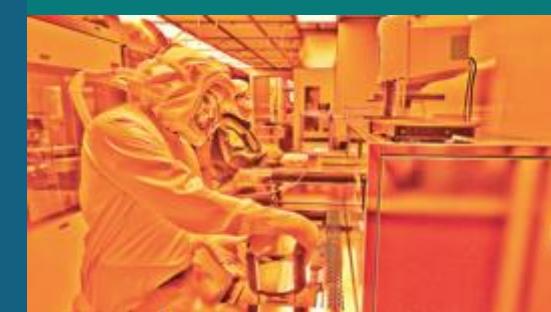


# High-Fidelity CFD Workshop 2022: SNL Steady Supersonic/Hypersonic Summary



PRESENTED BY

Travis Fisher

2022 AIAA 1<sup>st</sup> High-Fidelity CFD Workshop

*This material is a work of the U.S. Government and is not subject to copyright protection in the United States.*

Sandia National Laboratories is a multimission laboratory managed and operated by National Technology & Engineering Solutions of Sandia, LLC, a wholly owned subsidiary of Honeywell International Inc., for the U.S. Department of Energy's National Nuclear Security Administration under contract DE-NA0003525.



Sandia National Laboratories is a multimission laboratory managed and operated by National Technology & Engineering Solutions of Sandia, LLC, a wholly owned subsidiary of Honeywell International Inc., for the U.S. Department of Energy's National Nuclear Security Administration under contract DE-NA0003525.



### Spatial Discretization

- 2<sup>nd</sup> Order structured cell-centered finite volume
- Minmod limiter
- Modified Steger Warming Flux Reconstruction
- Modify entropy fix in wall-normal direction

### Nonlinear Solver

- Pseudotransient continuation for steady problems
- Adaptive CFL
  - User limits based on “run schedule”
  - CFL increases/decreases based on linear solver tolerance achieved, optionally solution percentage changes, and optionally line search
  - Can include or exclude temporal term in residual
  - Local/Global CFL options
- Different Linearization Options
  - Approximate Jacobian
  - Automatic Differentiation based Matrix-Free Jacobian

### Linear Solver

- Iterations and preconditioning sweeps are set in “run schedule”
- GMRES with block-tridiagonal preconditioning
- Fixed point block-tridiagonal



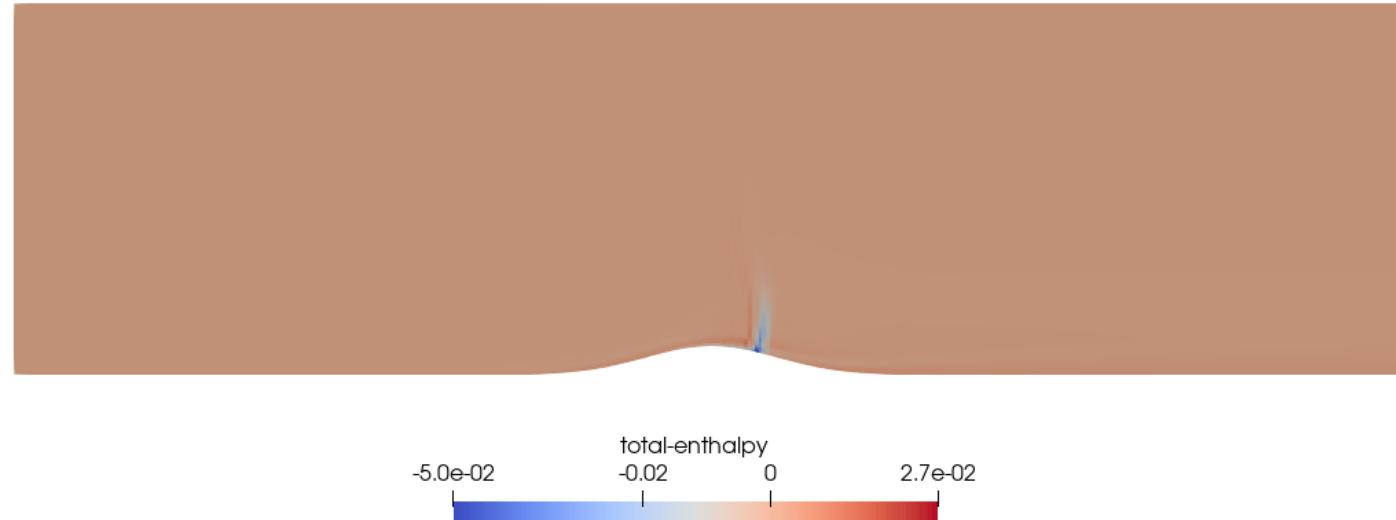
### 3 Supersonic Bump Summary



Very weak convergence of L2 total enthalpy (approx. 0.5)

Poor nonlinear convergence upon refinement

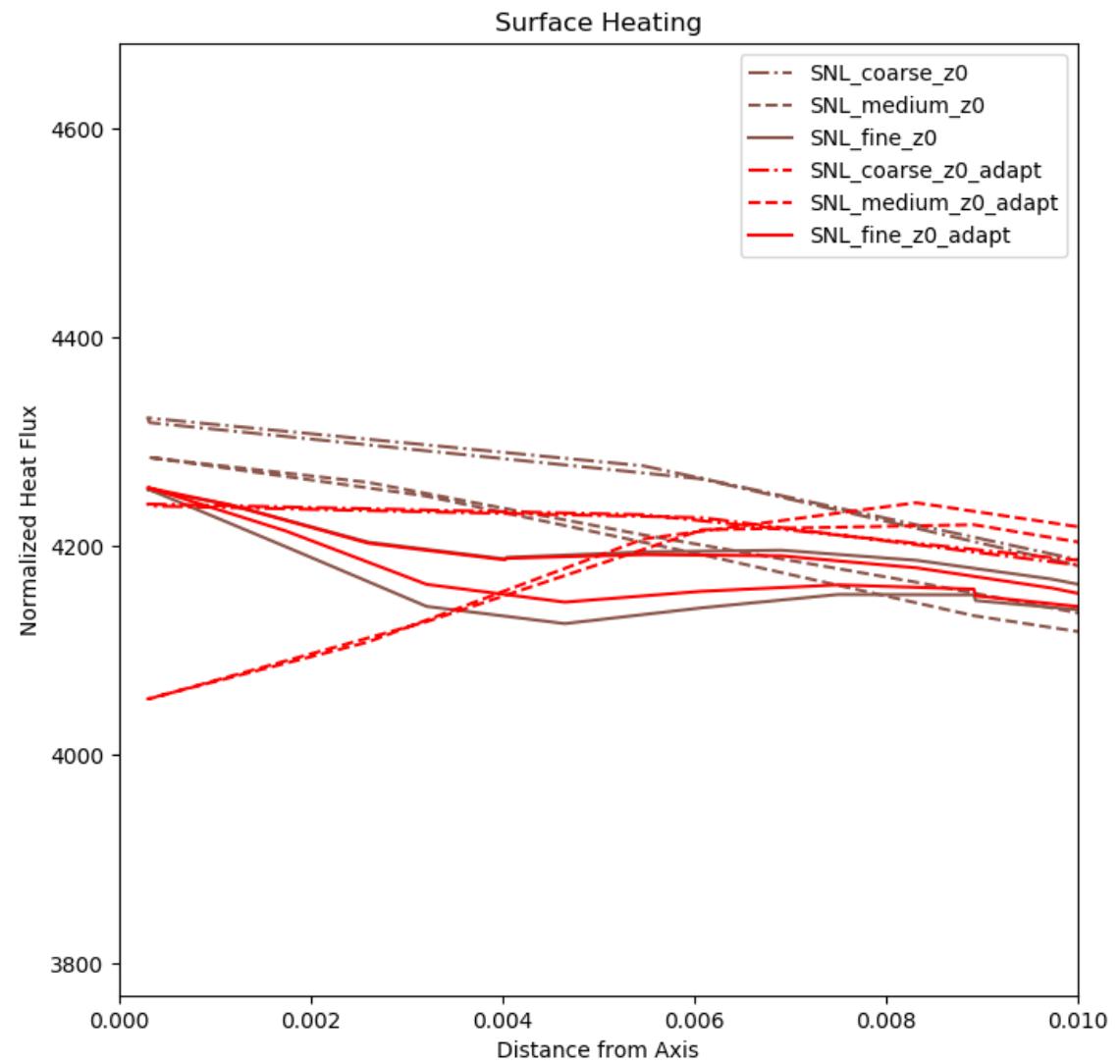
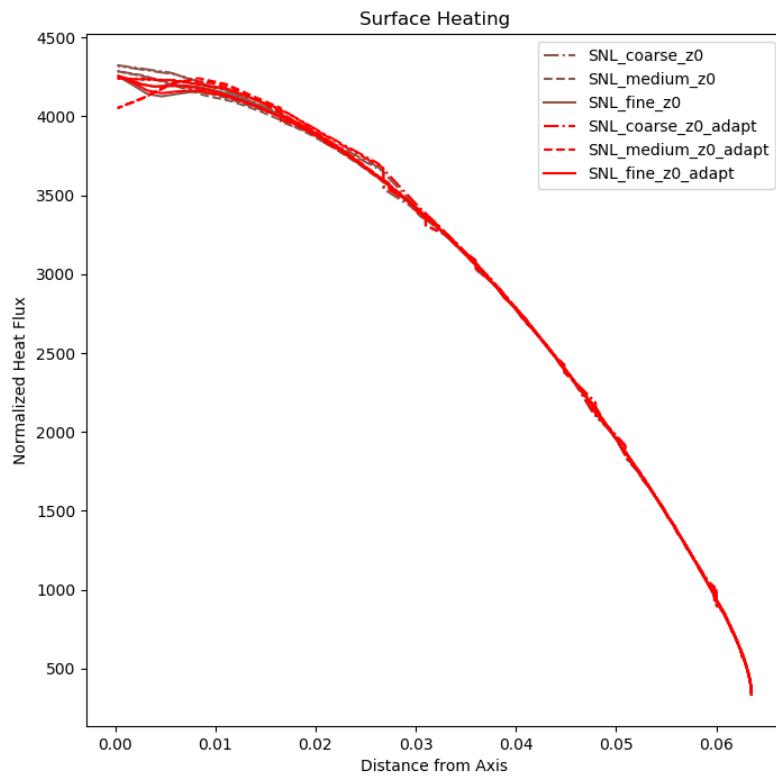
- Exact sensitivities do not help
- Static pressure fully recovers despite shock?



# Blottner Sphere Summary

## Sensitivity to boundary layer dissipation

- Finest mesh arguably a worse result
- Adaptivity makes this worse





Nonlinear convergence can be difficult to achieve for finest mesh

- Inexact Jacobian would not converge with automated schedule
- CFL controller strategy required more linear iterations with AD-based matrix-free Jacobian
- Aggressive CFL schedule leads to NaN

Laminar cone cases had convergence difficulties on coarser meshes

- AD-based matrix-free Jacobian needed to get deep convergence