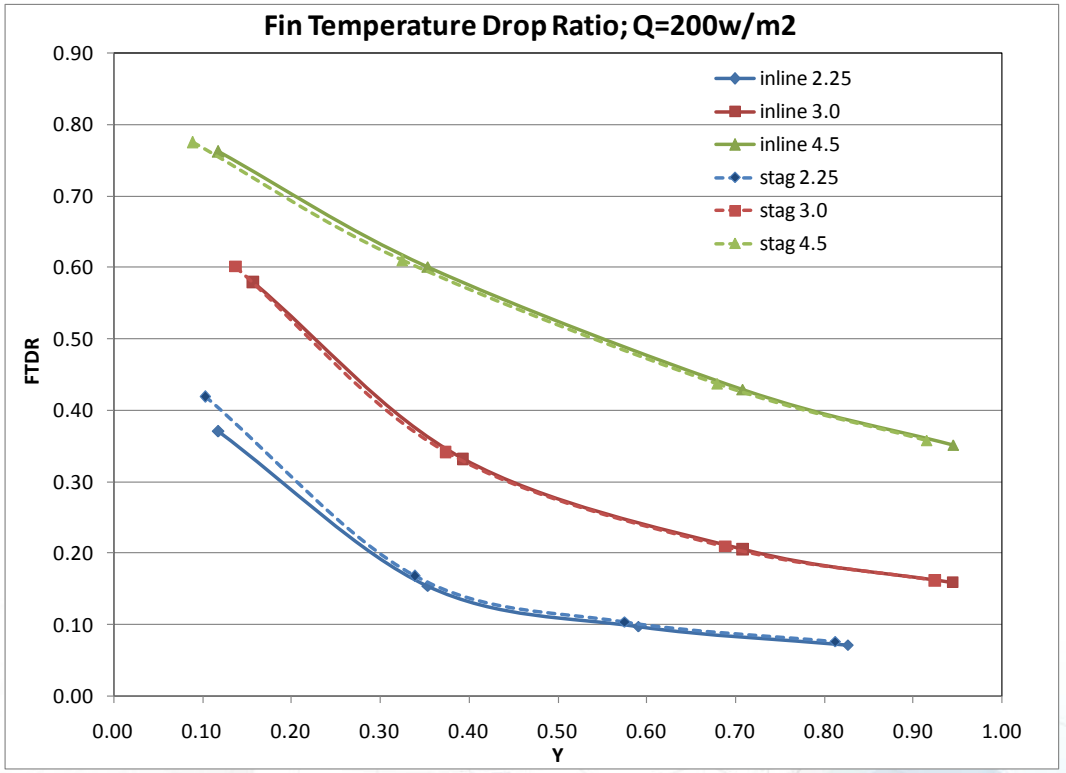
Pin-Fin array efficiency

Fin Temperature Drop Ratio

$$FTDR = \frac{(T_{base} - T_{tip})}{(T_{base} - T_{amb})}$$



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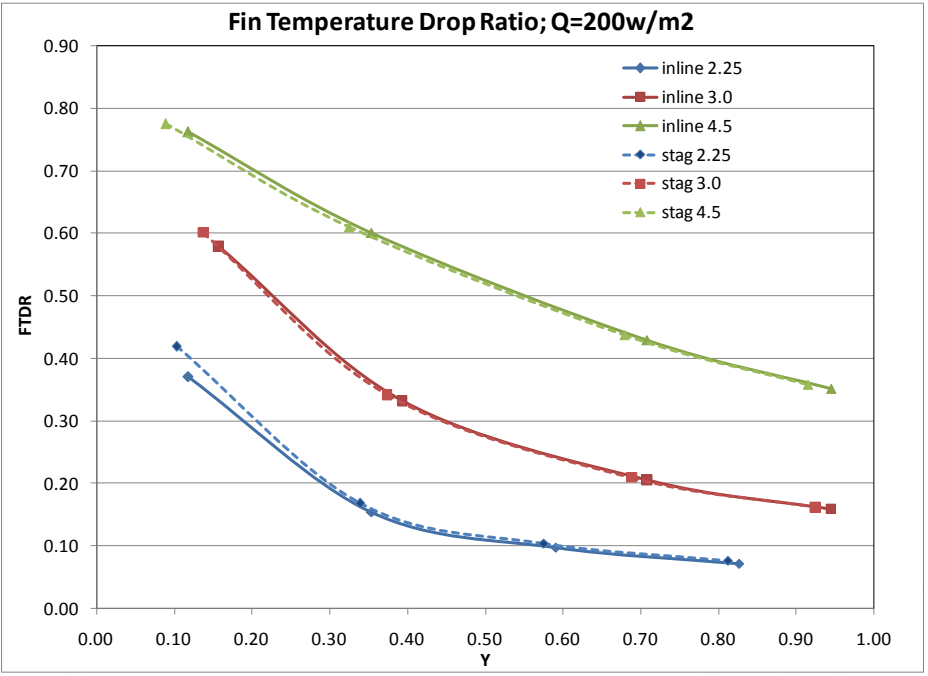
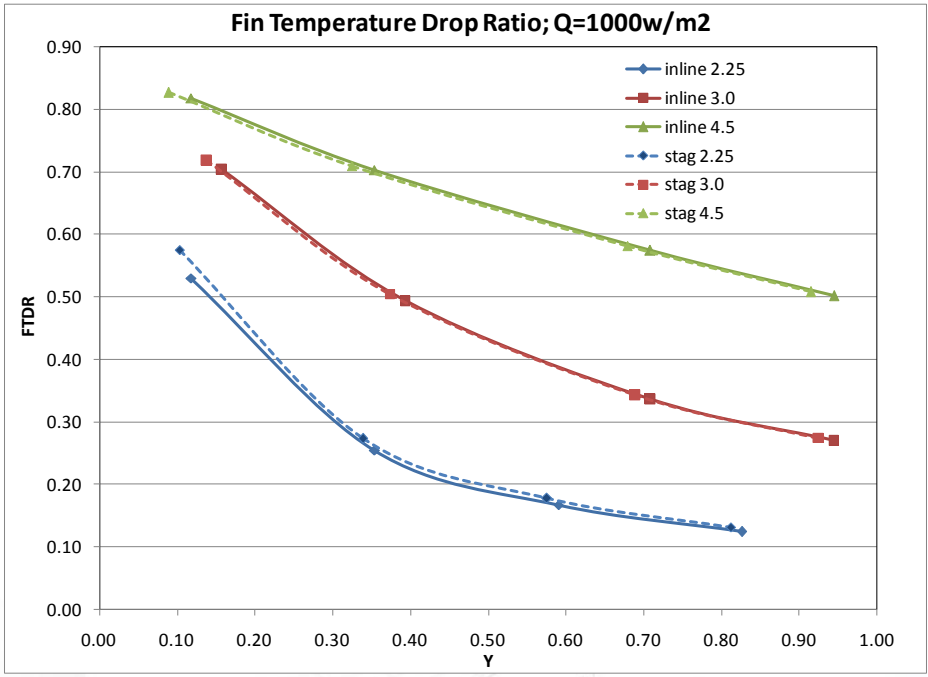
Pin-Fin array design

FTDR vs Height in array





In-line similar to Staggered
Limiting height for specific efficiency and power

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Summary

- Unit cell methodologies established for analyzing performance of Pin-Fin heat sinks
- Computational requirements for transient simulations are extensive
- Limiting size of array for extraction of specific heat levels