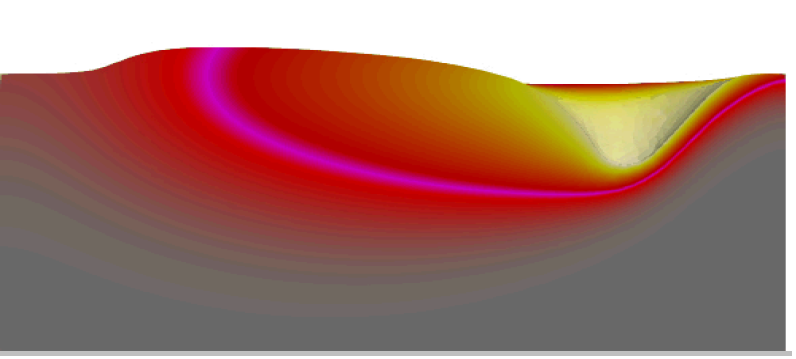
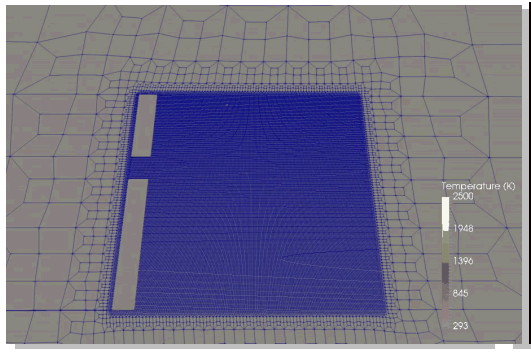
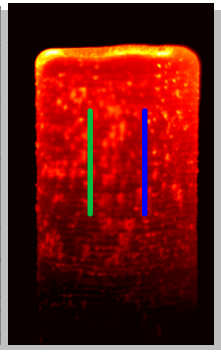
SAND2017-8873C







Overview of Additive Manufacturing at SNL NM

Kurtis Ford, Kyle Johnson, Joe Bishop

Mario Martinez, Brad Trembacki

U.S. DEPARTMENT OF ENERGY | NNSA National Nuclear Security Administration

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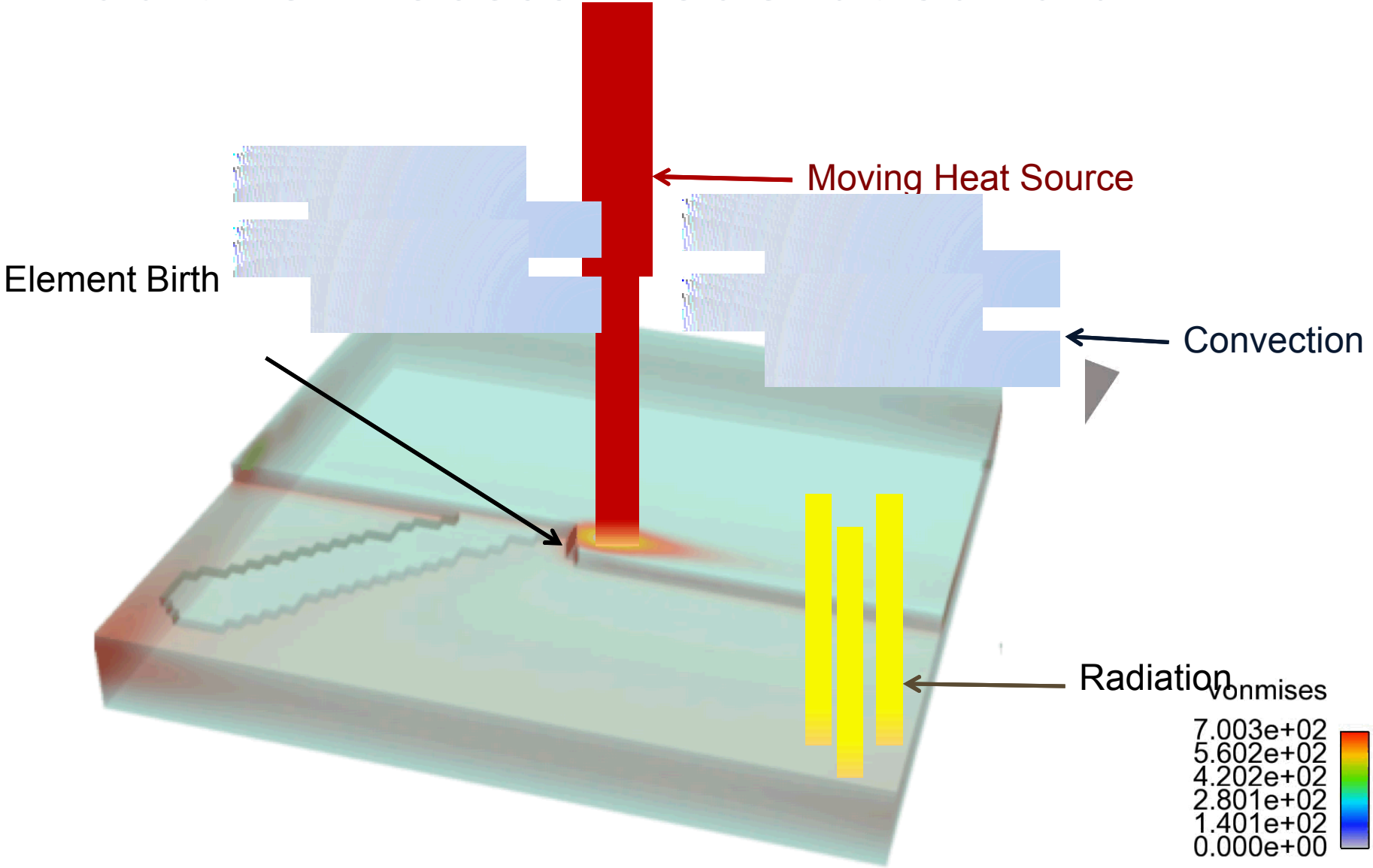
Additive Process Model at Sandia



Hot Spot to Approximate Melt Pool

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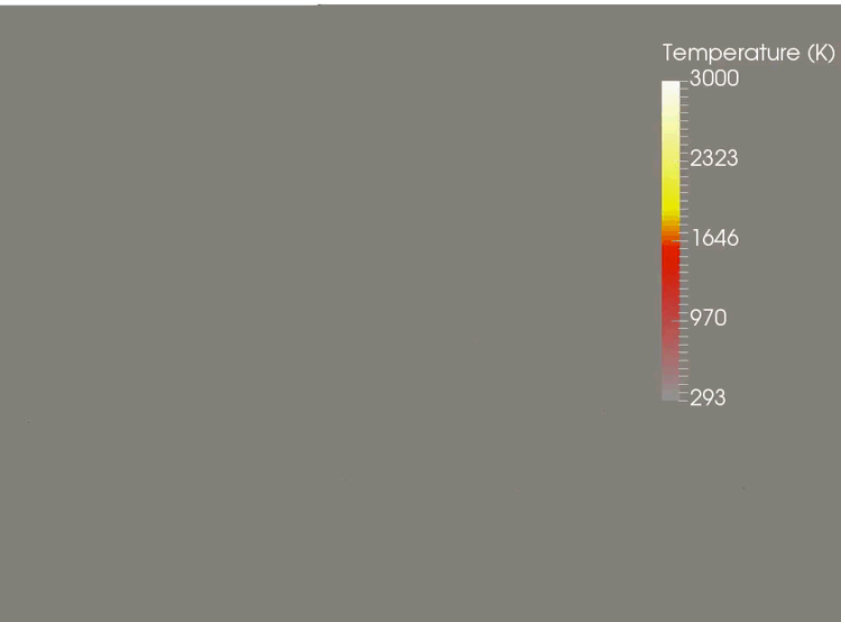
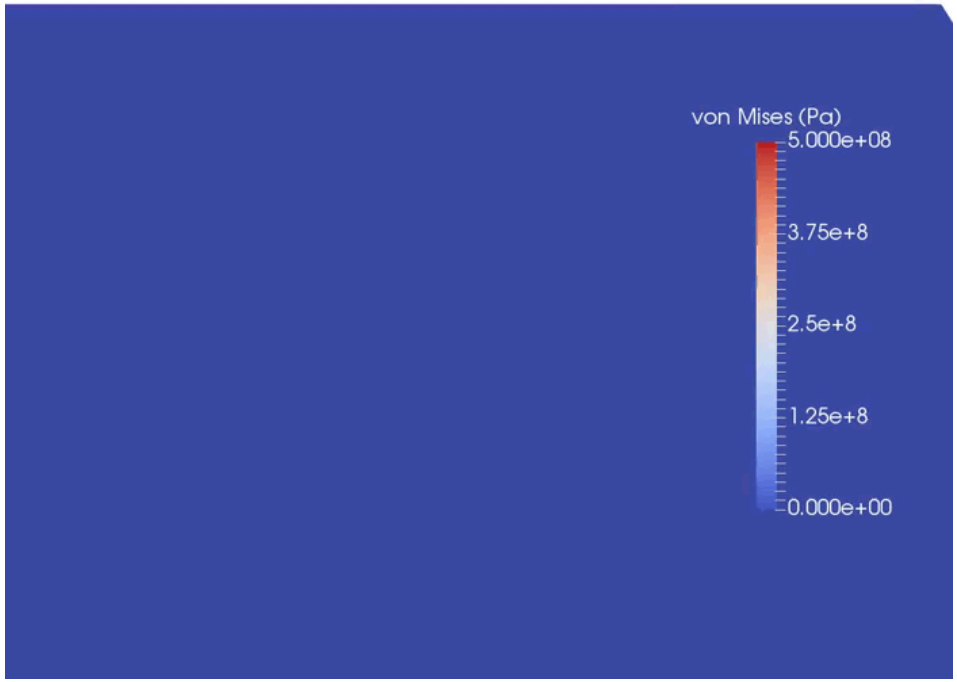
Time: 0.00 s





Kyle Johnson ------- He is Here too!!

Delay time inhibits equiaxed to columnar transition

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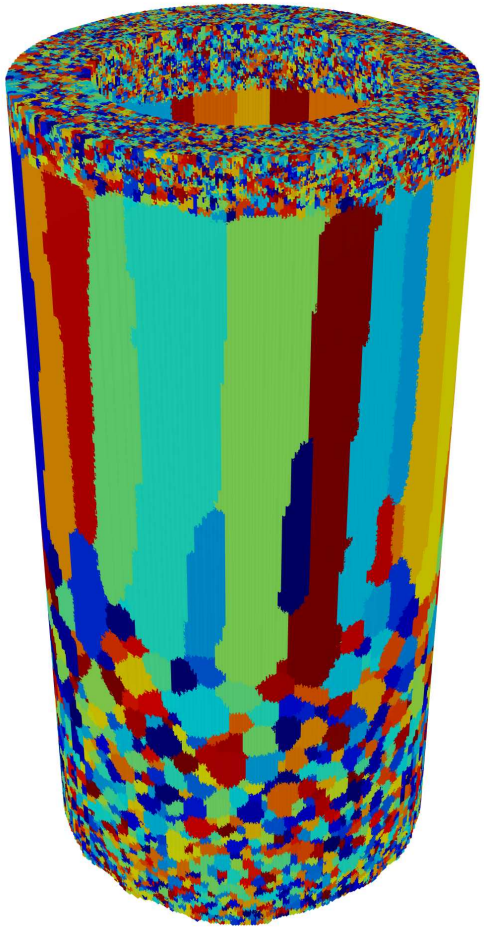
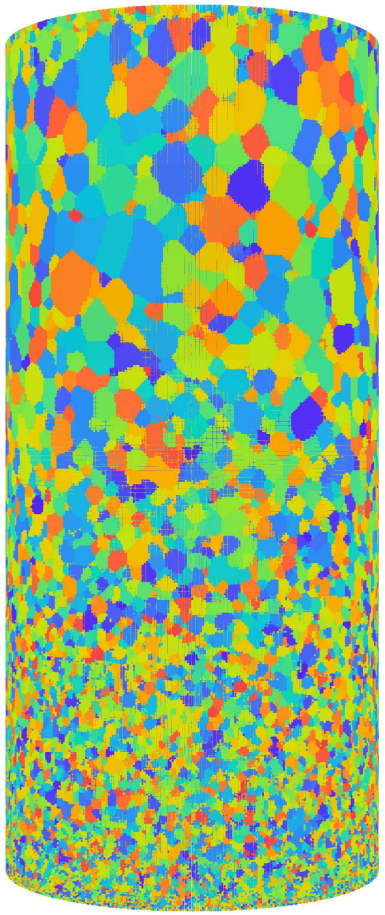
Single Build

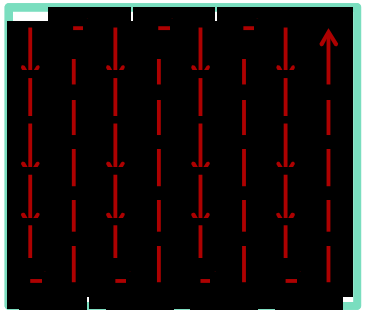


Double Build – 8 Second Inter-layer Delay



Hot Spot to Approximate Raster Pattern

Raster “Island”



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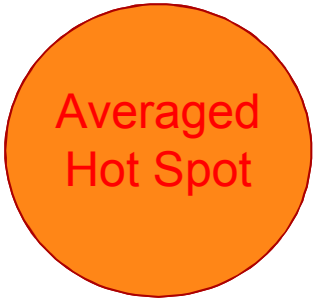
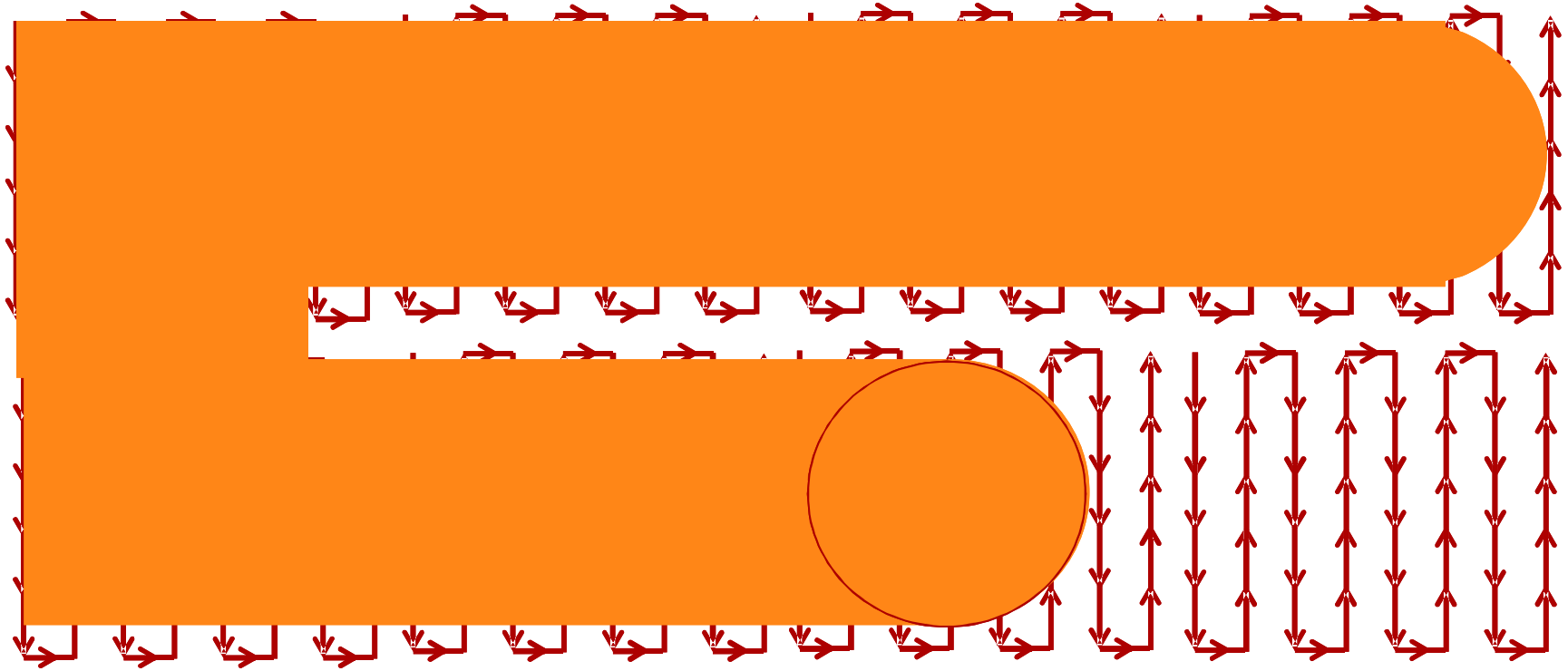
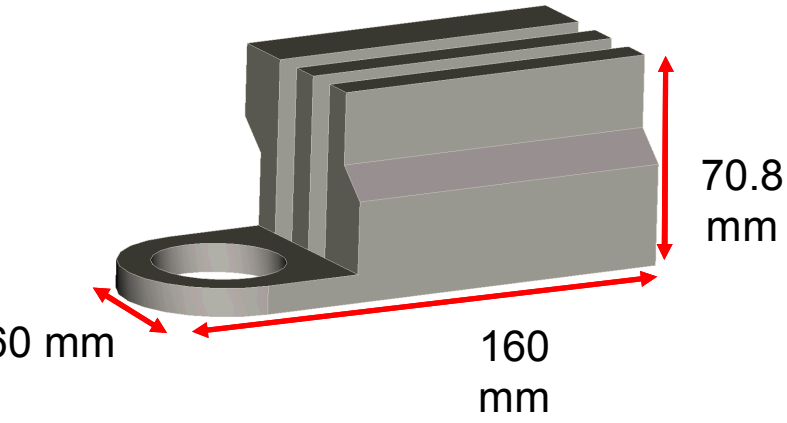
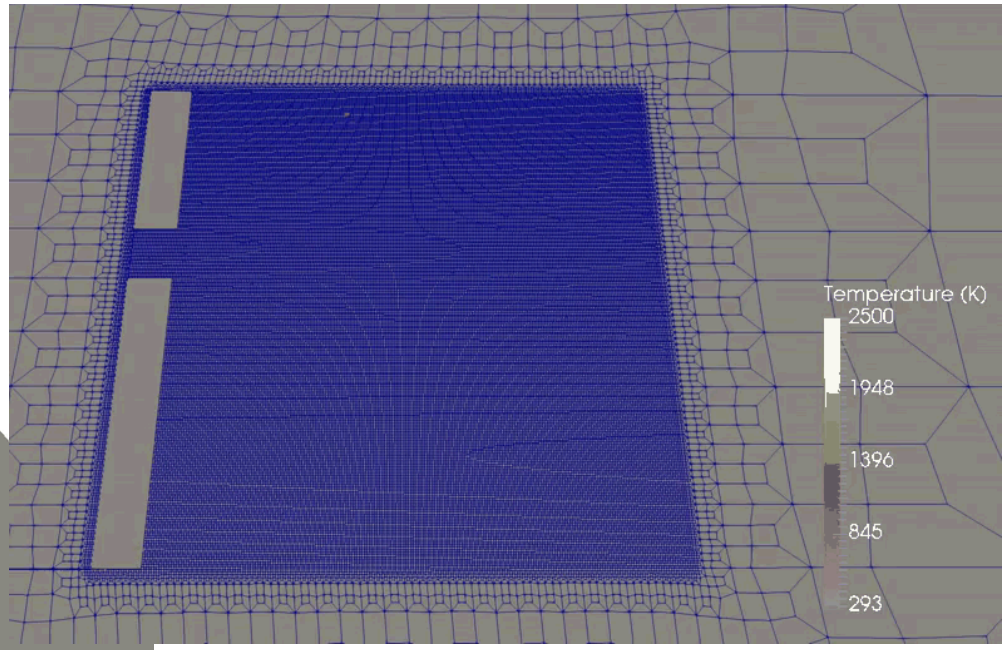




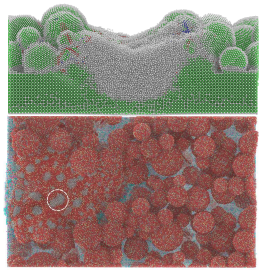
Hot Spot to Approximate Raster Pattern





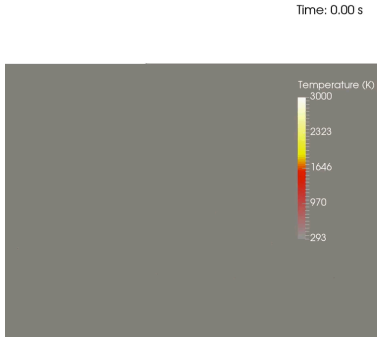
Fundamental Questions

- What is lost by approximating a raster island with a single hotspot?
- What is lost by averaging the melt pool into a monolithic hotspot?
- Can higher fidelity models be used to inform low fidelity models?



Molecular Scale
Mark Wilson

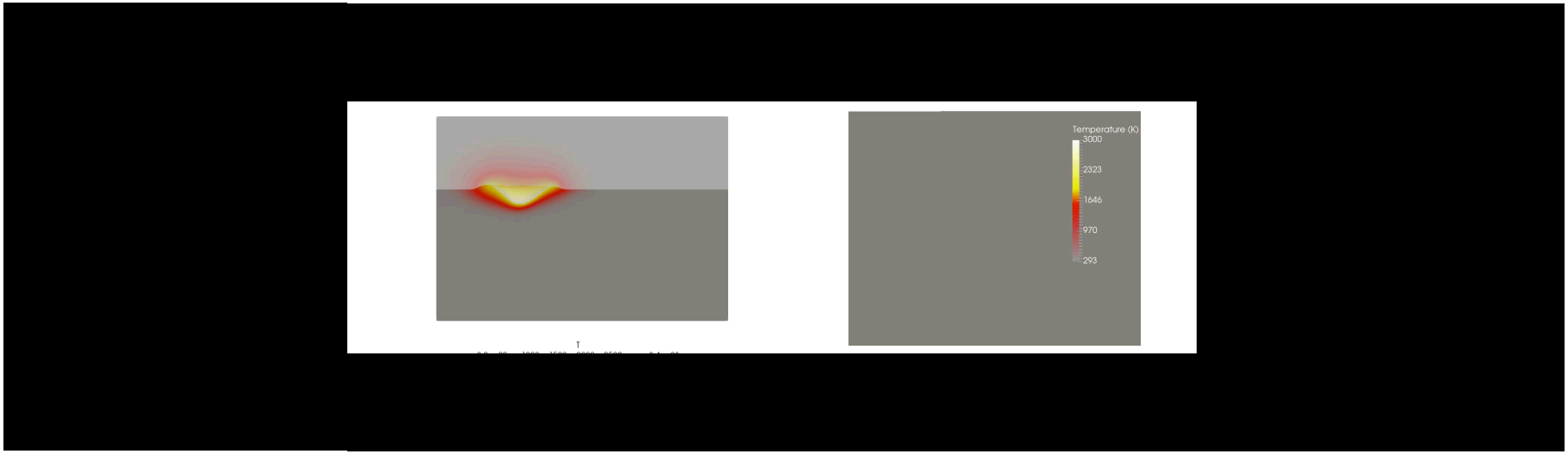
Fluid Scale
Mario Martinez, Kurtis Ford



Part Scale
Kyle Johnson – He is still Here

High Part Volume Scale
Kyle Johnson, Kurtis Ford

Can a Fluid Mechanics Model

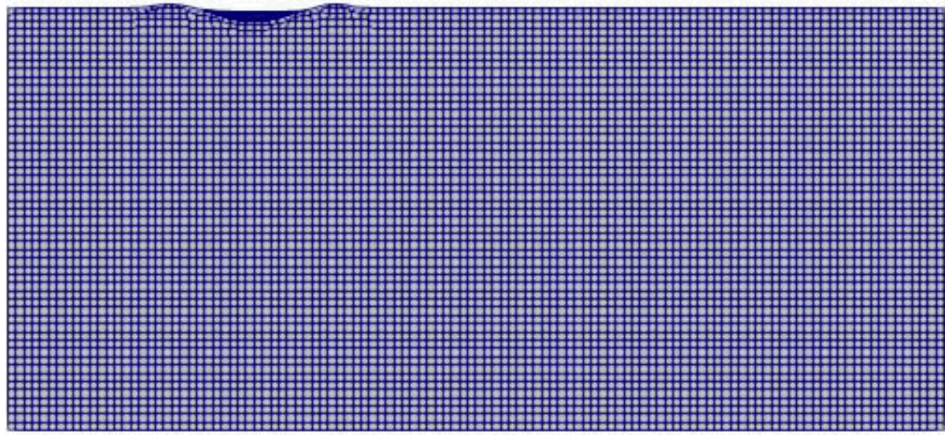


1. Can we use a meso scale fluid model to inform a part scale model?

2. Would a fluid model predict a different residual Stress than a part scale model

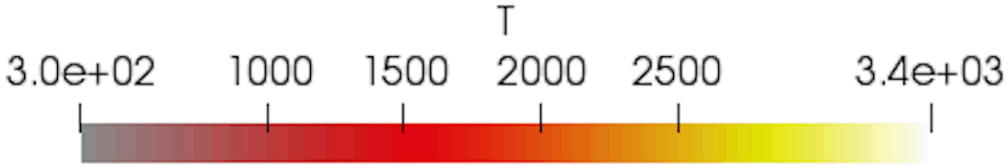
Residual Stress from Fluid Model

CDFEM fluid model predicts an evolving boundary



Generate a Lagrangian mesh from fluid model results to use for Solid mechanics calculation. Element stiffness transitions from soft to stiff based on the solidous wave front.

Fluid contains a solidus wave front (purple) where material



Additional Physics in Meso Scale Fluid Model

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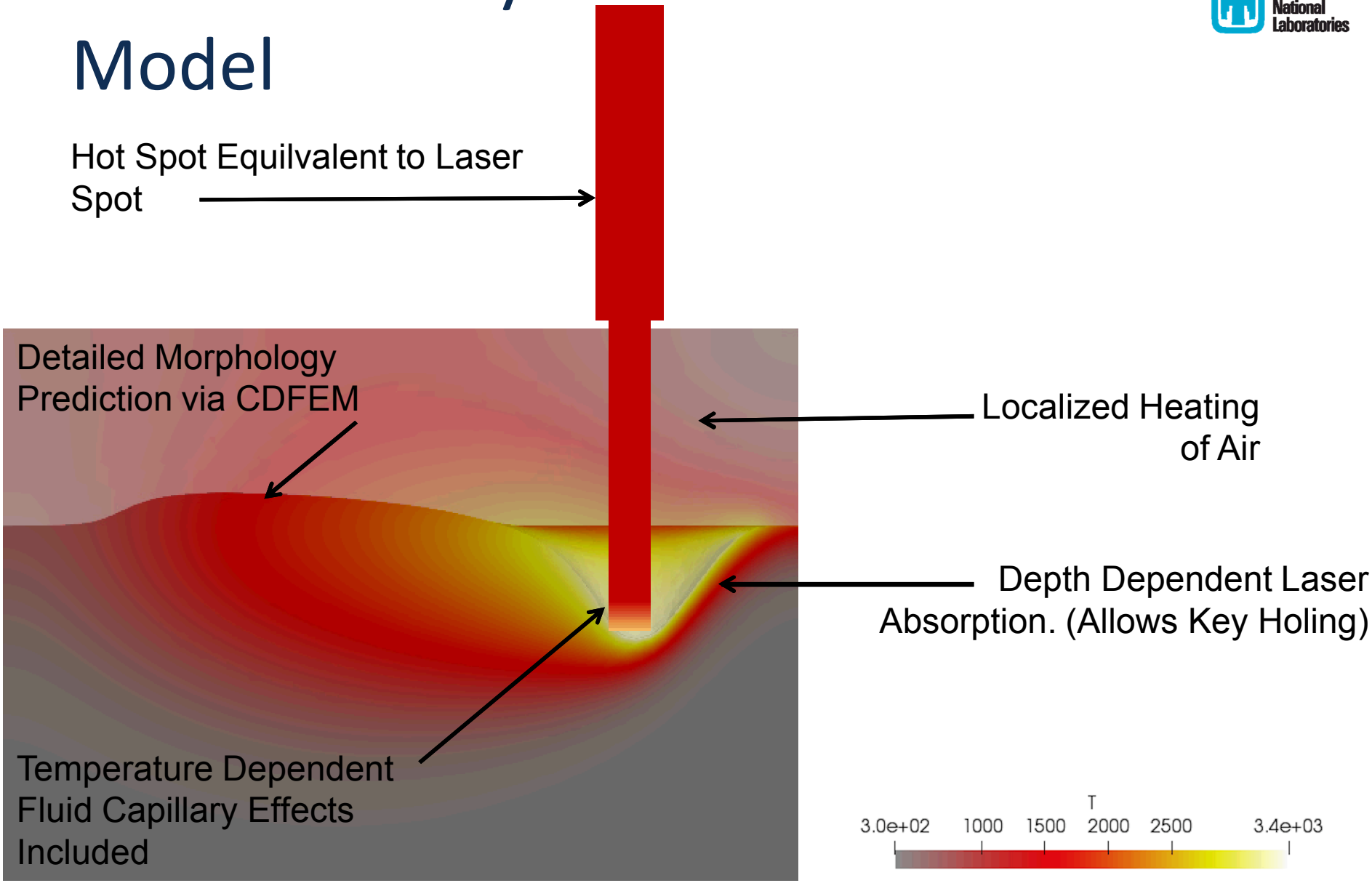
Hot Spot Equilvalent to Laser Spot



Additional Physics in Meso Scale Fluid Model Continued

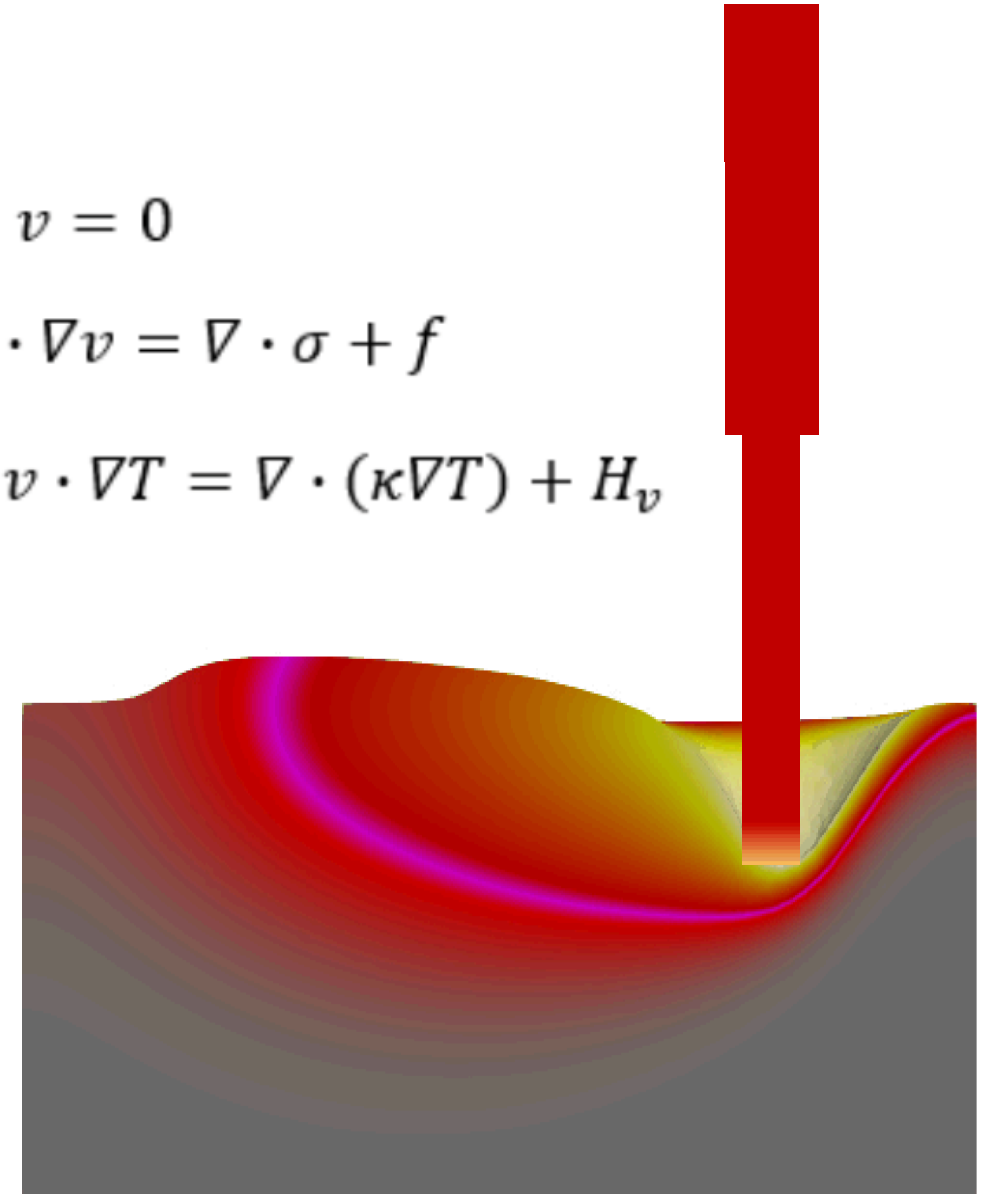
Sandia National Laboratories

Continuity: $$\nabla \cdot v = 0$$

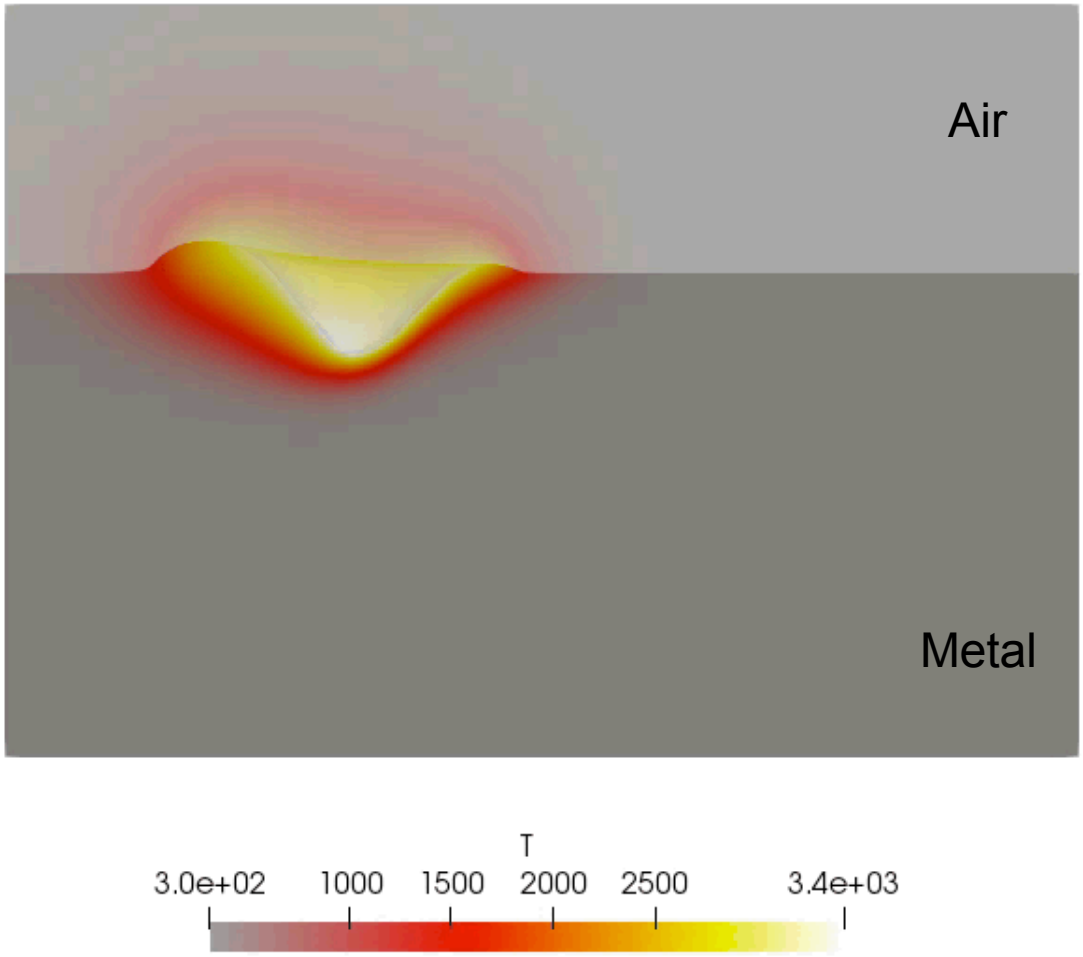
Momentum: $$\rho \frac{\partial v}{\partial t} + \rho v \cdot \nabla v = \nabla \cdot \sigma + f$$

Energy: $$\rho C_p \frac{\partial T}{\partial t} + \rho C_p v \cdot \nabla T = \nabla \cdot (\kappa \nabla T) + H_v$$

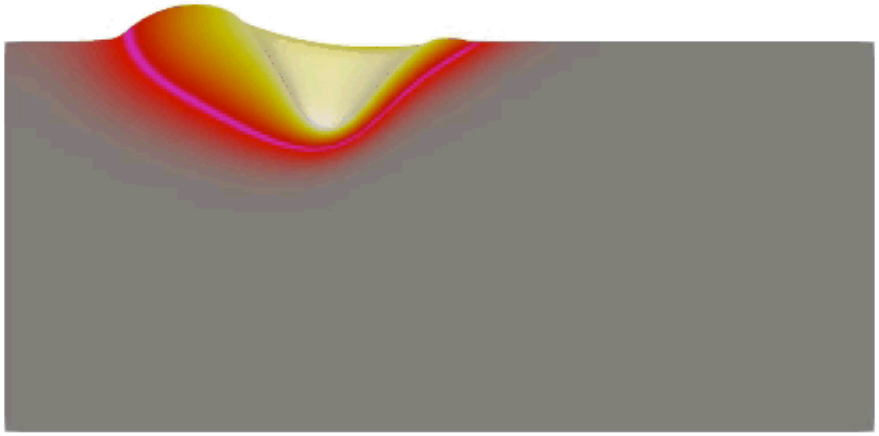
Solid Liquid phase transition created Sudden Increase in Viscosity at Melt Temperature

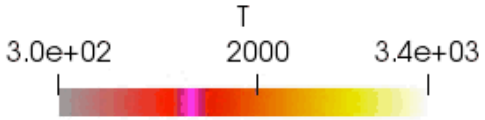


Fluid Model Results



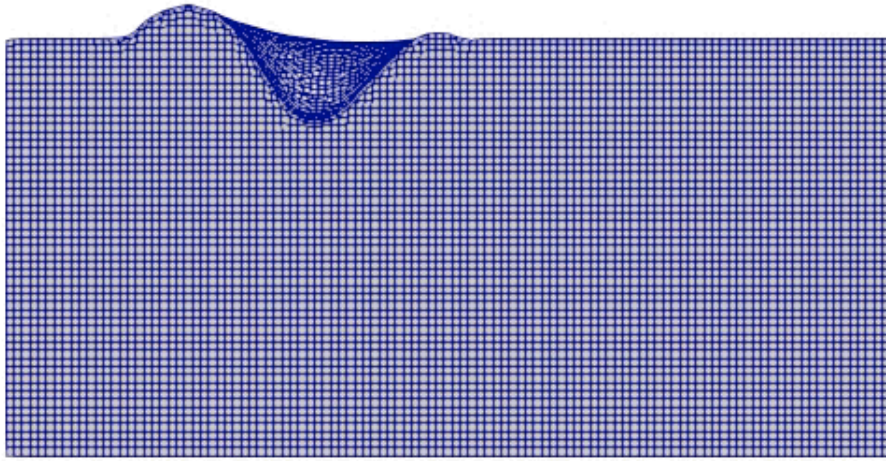
Solid mechanics Couple



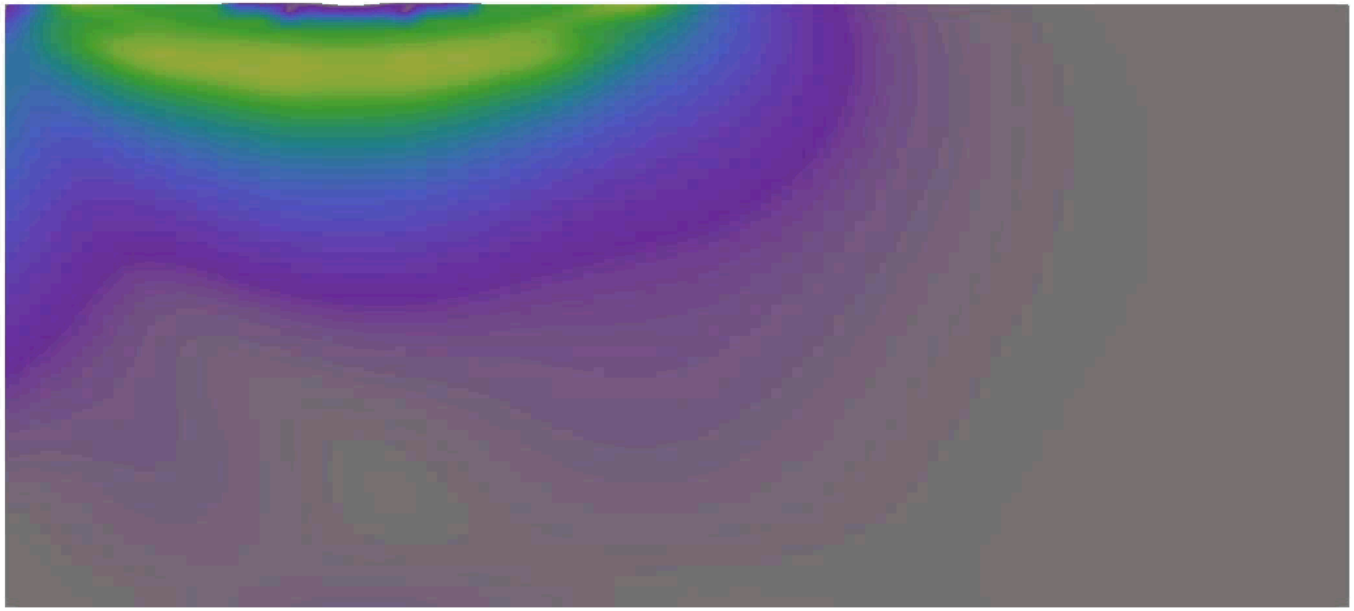


Map Temperature History to conformal mesh of CDFEM geometry

Drastically reduce stiffness of “melted Elements



Residual Stress Predicted By Fluid Model



Laser Engineered Net Shaping (LENS) Process Overview

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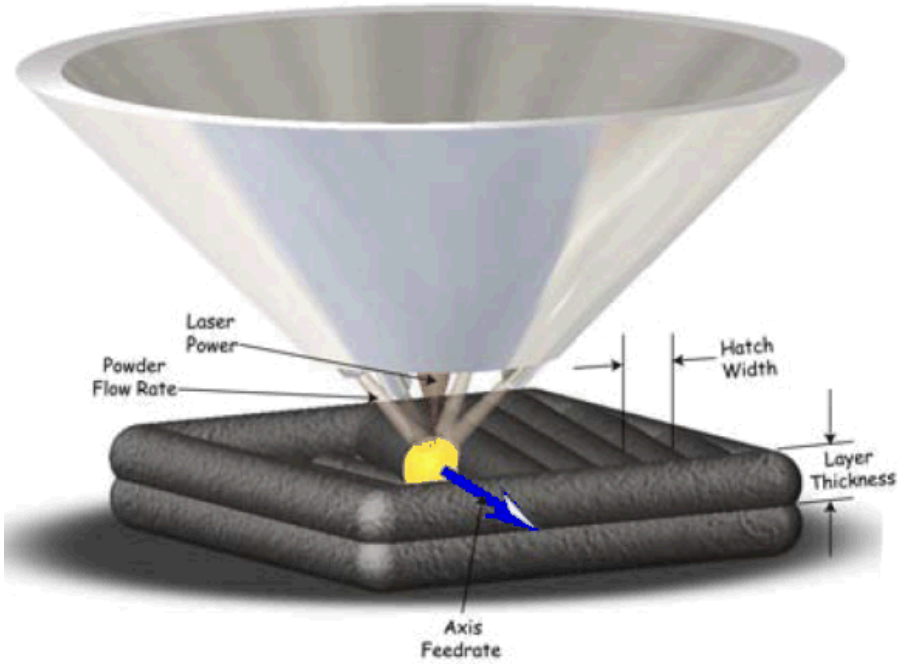
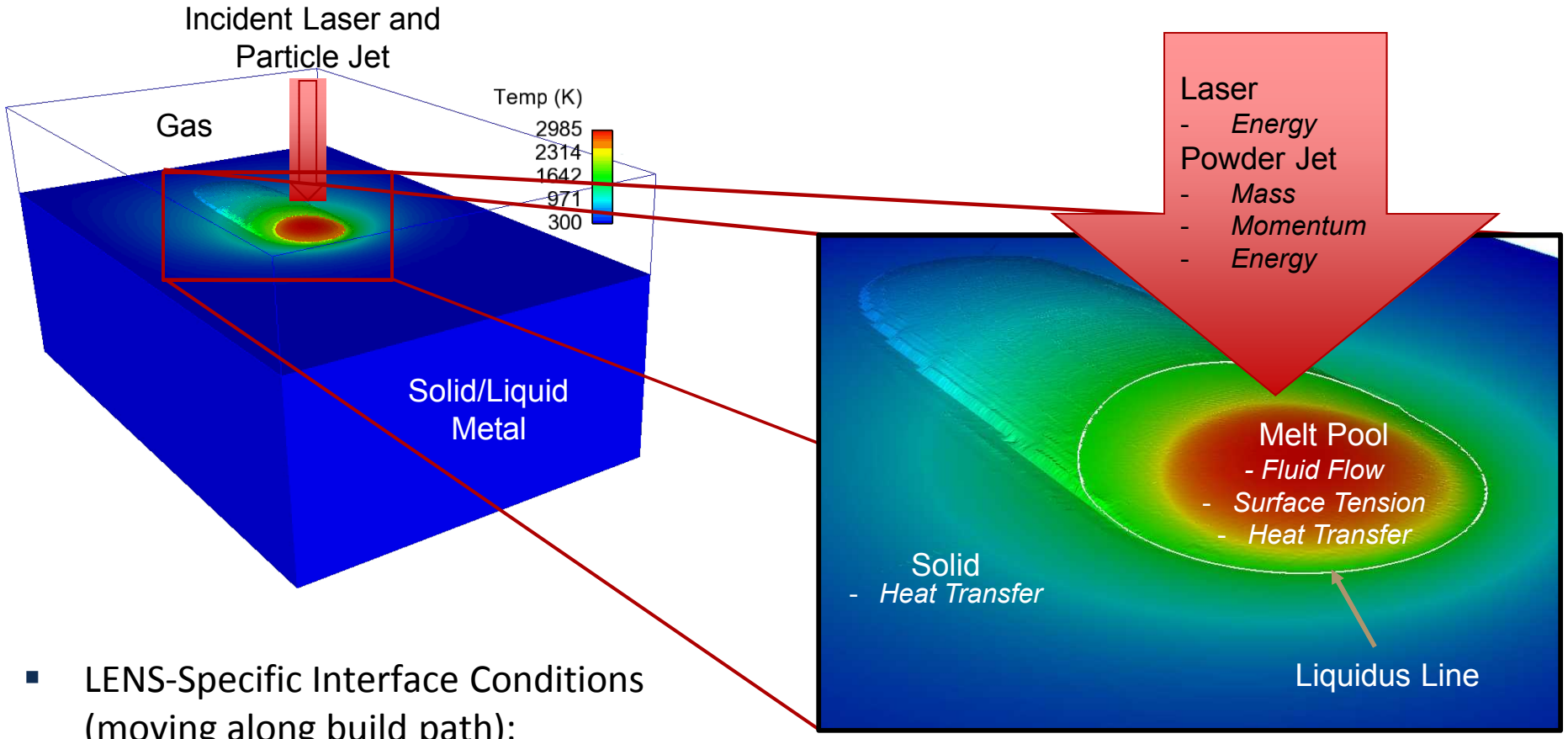
- Laser and powder jets move along prescribed path
  - Laser heats the metal surface, creating a melt pool
  - Powder that lands in melt pool is deposited
- Capable of depositing freeform structures on metal substrates
  - Additive manufacturing technique
  - Ideal for repair
- Can result in fully dense (non-porous) material



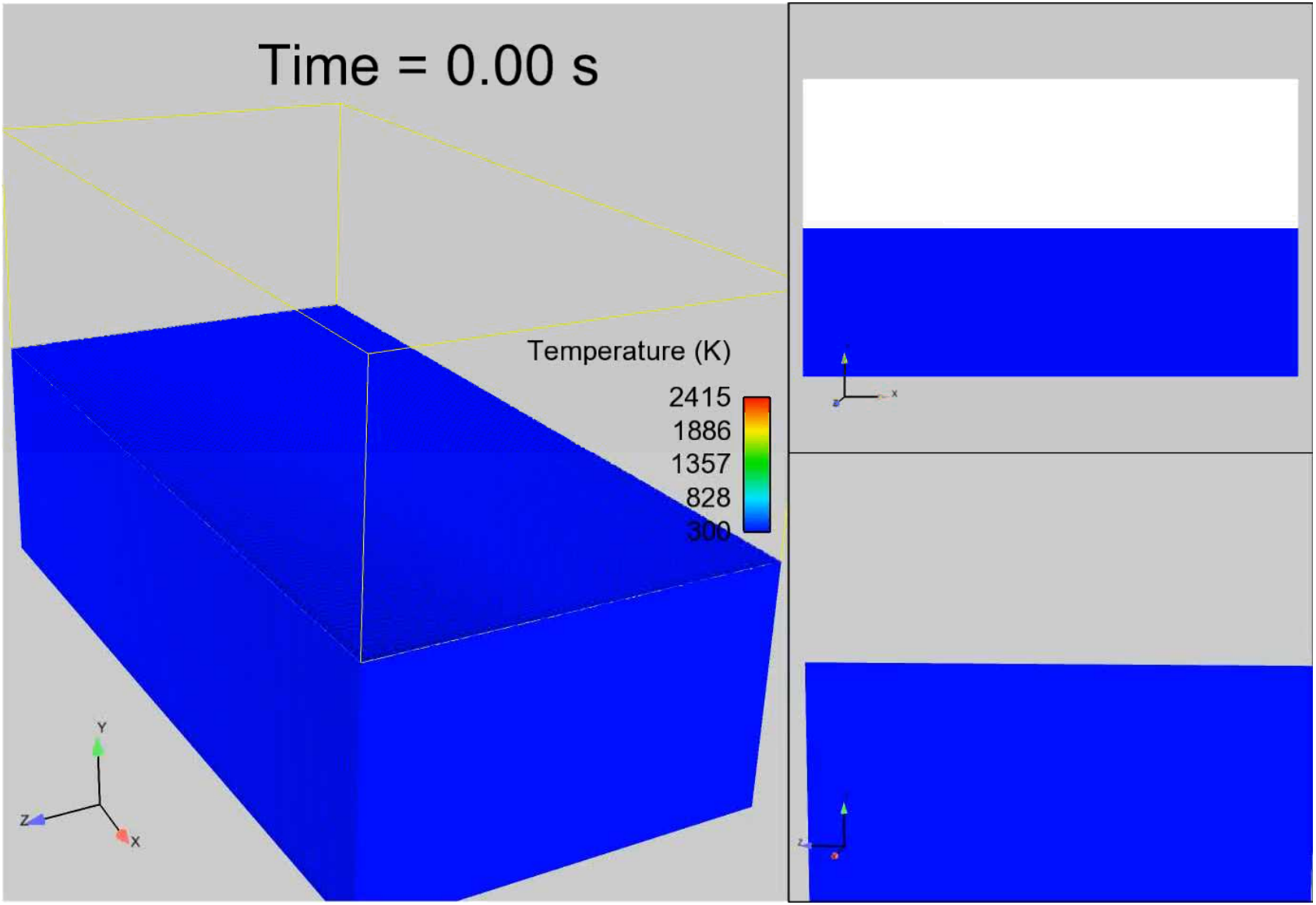
Mesoscale Thermal/Fluid Modeling



- LENS-Specific Interface Conditions (moving along build path):
  - Laser energy flux
  - Particle absorption into melt pool
    - Energy flux
    - Mass flux
    - Momentum Flux

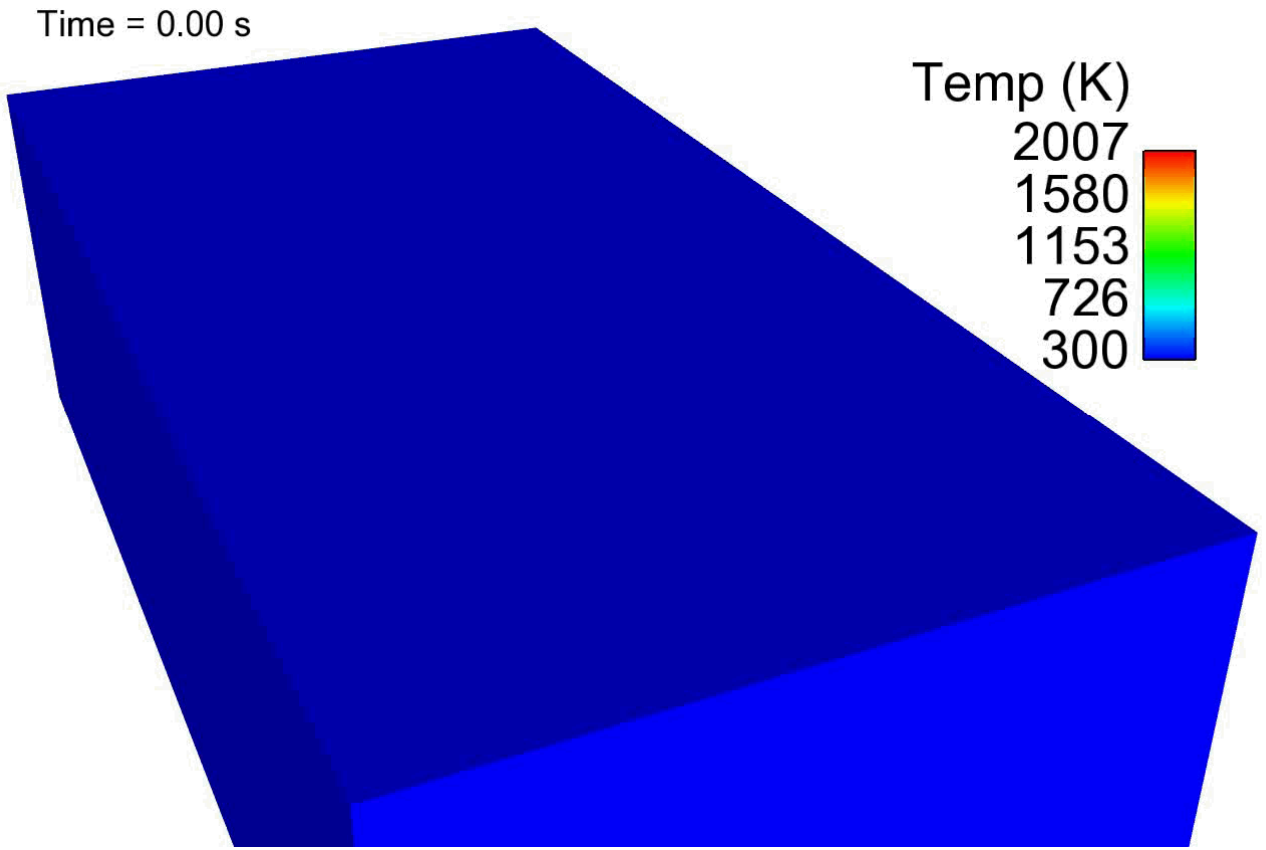
- Boundary/Interface Conditions:
  - Convective and radiative heat loss on surface
  - Free surface boundary condition
    - Surface tension function of temperature

3D 3-Layer Wall Simulation



3D Side-by-Side Simulation Example

- Single layers side-by-side
- Usefu
  - Vi

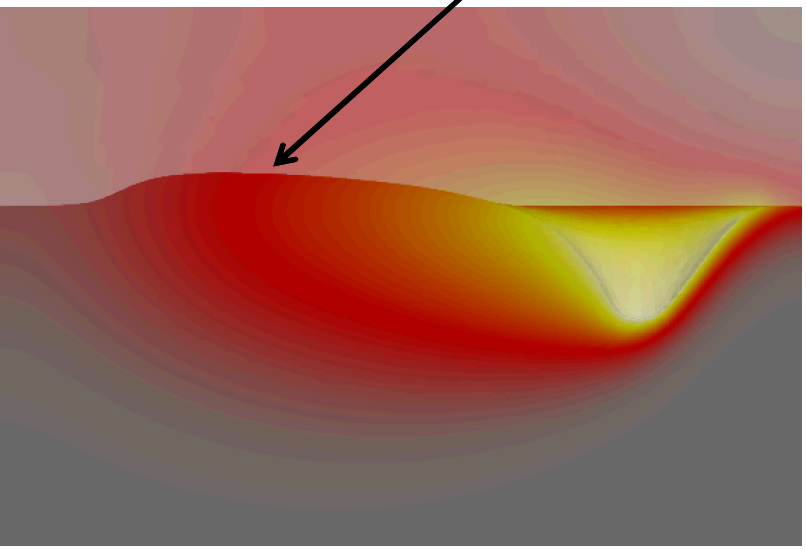


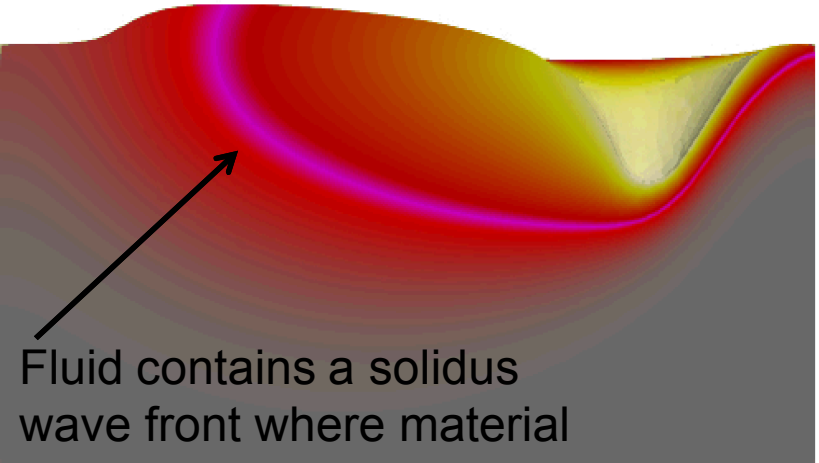
Conclusions

- A CDFEM fluid model has been coupled to a solid mechanics mesh to predict residual stress of a material during welding.
- A part scale model will be compared to this fluid model to look for differences between residual stress and thermal history
- A rectangular tube with a bead of material will be used to make measurements of residual stress to compare to models

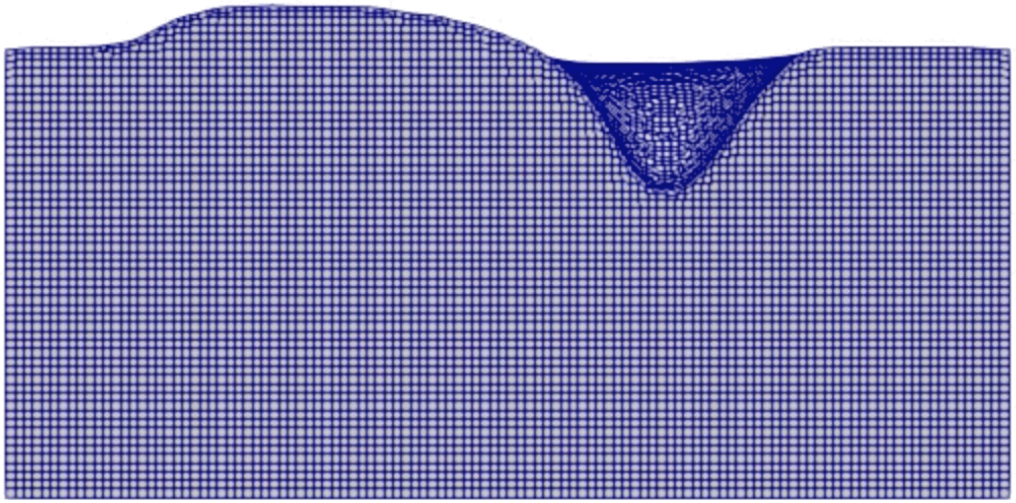
Residual Stress from Fluid Model

Fluid model predicts an evolving gas boundary



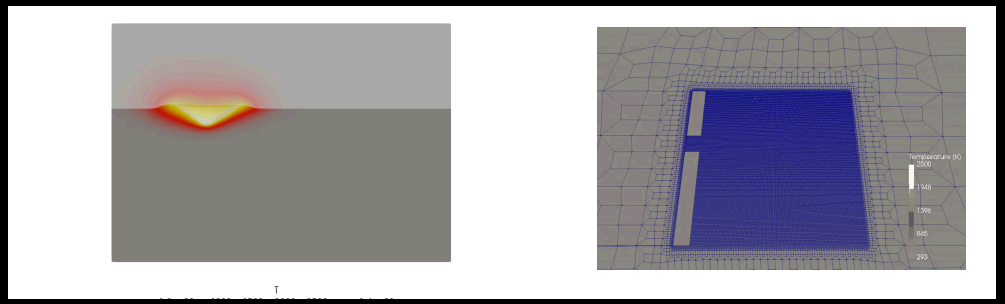


Fluid contains a solidus wave front where material

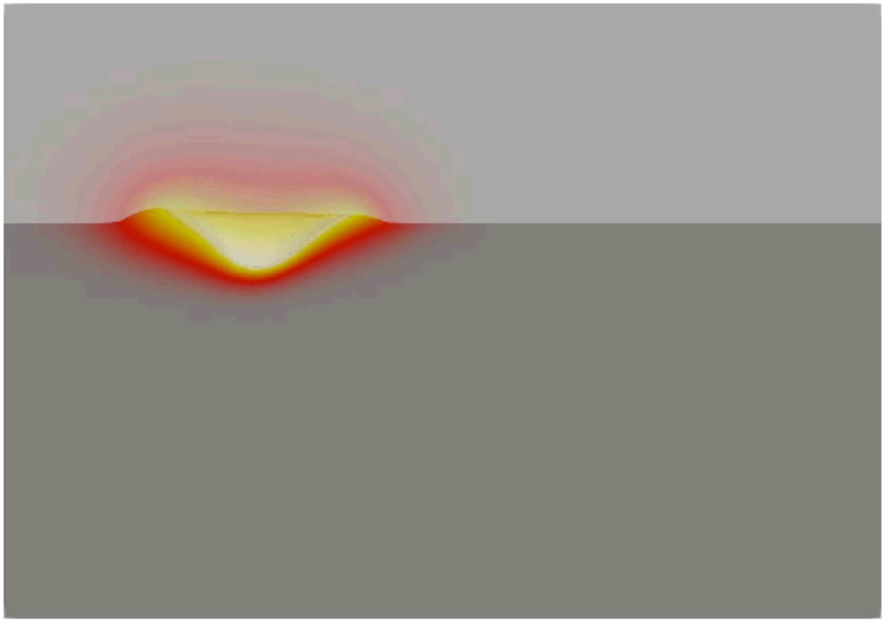


Generate a Lagrangian mesh from fluid model results to use for Solid mechanics calculation. Element stiffness transitions from soft to stiff based on the solidous wave front.

Can a Fluid Mechanics Model



Meso Scale	CDFEM Fluid Model	Visco-plastic Structural Model
Part Scale	Solid Thermal Model	Visco-plastic Structural Model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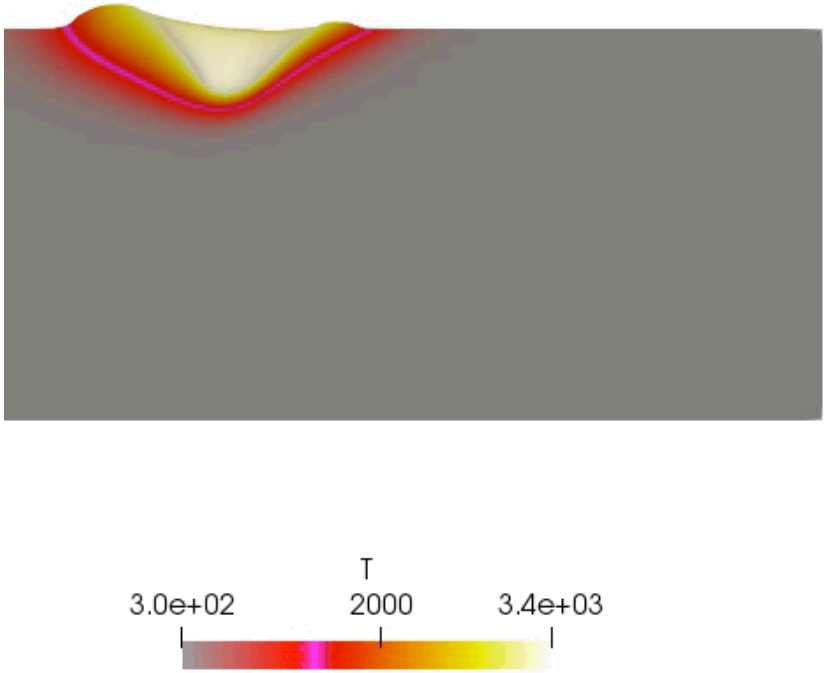
T
3.0e+02
2000
3.4e+03

Model a Bead with Both Methods

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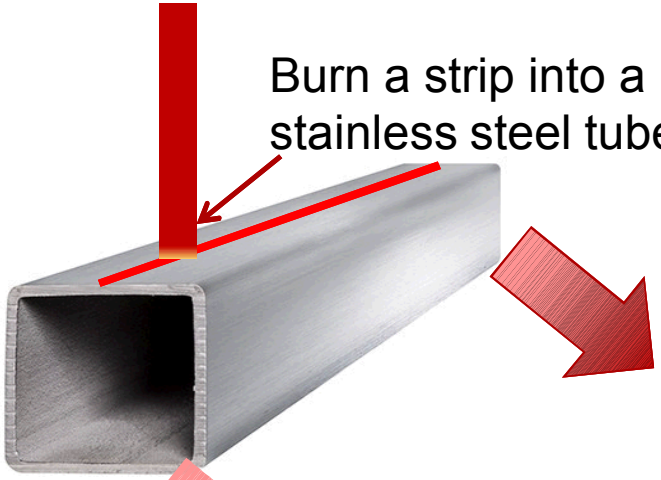
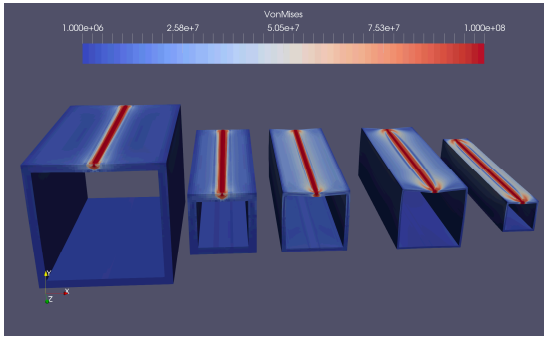
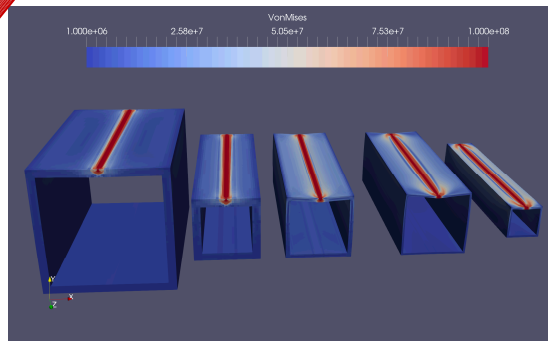


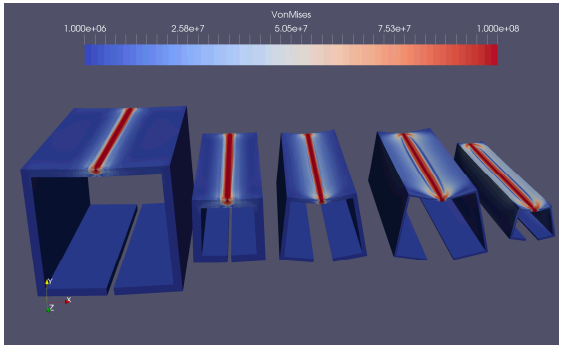
Burn a strip into a stainless steel tube

Model Stress of Bead with a part solid thermal model





Model Stress of Bead with a meso scale fluid model



Measure Stress Experimentally