Second AIAA Sonic Boom Prediction Workshop Nearfield CFD Introduction

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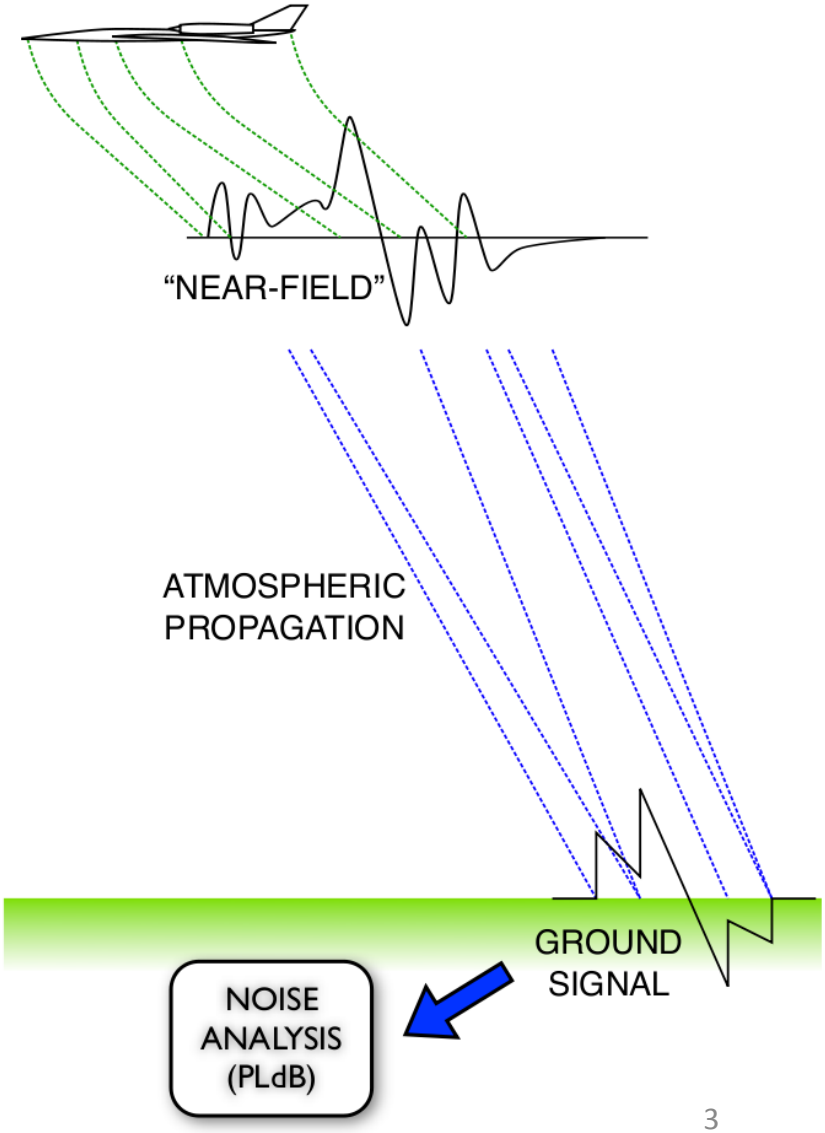
Motivation

- Commercial supersonic overland flight is currently prohibited
  - Supersonic overland flight is an enabler for entry into new vehicle market
- Replacing the prohibition with a certification standard requires an international effort to quantify the accuracy and reliability of prediction methods
- Deficiencies in existing methods should be noted to focus research on addressing weaknesses

Motivation

- Nearfield CFD is part of sonic boom prediction
- Explore the issues
- Impartially compare signatures by uniform application of
  - Nearfield statistics
  - Propagation
  - Loudness measures



Workshop Culture

- Adjectives such as good, bad, right, and wrong oversimplify issues and should be avoided
- Focus on describing observed differences and communicate why things are different

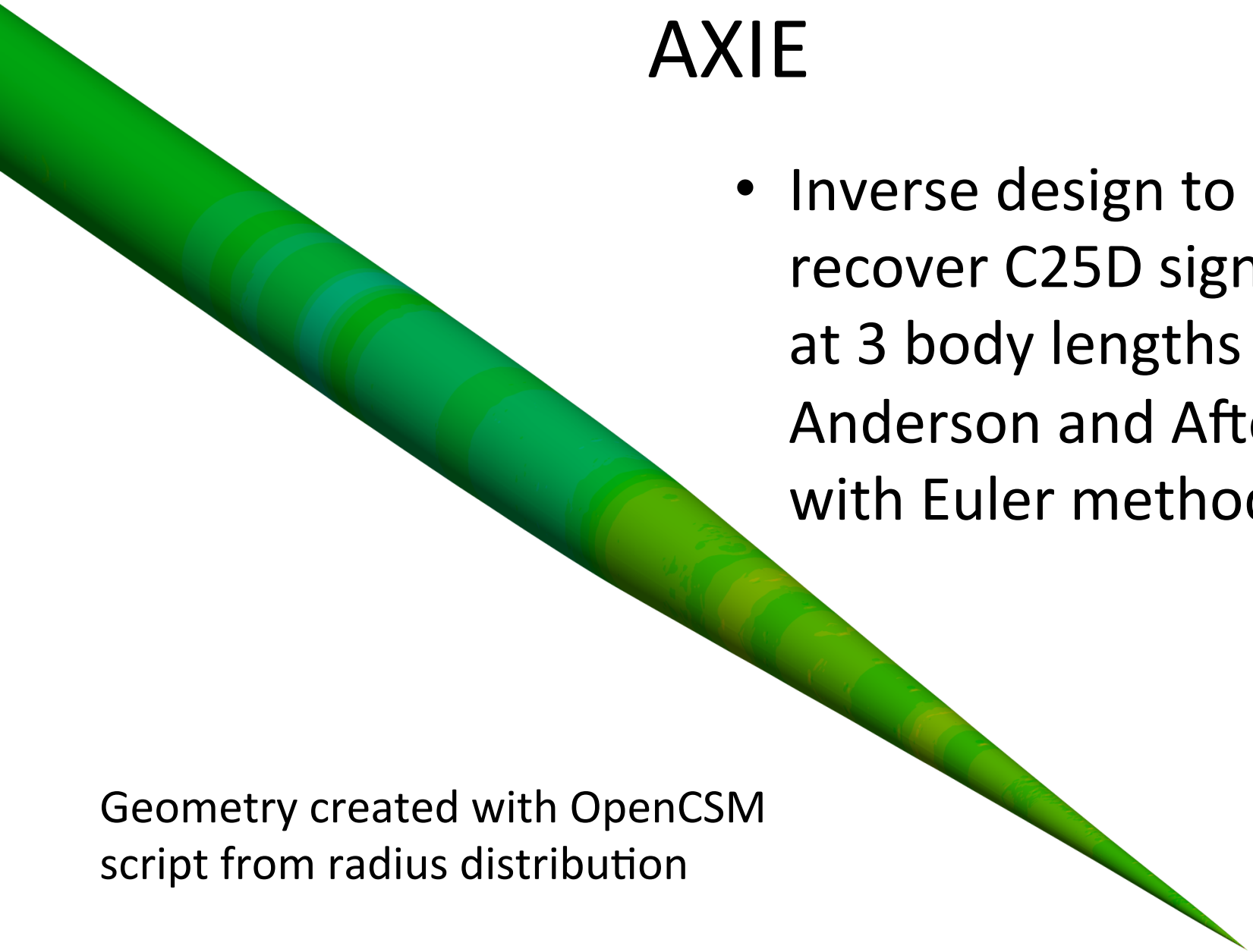
Models and Cases

- Designed to produce similar signatures with a range of simulation complexity
- AXIE C25D Equivalent Area Distribution
- JWB JAXA Delta Wing Body
- C25F C25D Wing Body Flow Through Nacelle
- C25P C25D Wing Body Powered Nacelle (optional)
- STEP geometry files and grids provided

Models and Cases

- All geometry and grids included required angle of attack (grids are Mach cone aligned)
- Mach 1.6
- Euler and Reynolds-averaged Navier-Stokes (RANS) at flight Reynolds number of 5.7 million per meter requested
- US Standard atmosphere at 15,760 meter altitude
- Propulsion boundary conditions provided

AXIE

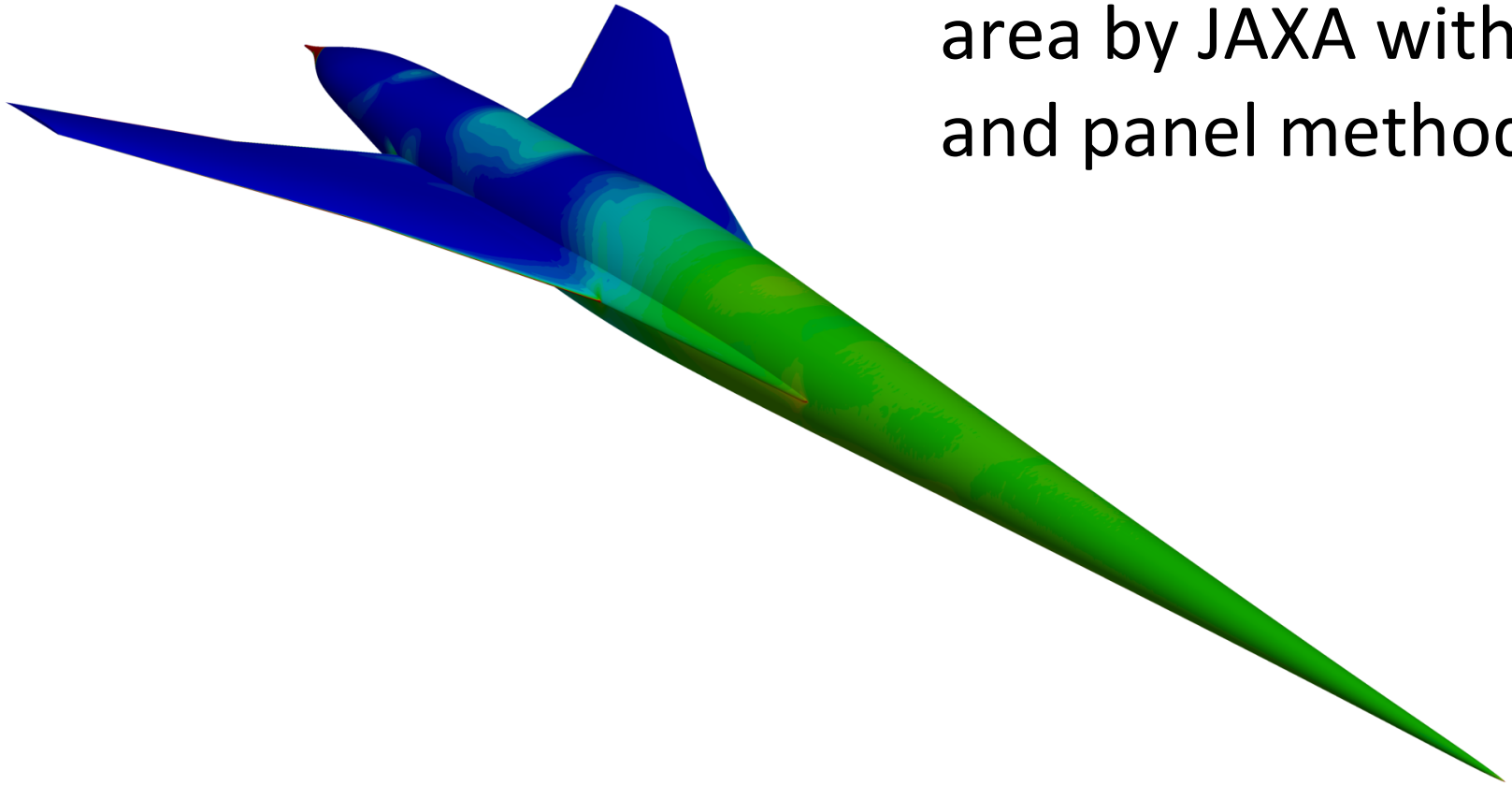


- Inverse design to recover C25D signature at 3 body lengths by Anderson and Aftosmis with Euler method

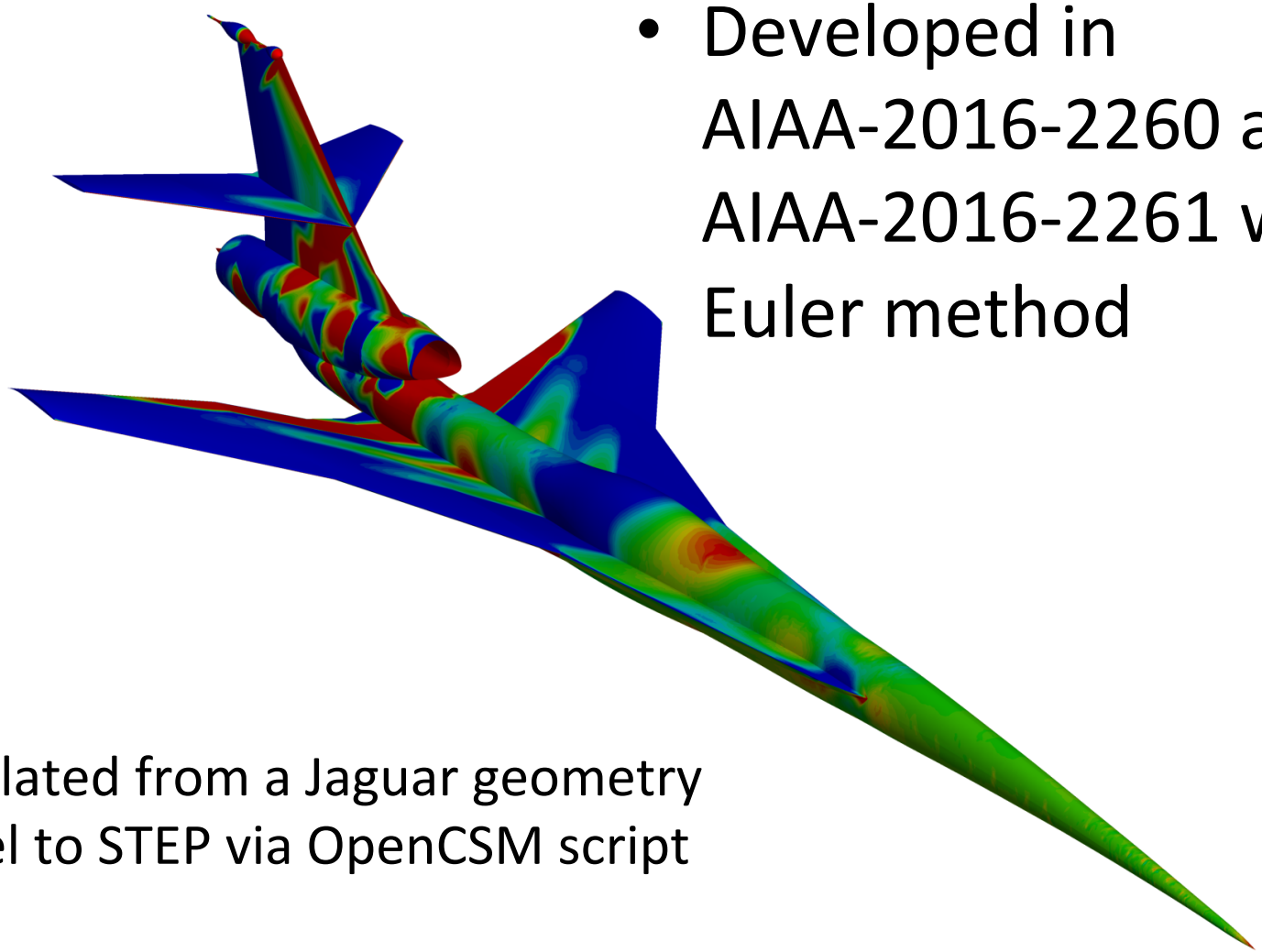
Geometry created with OpenCSM script from radius distribution

JWB

- Inverse design to recover C25D equivalent area by JAXA with Euler and panel methods



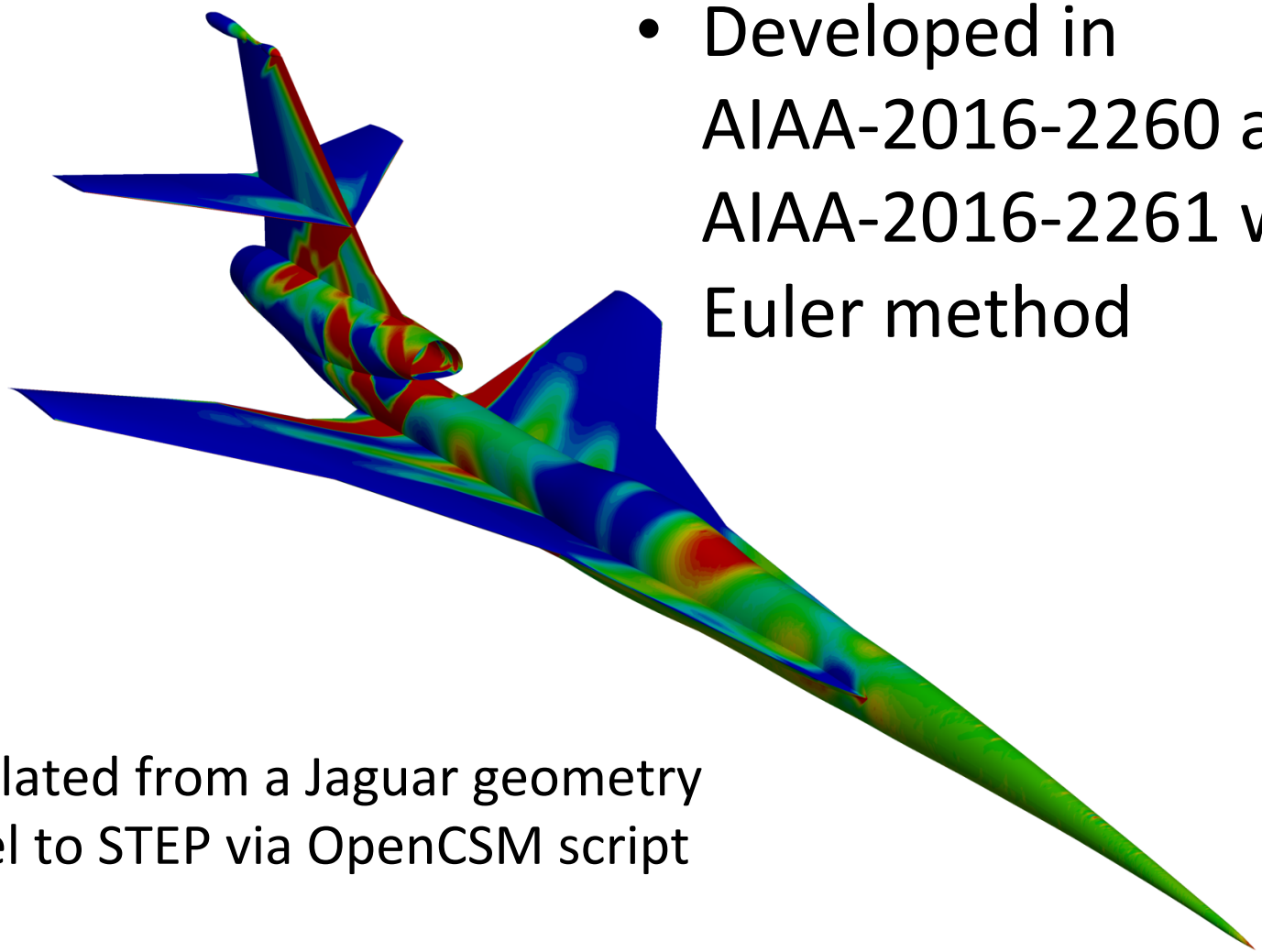
C25P



- Developed in AIAA-2016-2260 and AIAA-2016-2261 with Euler method

Translated from a Jaguar geometry model to STEP via OpenCSM script

C25F



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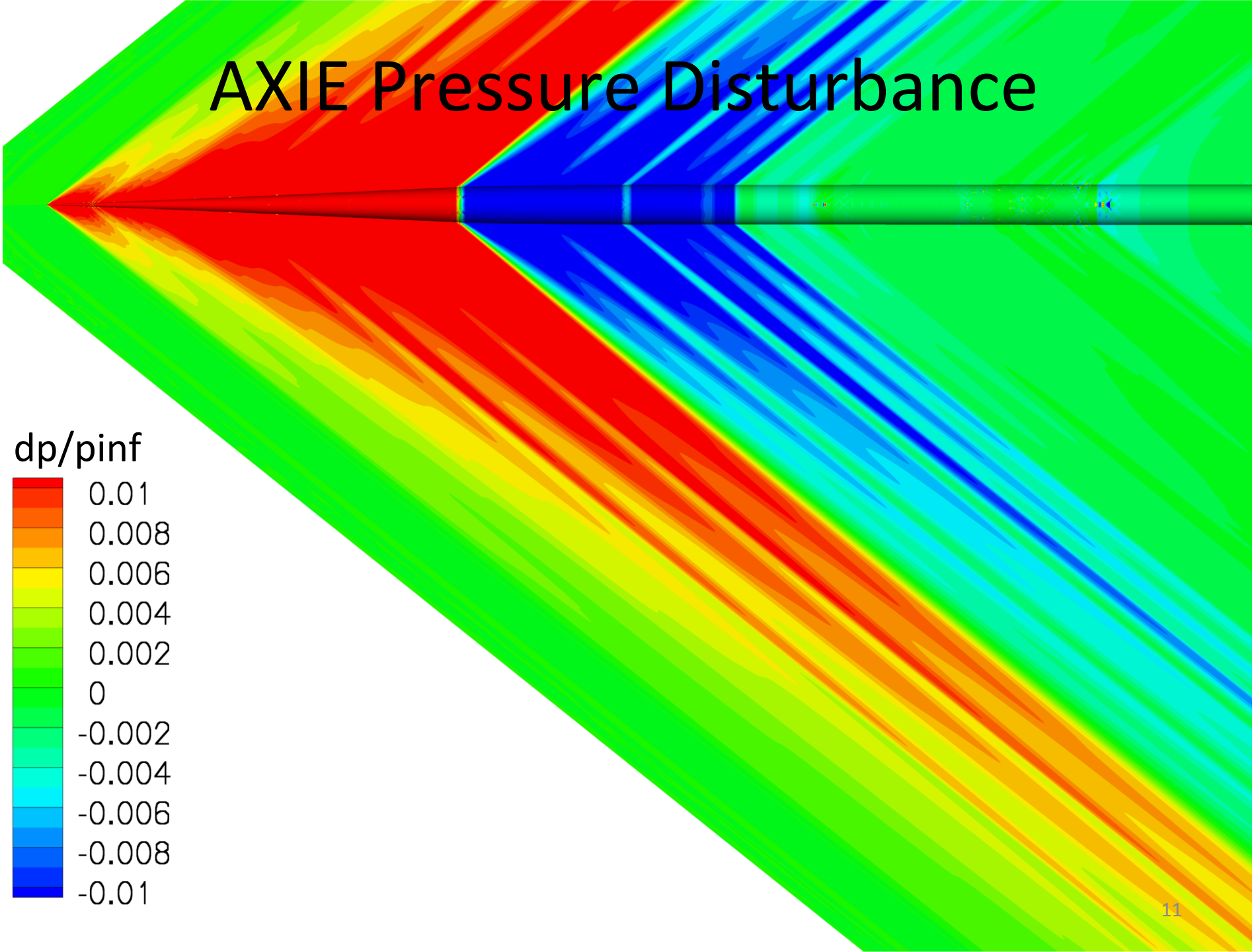
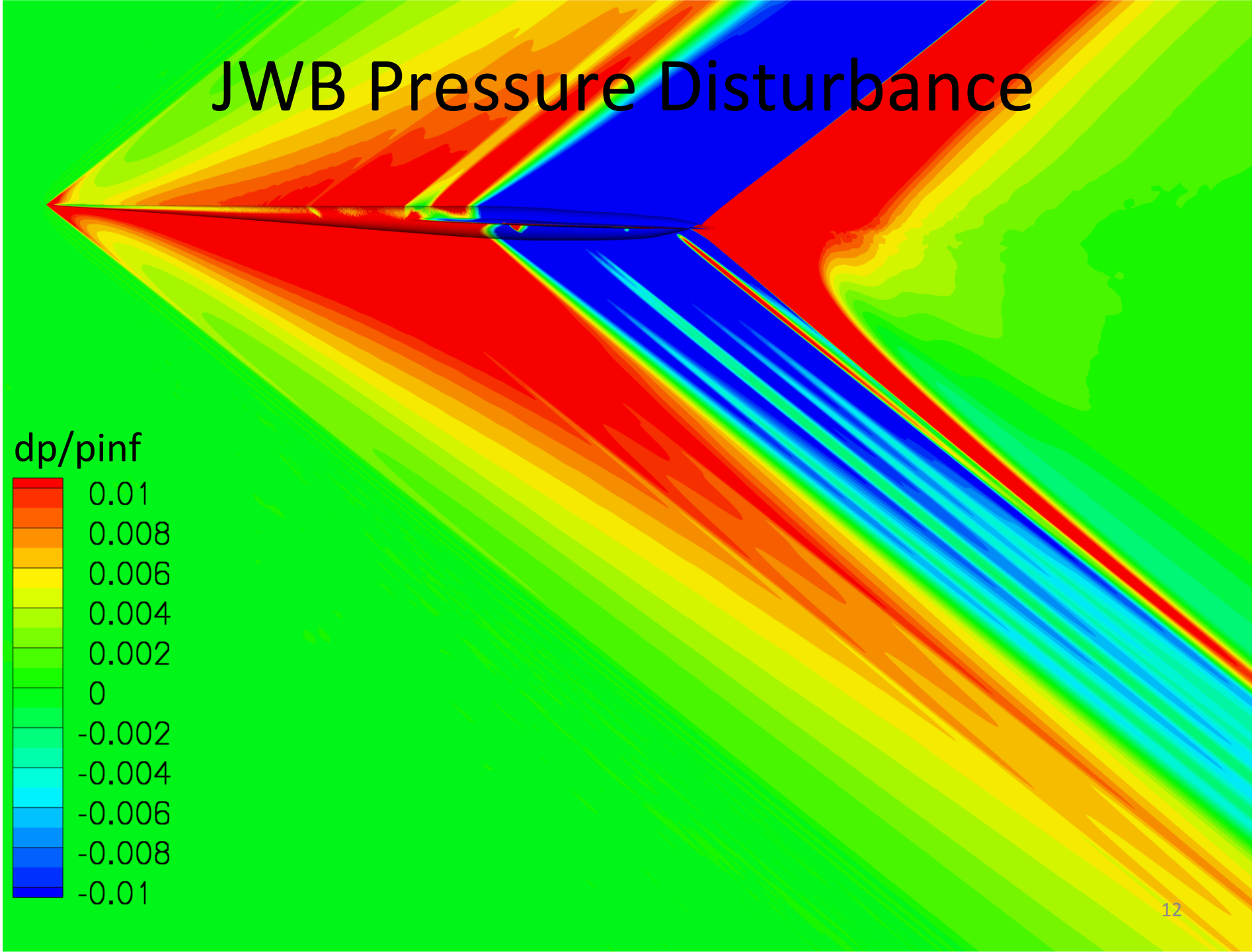
Translated from a Jaguar geometry model to STEP via OpenCSM script

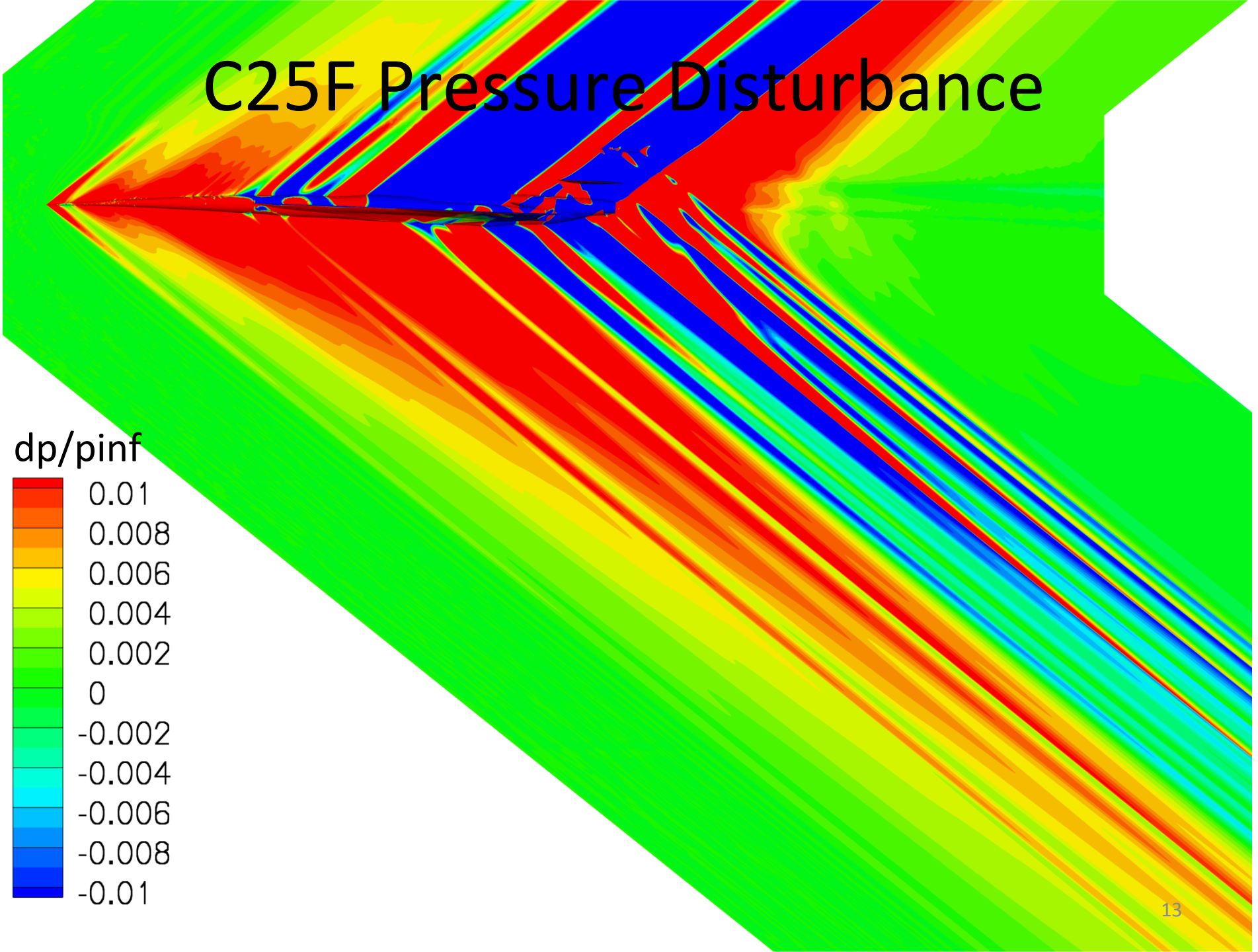
AXIE Pressure Disturbance



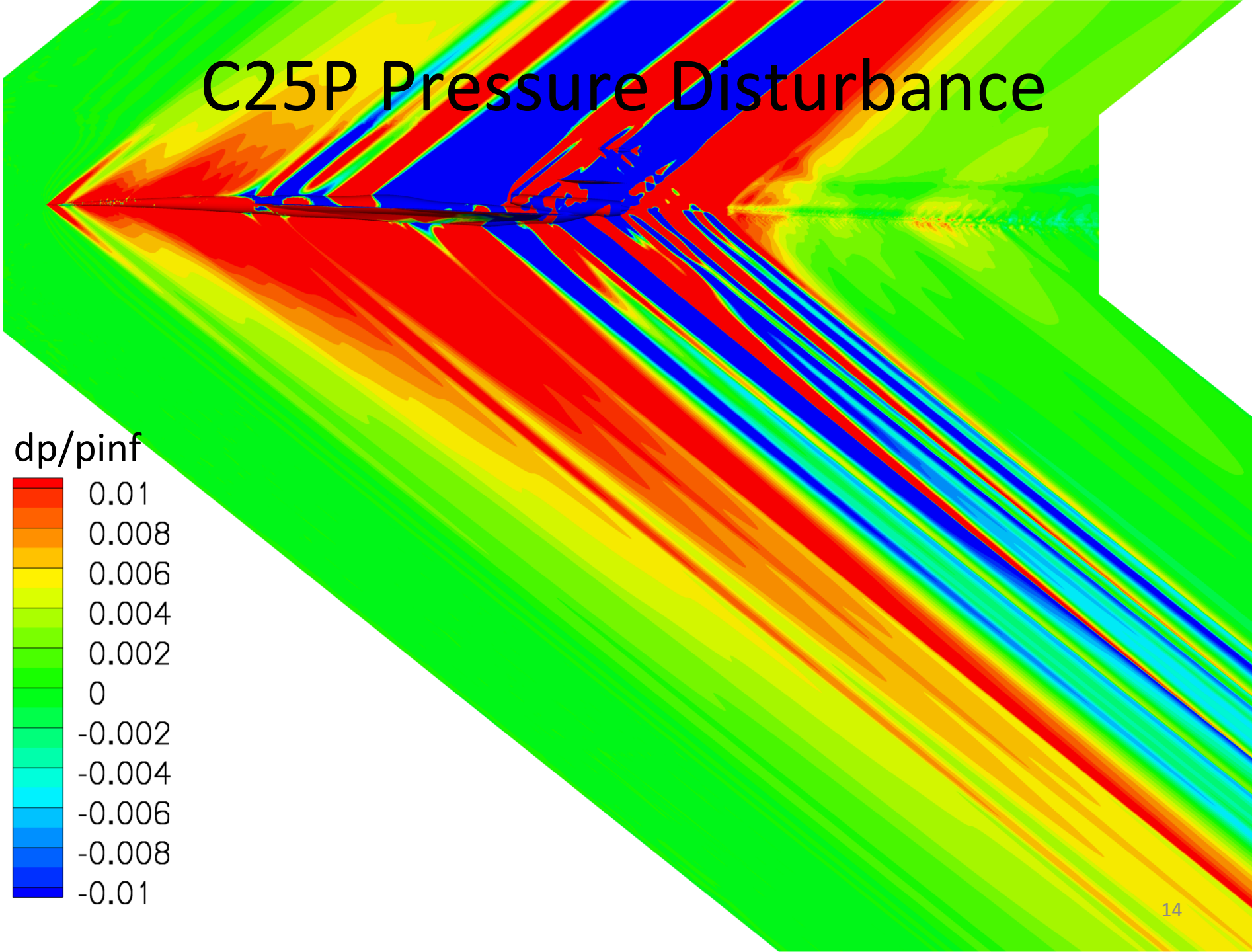
JWB Pressure Disturbance



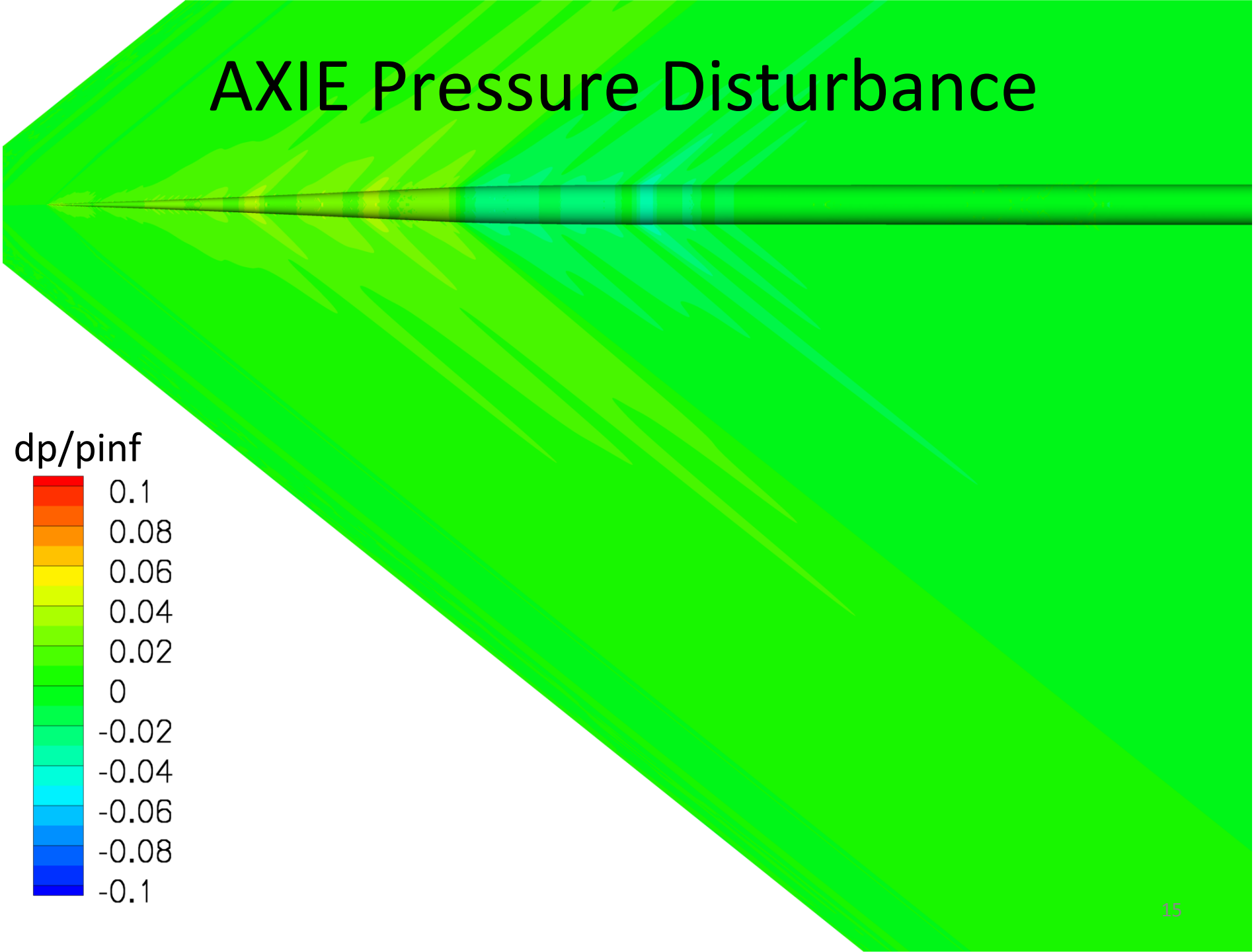
C25F Pressure Disturbance



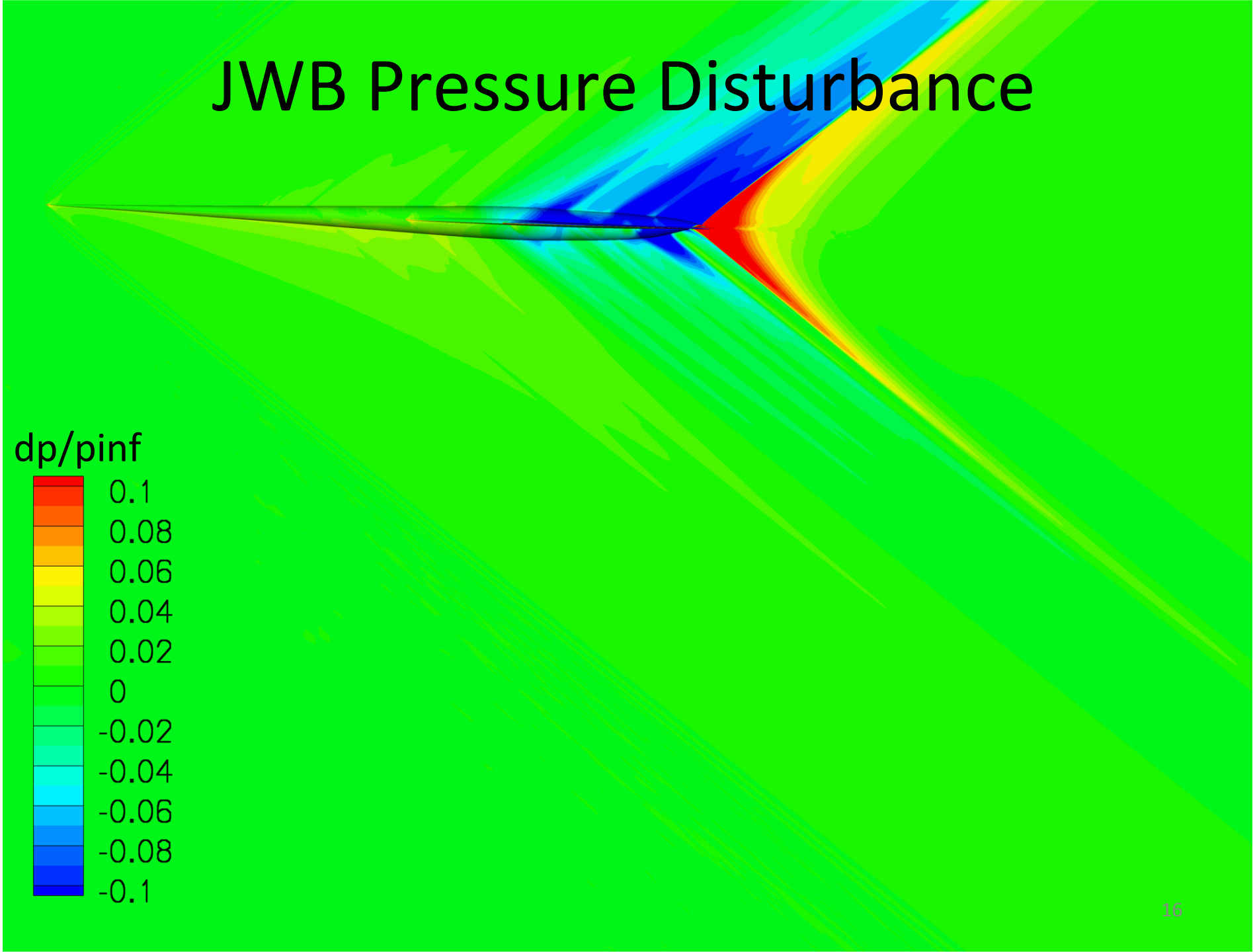
C25P Pressure Disturbance



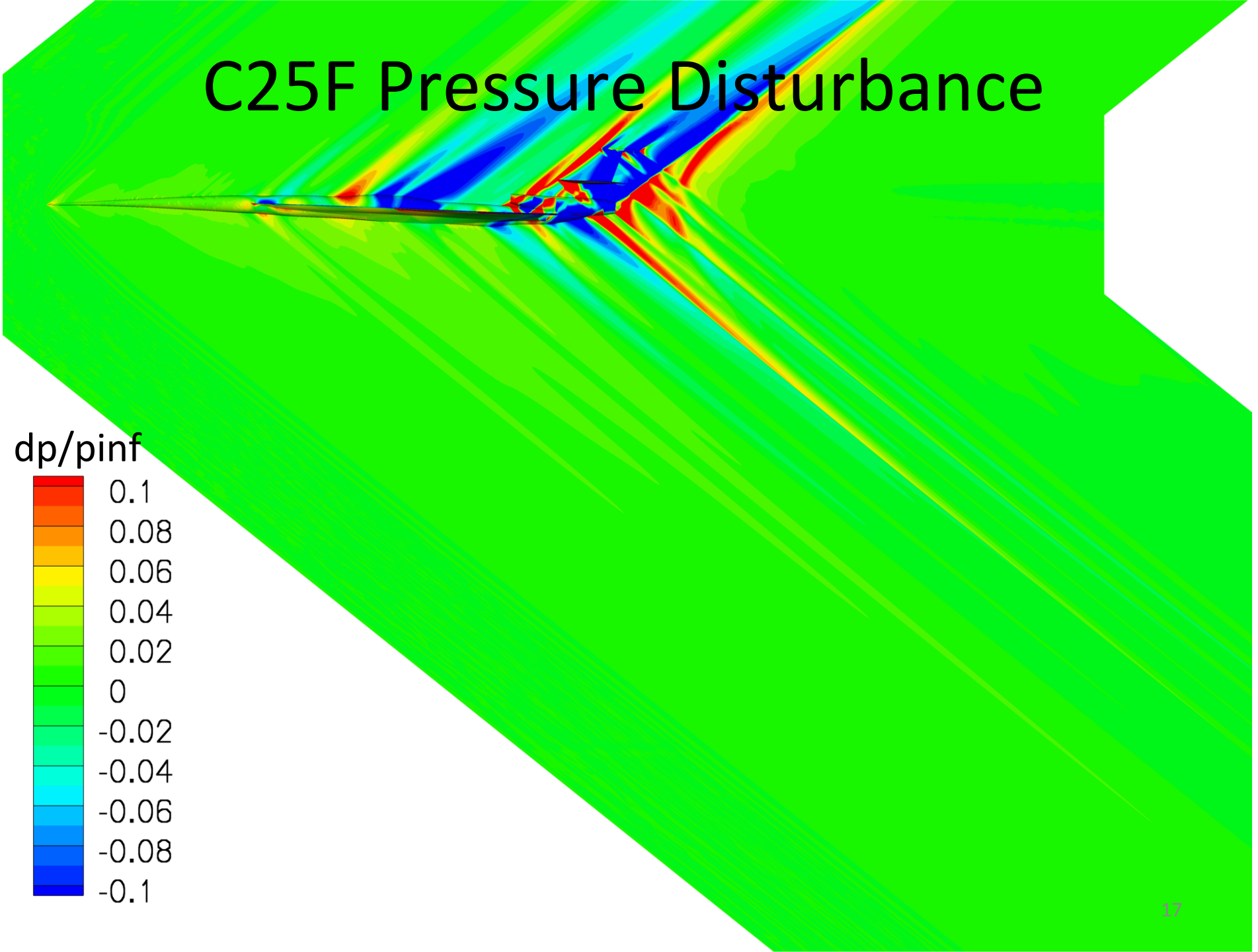
AXIE Pressure Disturbance



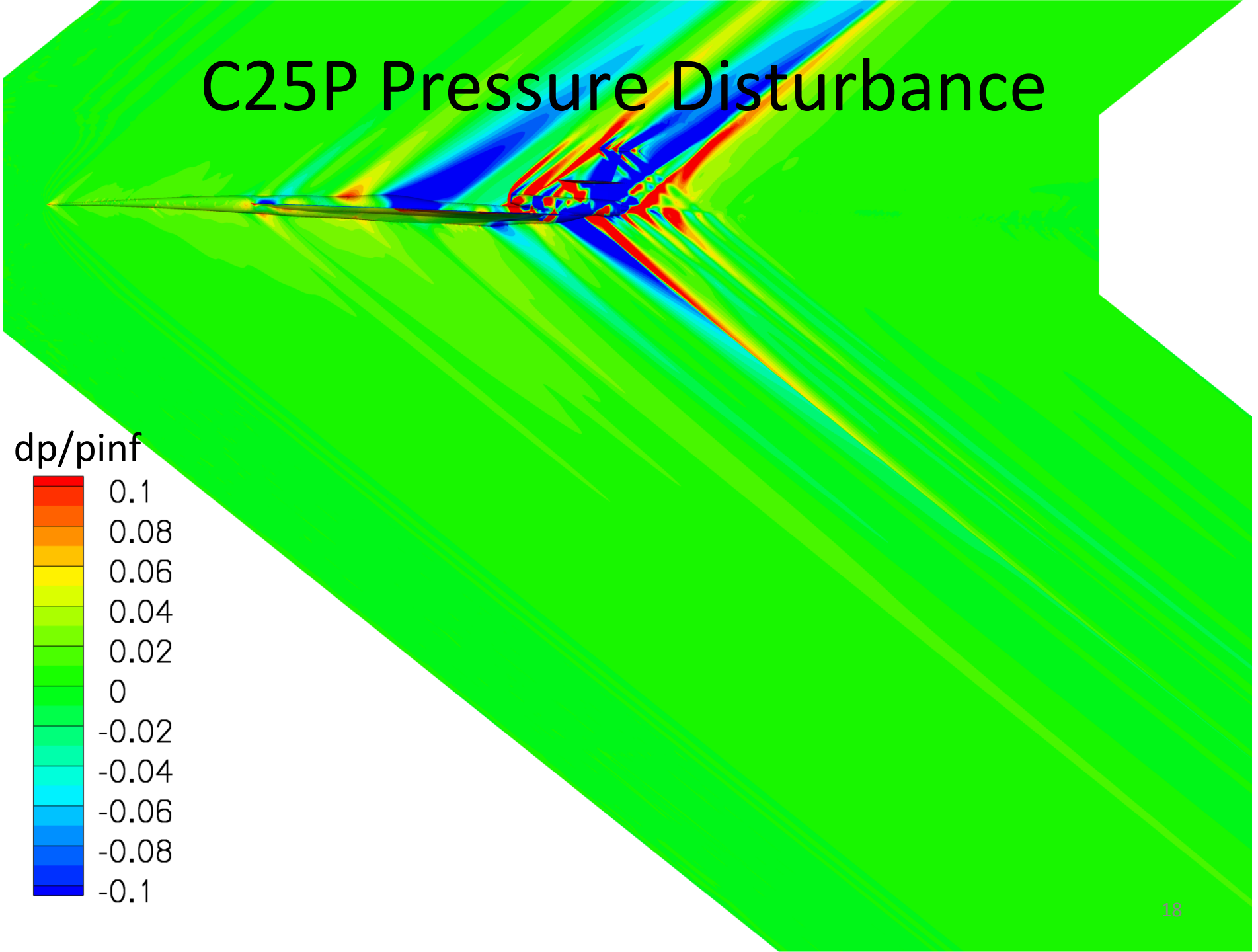
JWB Pressure Disturbance



C25F Pressure Disturbance



C25P Pressure Disturbance



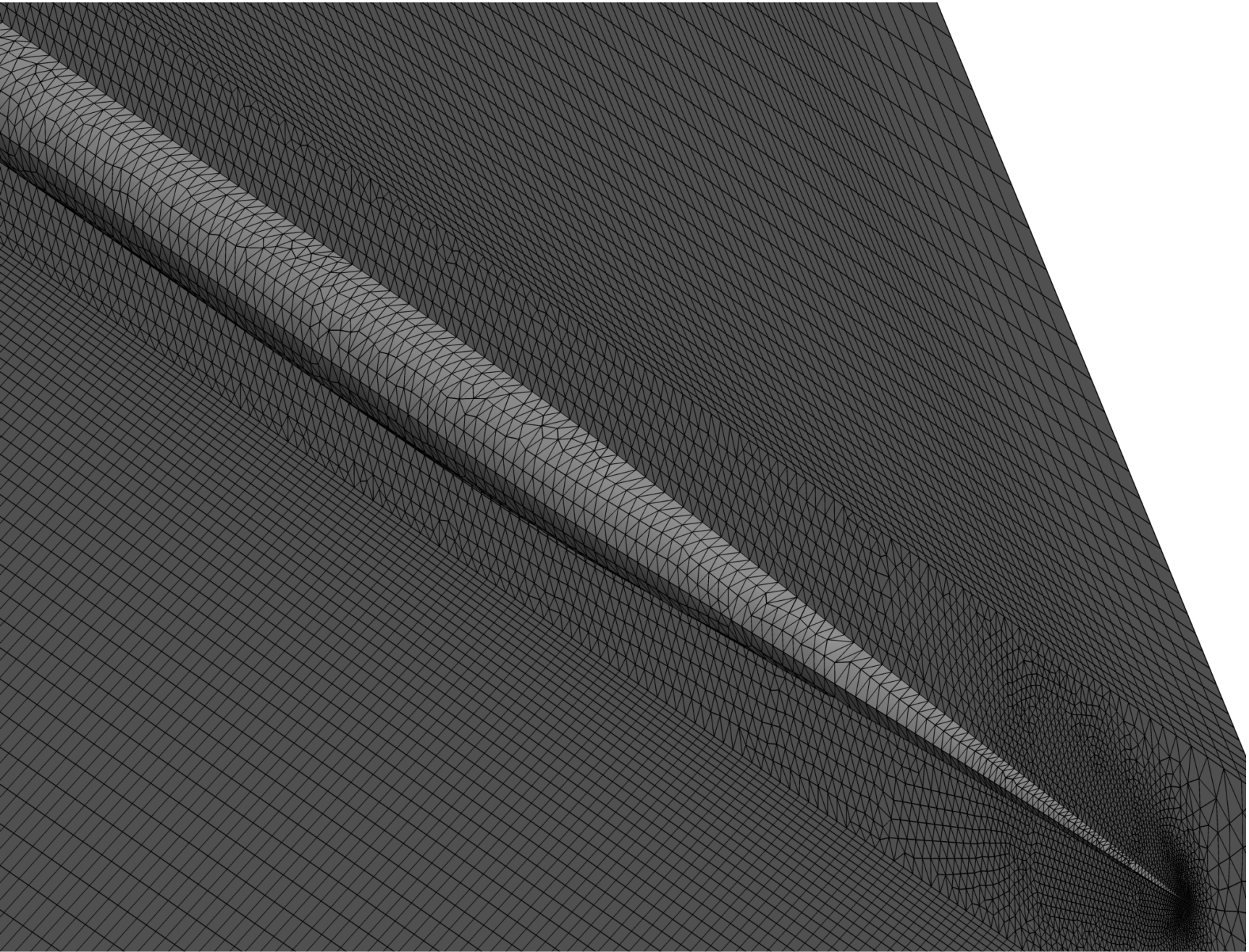
AXIE, C25F, and C25P Grids

- Same process as SBPW1 uniformly refined unstructured grids, see AIAA-2014-115
  - VGrid spacing field
  - FELISA surface grid generation via GridEx and CAPRI
  - AFLR3 Euler and viscous volume core grid generation
  - Inflate collar grid generation
  - Proved in UGRID, CGNS, and USM3D formats

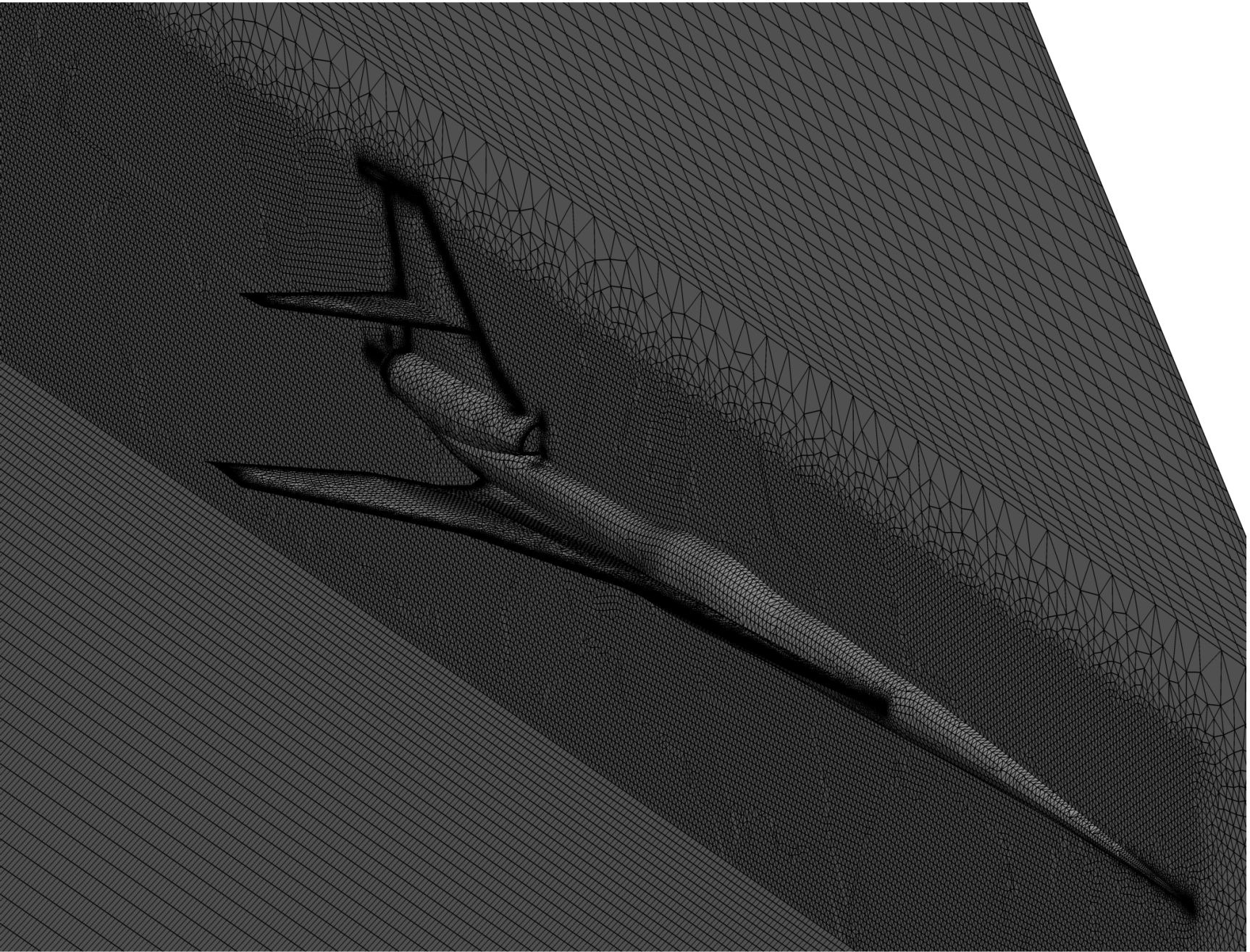
Grid Sizes

- Mixed element and tetrahedra only families with a factor of 0.8 in characteristic length and doubling of nodes and elements between grids
  - 0.6 to 56 million node Euler AXIE (5)
  - 3-104 million node Euler C25F (6)
  - 5-138 million node viscous C25F (6)
  - 3-52 million node Euler C25P (5)
  - 5-70 million node viscous C25P (5)

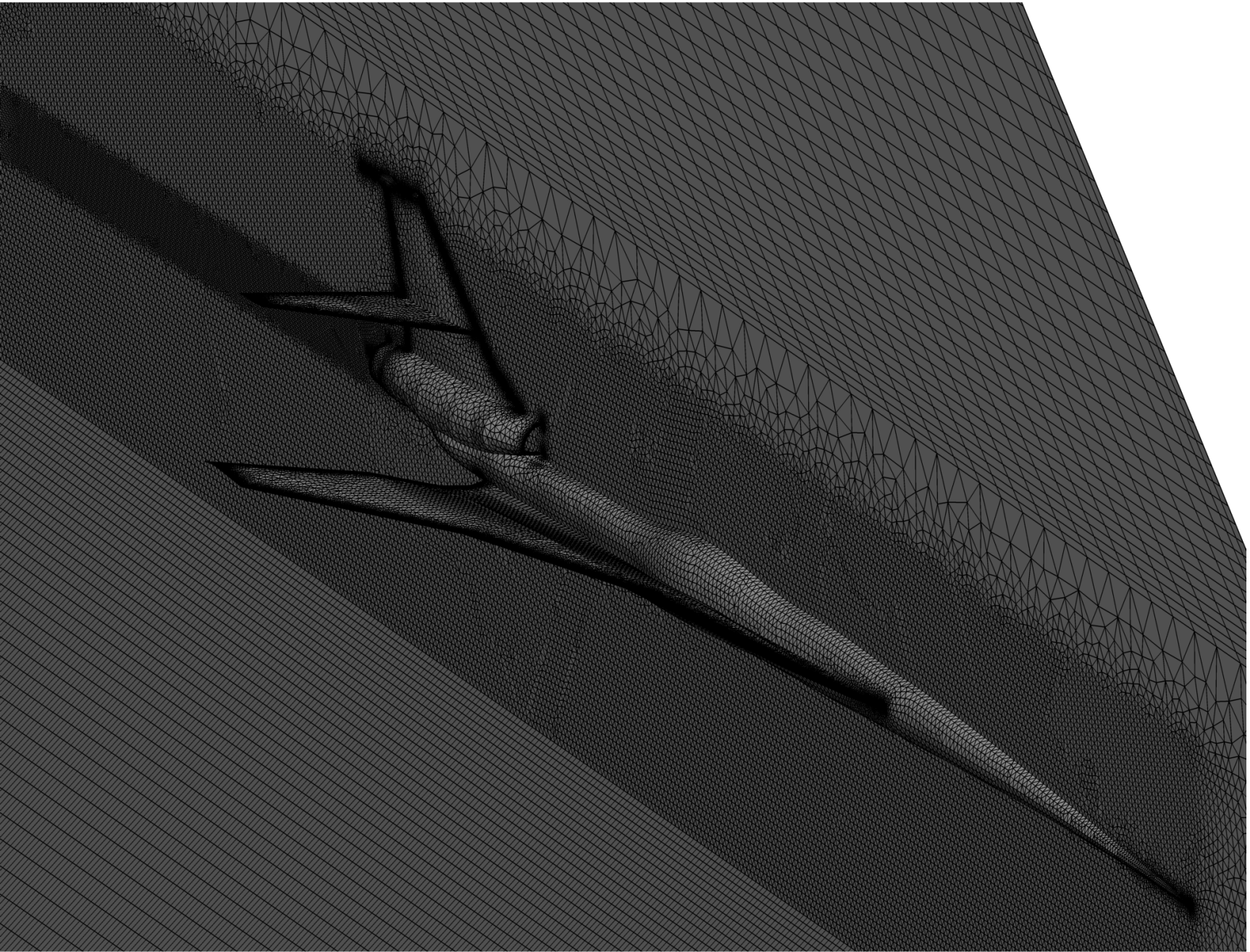
AXIE h=2.56, 0.6M Nodes



C25F h=2.00, 3.4M Nodes



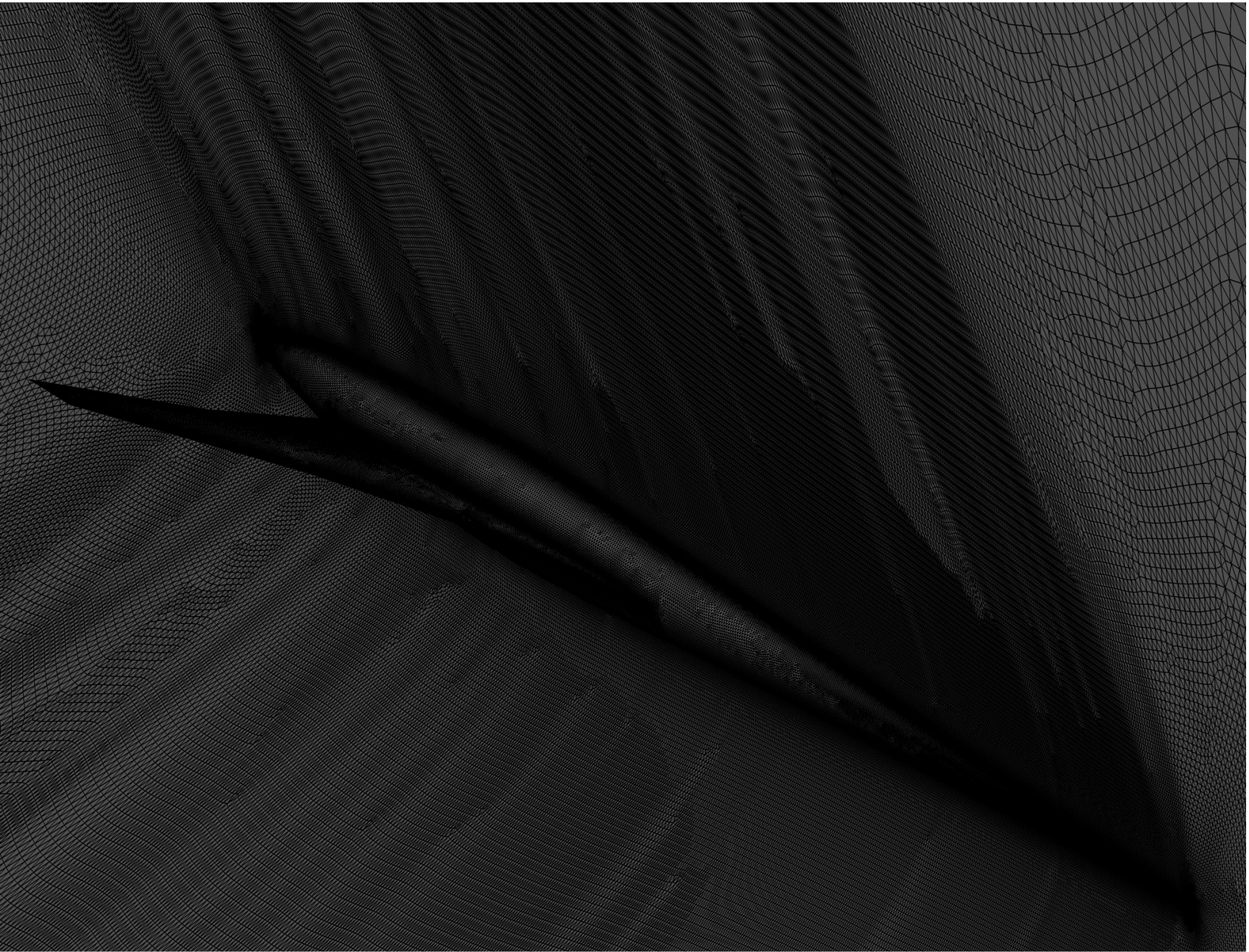
C25P h=2.00, 3.4M Nodes



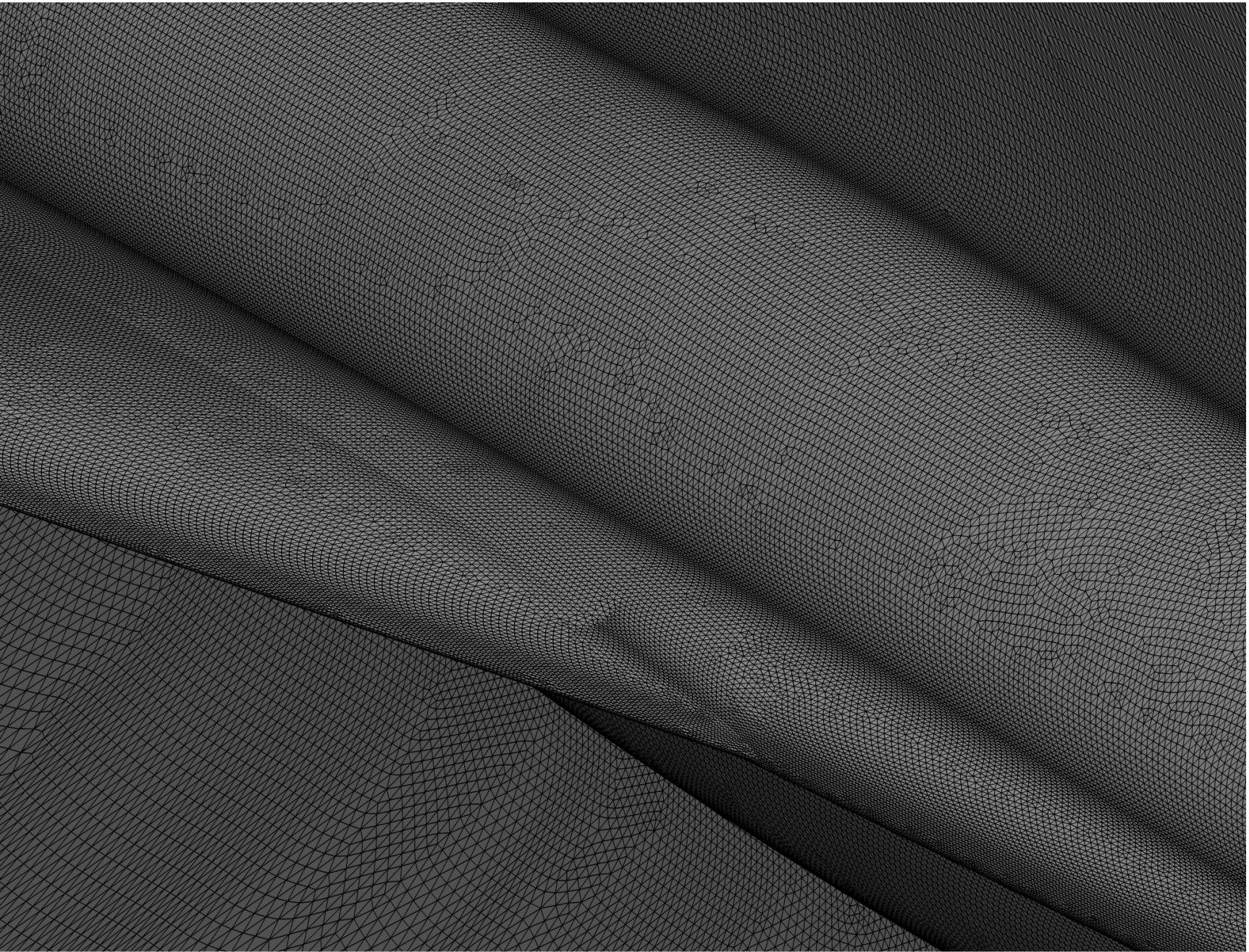
JWB Grids

- IGES surfaces prepared in Pointwise
- Patches built from Pointwise surfaces in Gridtool
- Shock locations and local surface spacing provided in HeldenMesh input file
- HeldenMesh generated surface and volume grids

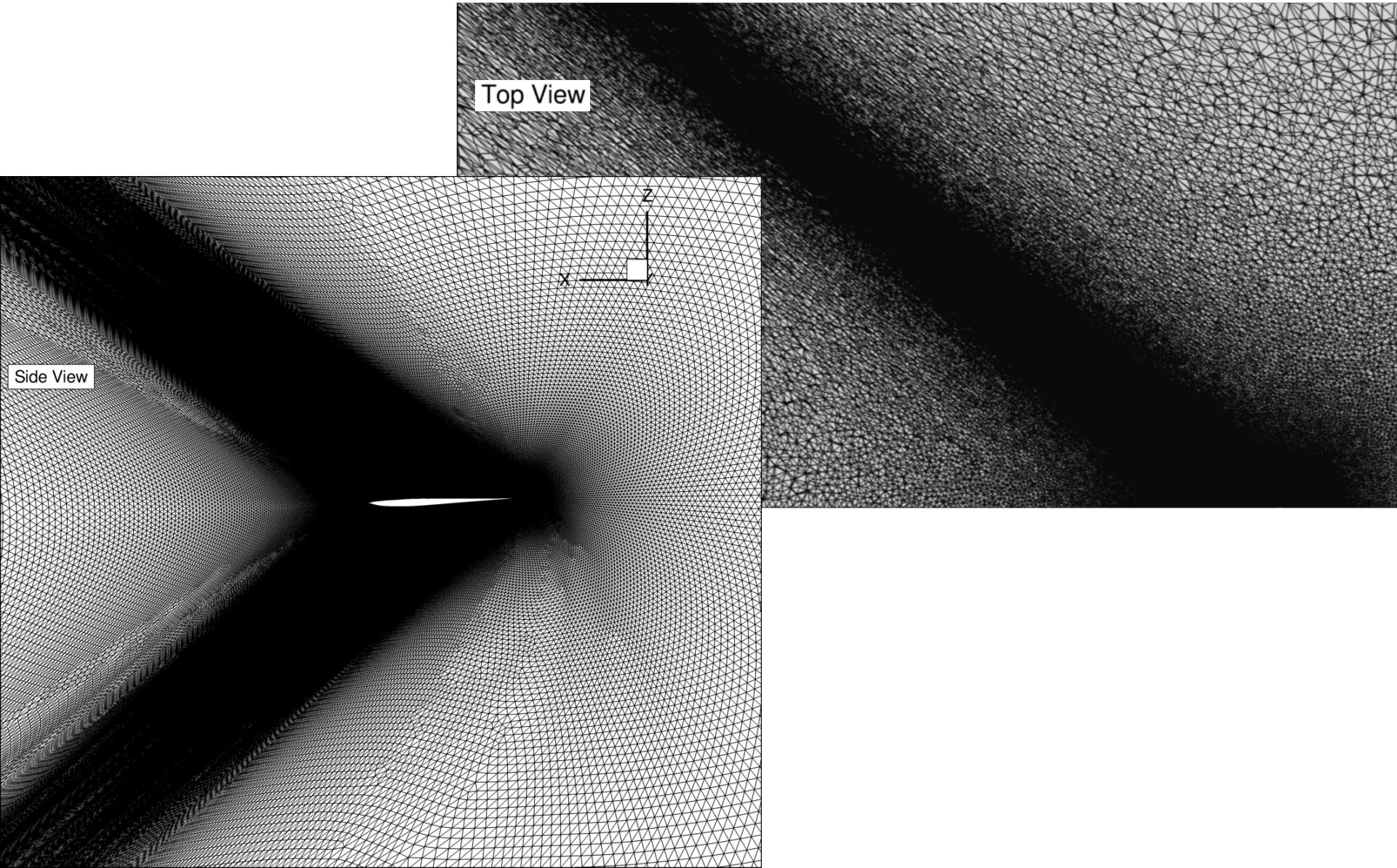
JWB h=1.00, 6M Nodes



JWB h=1.00, 6M Nodes, Zoom



JWB h=1.00, 6M Nodes, Top and Side



Grid Sizes

- Tetrahedra only versions
  - 6, 11, and 18 million node Euler JWB (3)

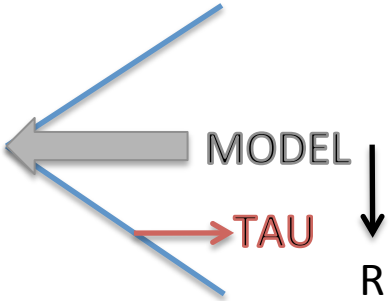
Tecplot Extraction Macro

- Consistent method to extract signatures from a volume
  - 1, 3, and 5 body lengths, L = 32.92 m
  - 0, 10, 20, 30, 40, and 50 off-track angles (PHI)
  - AXIE centerline only
  - JWB grid did not extend to 5 body lengths
    - L = 38.7 m with R = 0.85, 2.55 requested
    - Analysis uses equivalent L = 32.92 m with R = 1, 3

Data Processing

- Thank You! Consistency improved from first workshop
- Received signatures via FTP or email
- Some were reformatted, zero padded, or sorted
- Plotted
- Contacted participants for clarification/update when
  - Incorrect location or incomplete signature
  - Significant differences between submissions of same participant (iterative convergence)
  - Reference or boundary conditions suspect

Nearfield Plotting

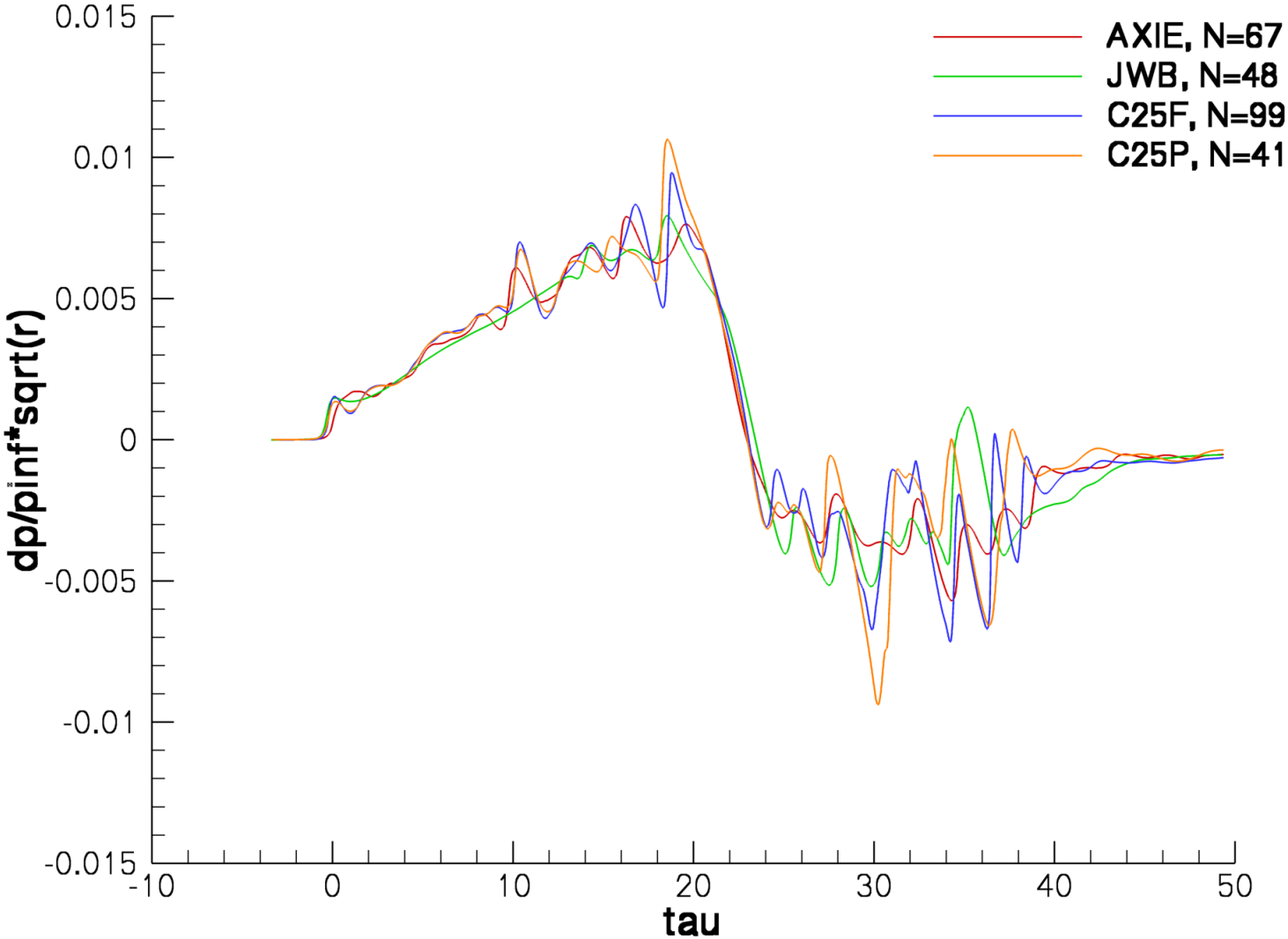


- Tau is distance from freestream Mach cone originating at tip of nose
- Delta pressure divided by freestream pressure is scaled by the square root of radius in body lengths
  - Signatures at different radii readily comparable and “aging” effect observed

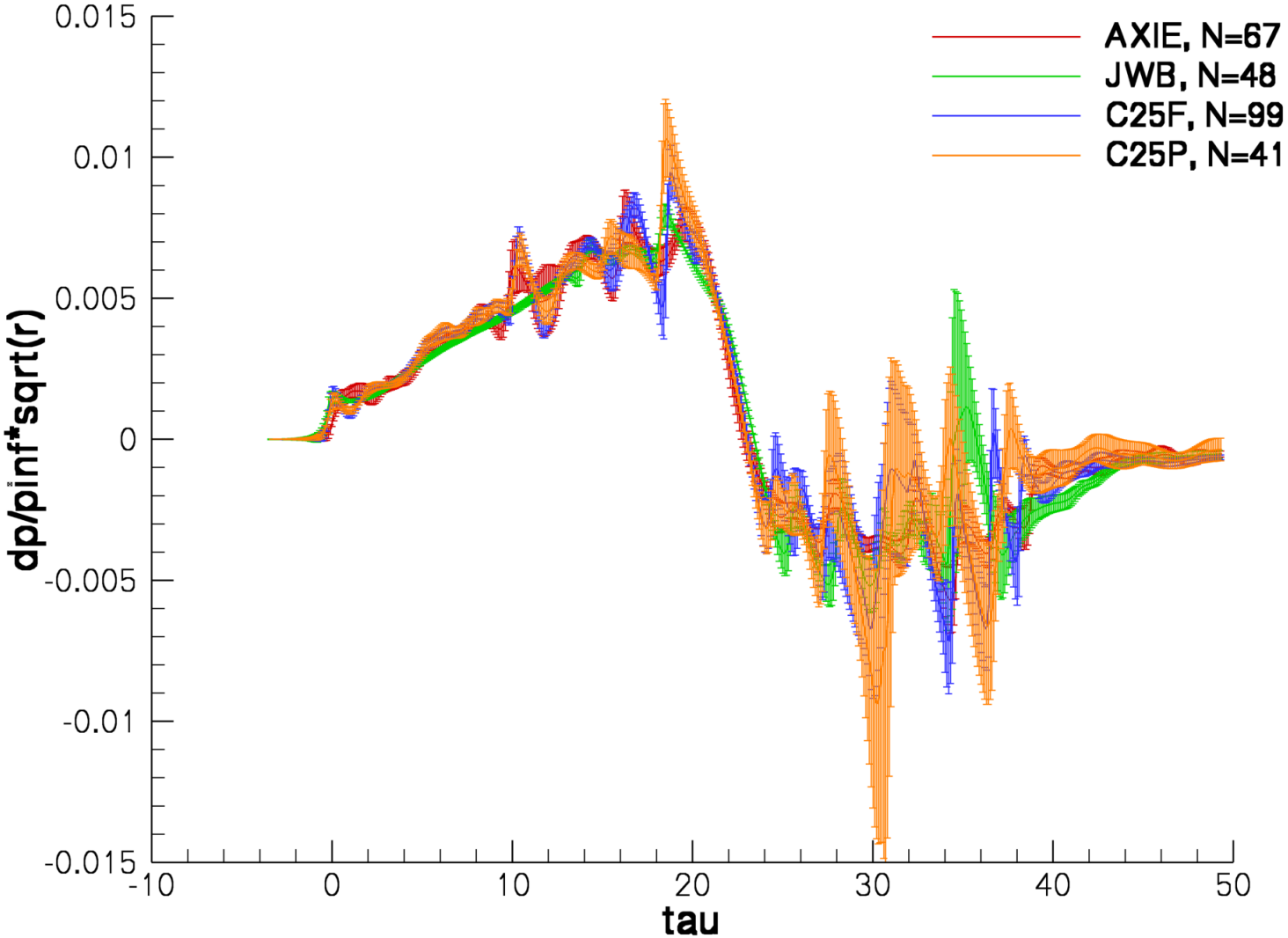
Nearfield Signature Statistics

- Population mean and standard deviation of interpolated signature every centimeter
- Analogous to wind tunnel spatial averaging

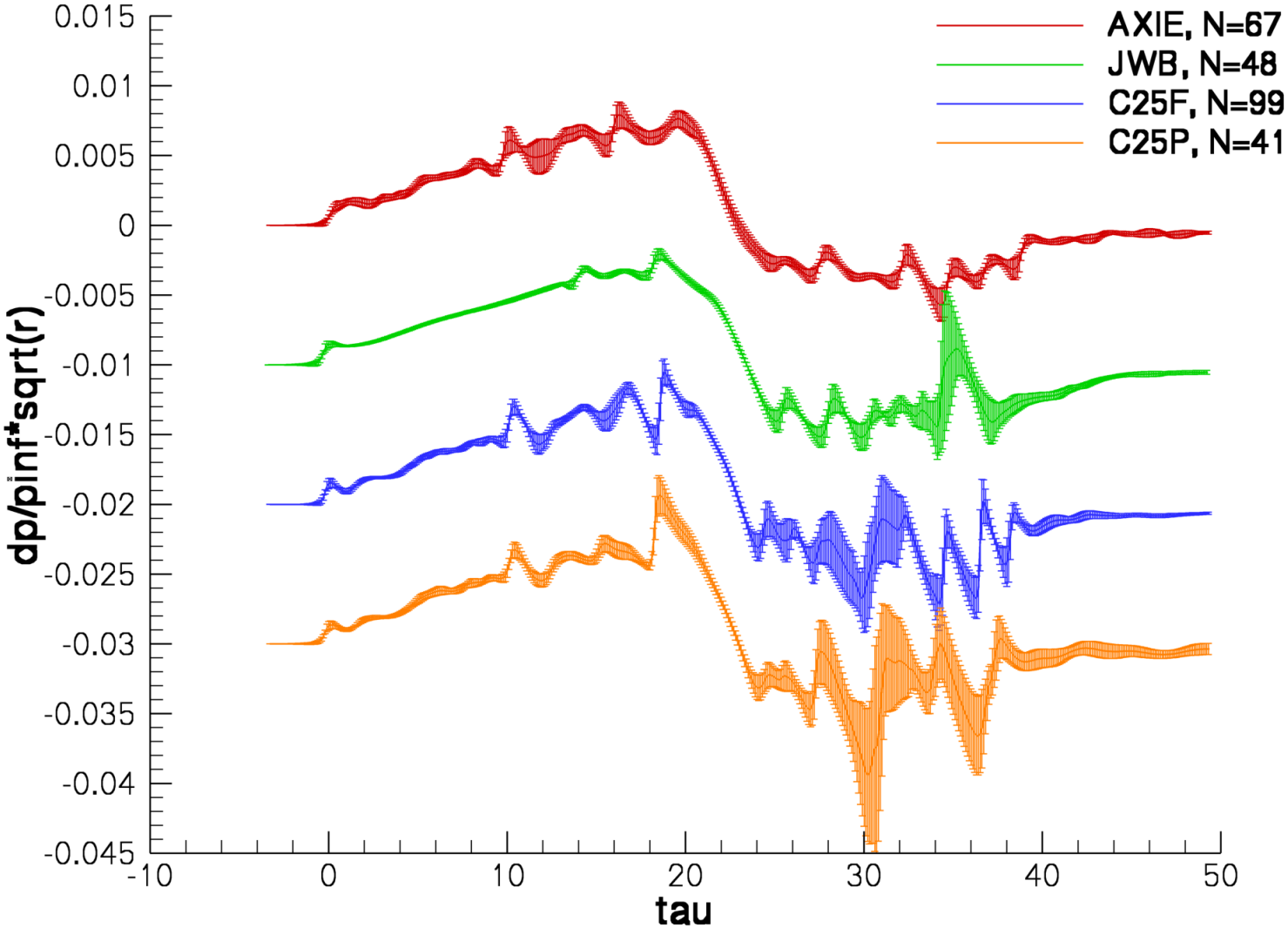
Nearfield Mean R=3, PHI=0°



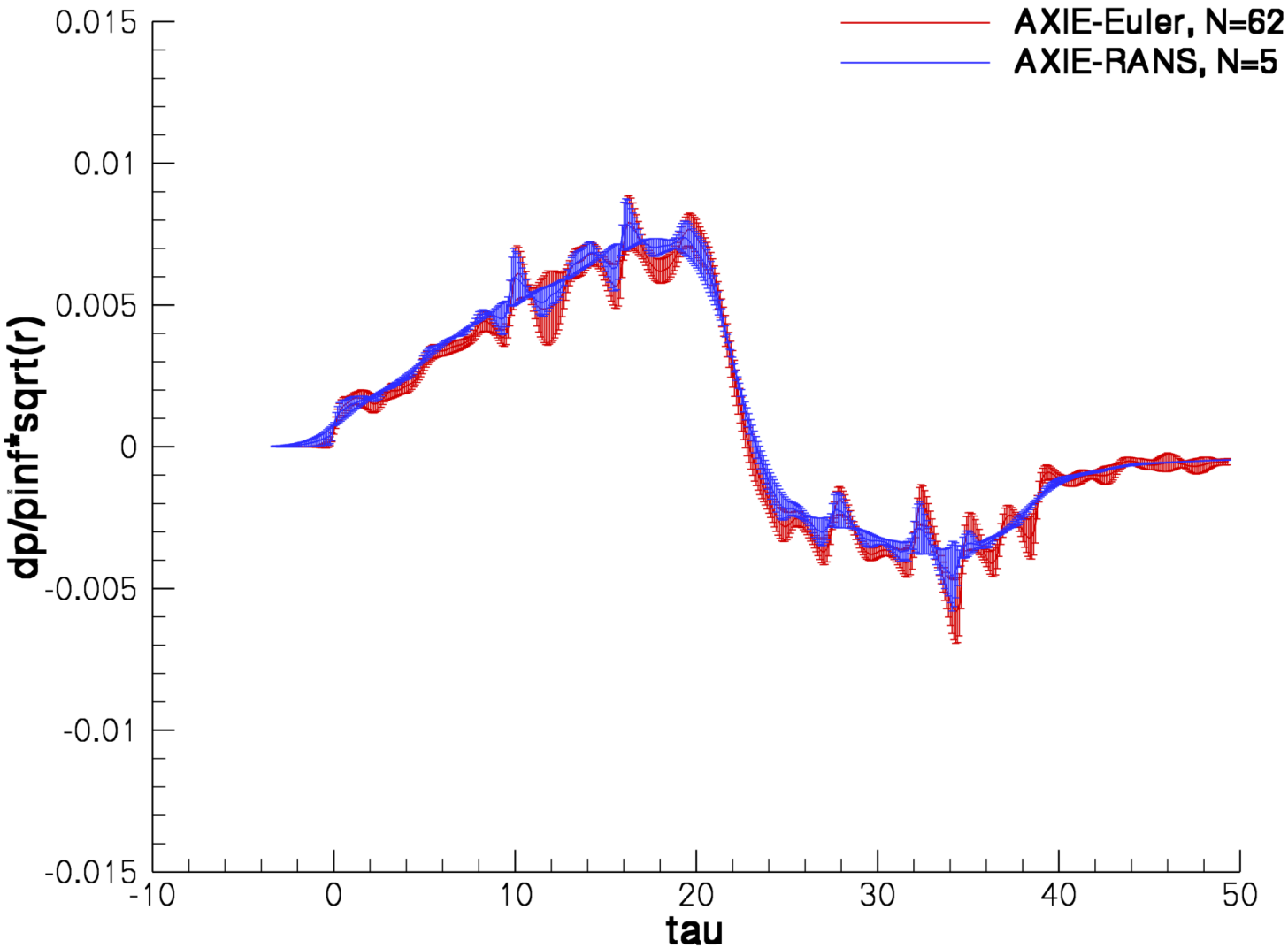
Nearfield Variation R=3, PHI=0°



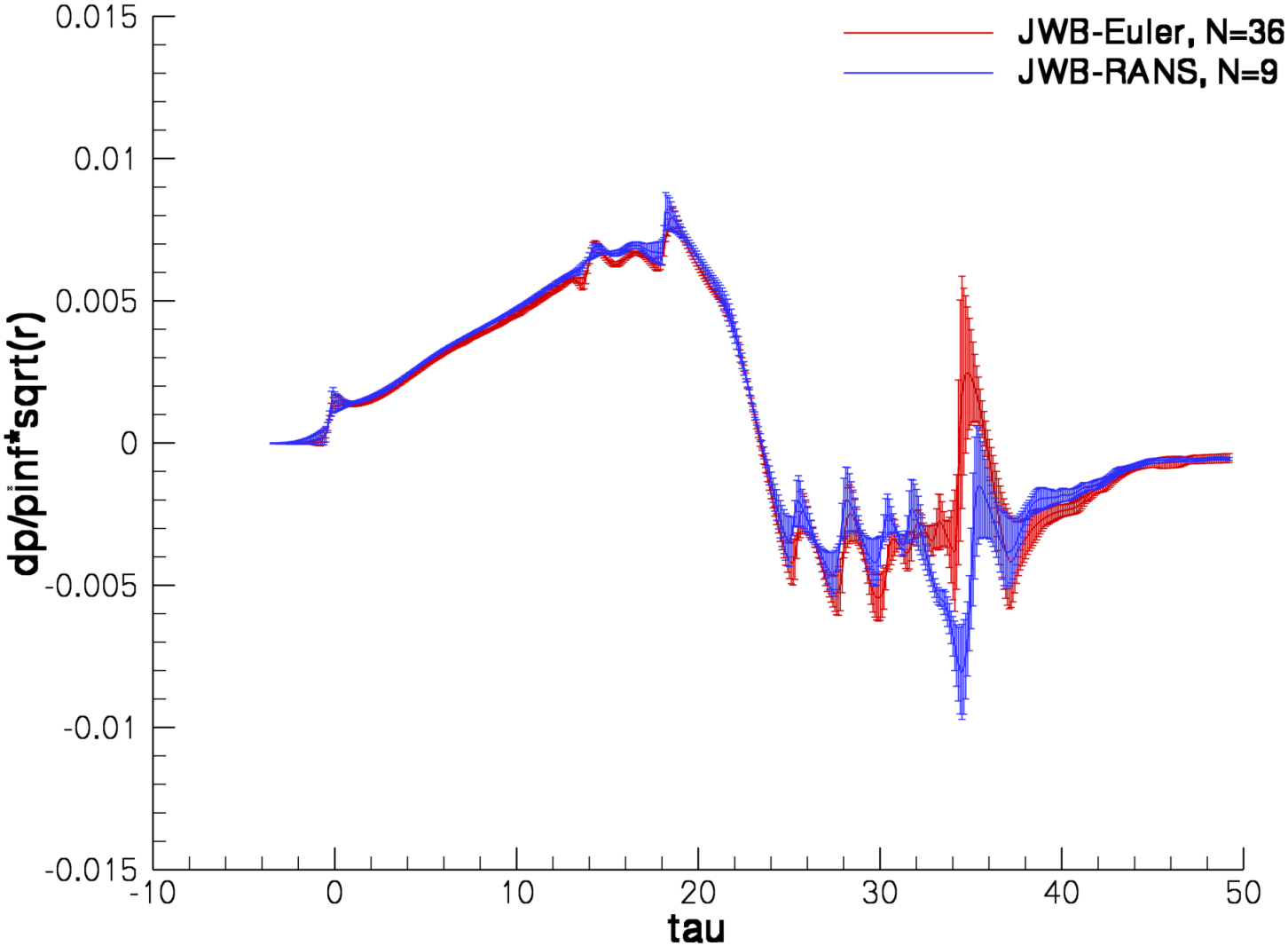
Nearfield Variation R=3, PHI=0°



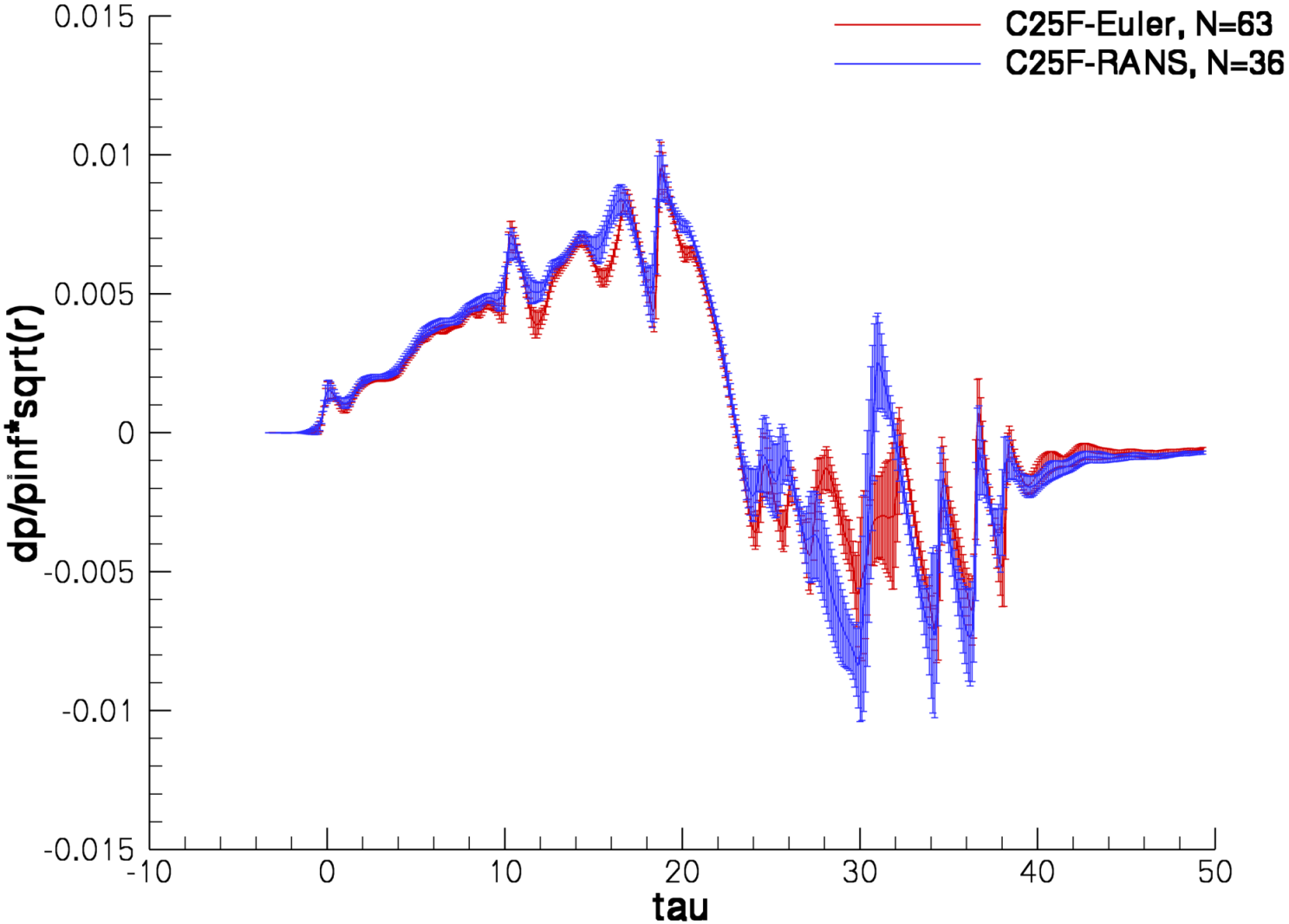
AXIE Nearfield Physics R=3, PHI=0°



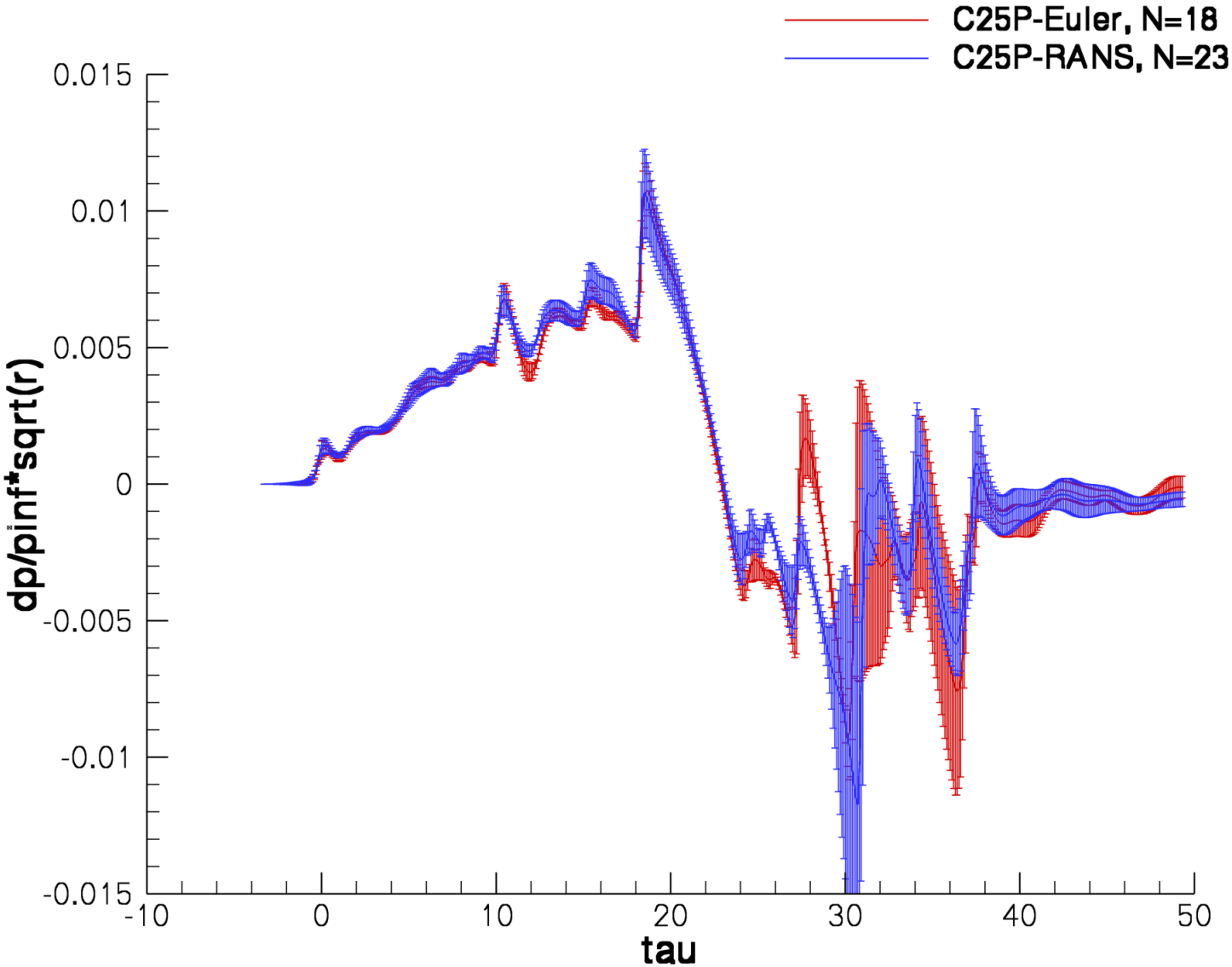
JWB Nearfield Physics R=3, PHI=0°



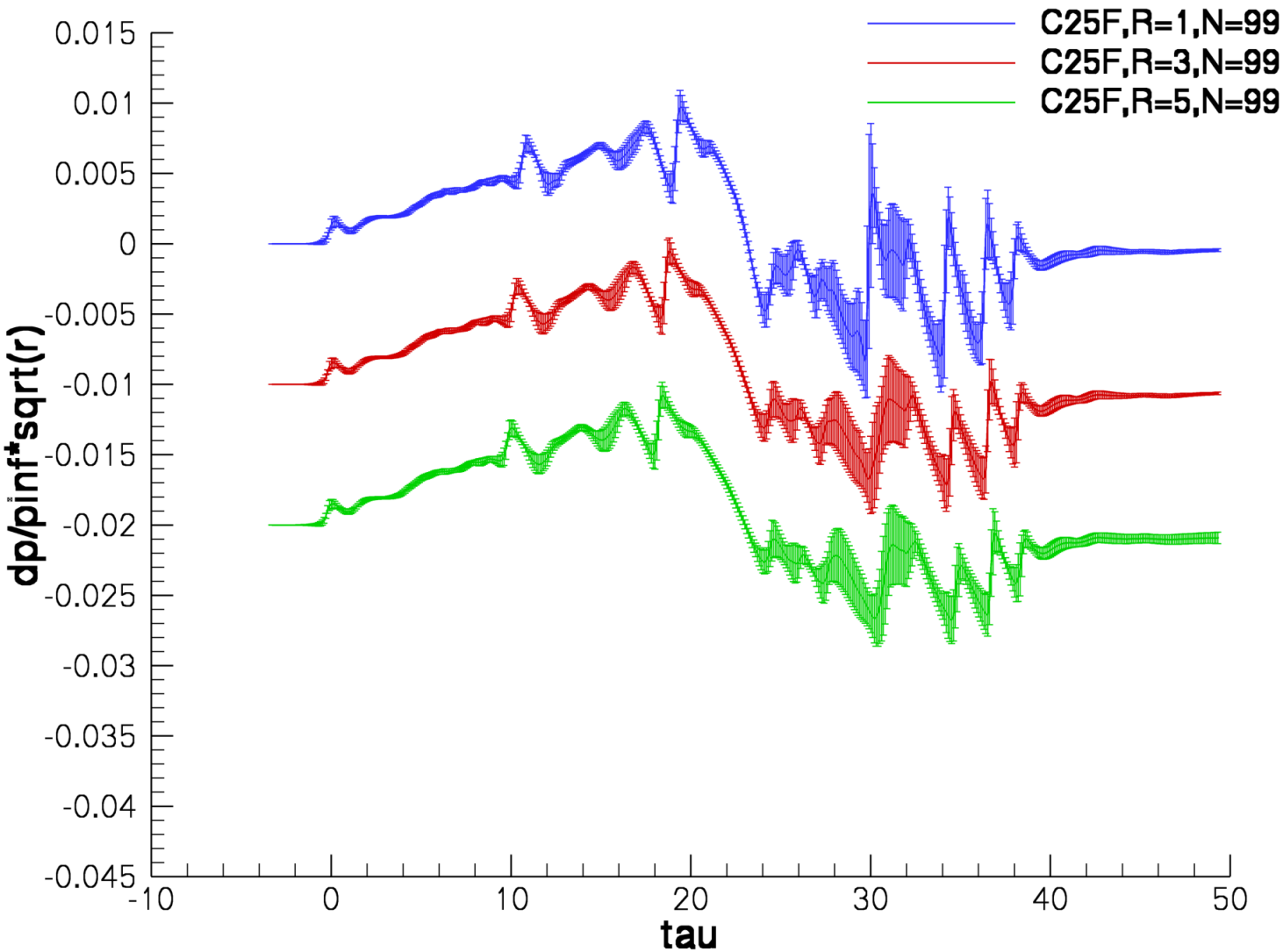
C25F Nearfield Physics R=3, PHI=0°



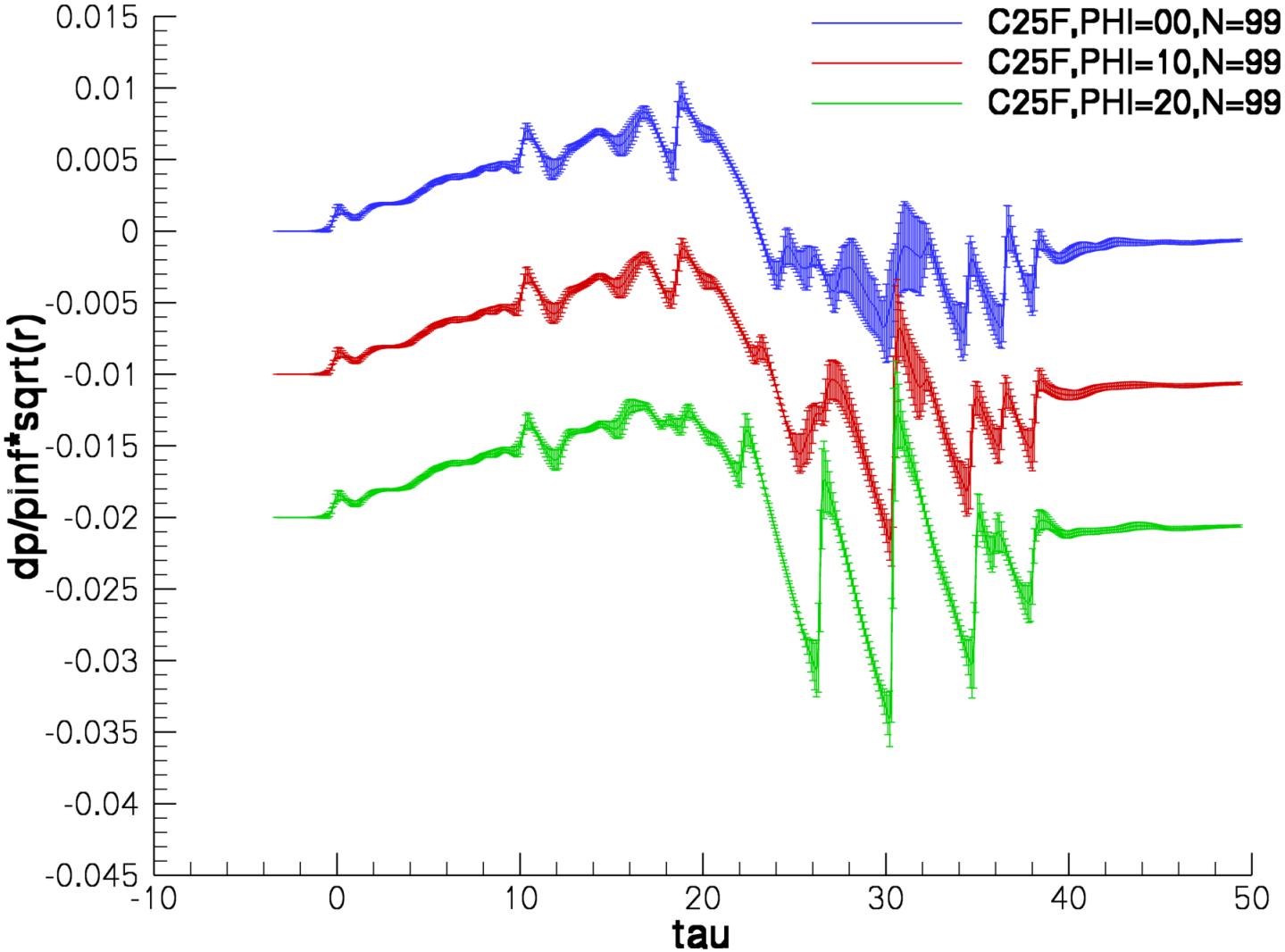
C25P Nearfield Physics R=3, PHI=0°



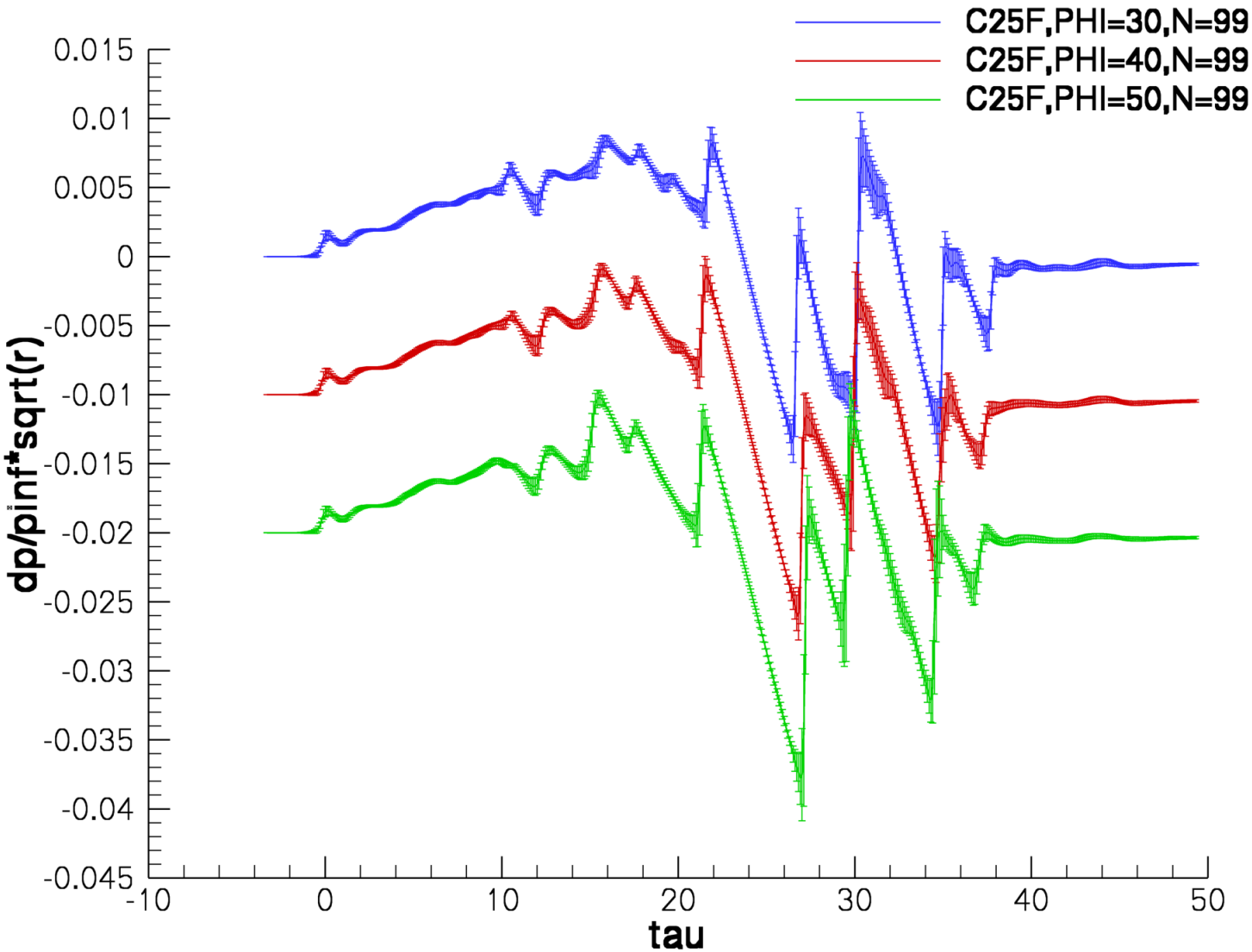
C25F Nearfield Centerline



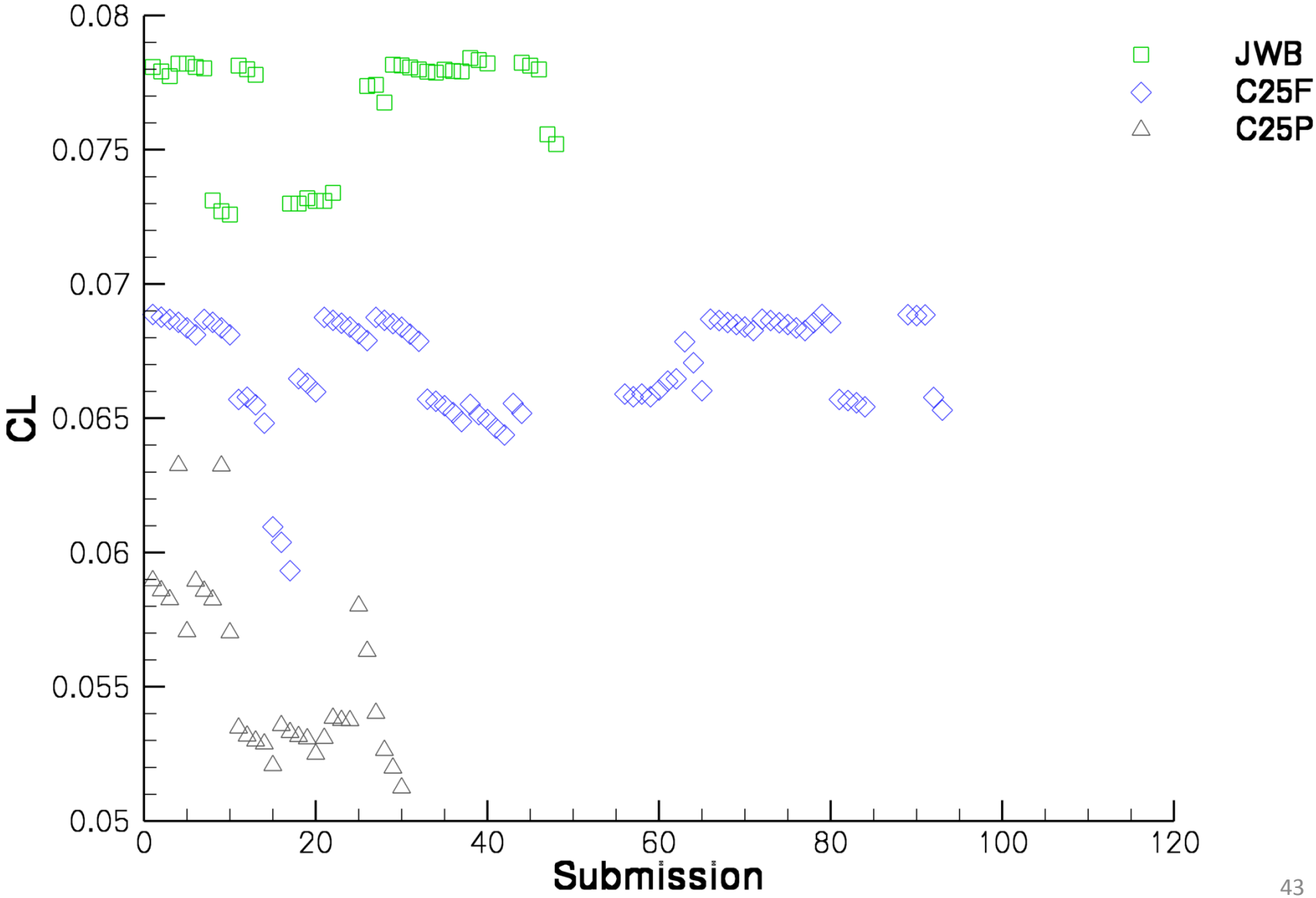
C25F Nearfield R=3, Off-Track



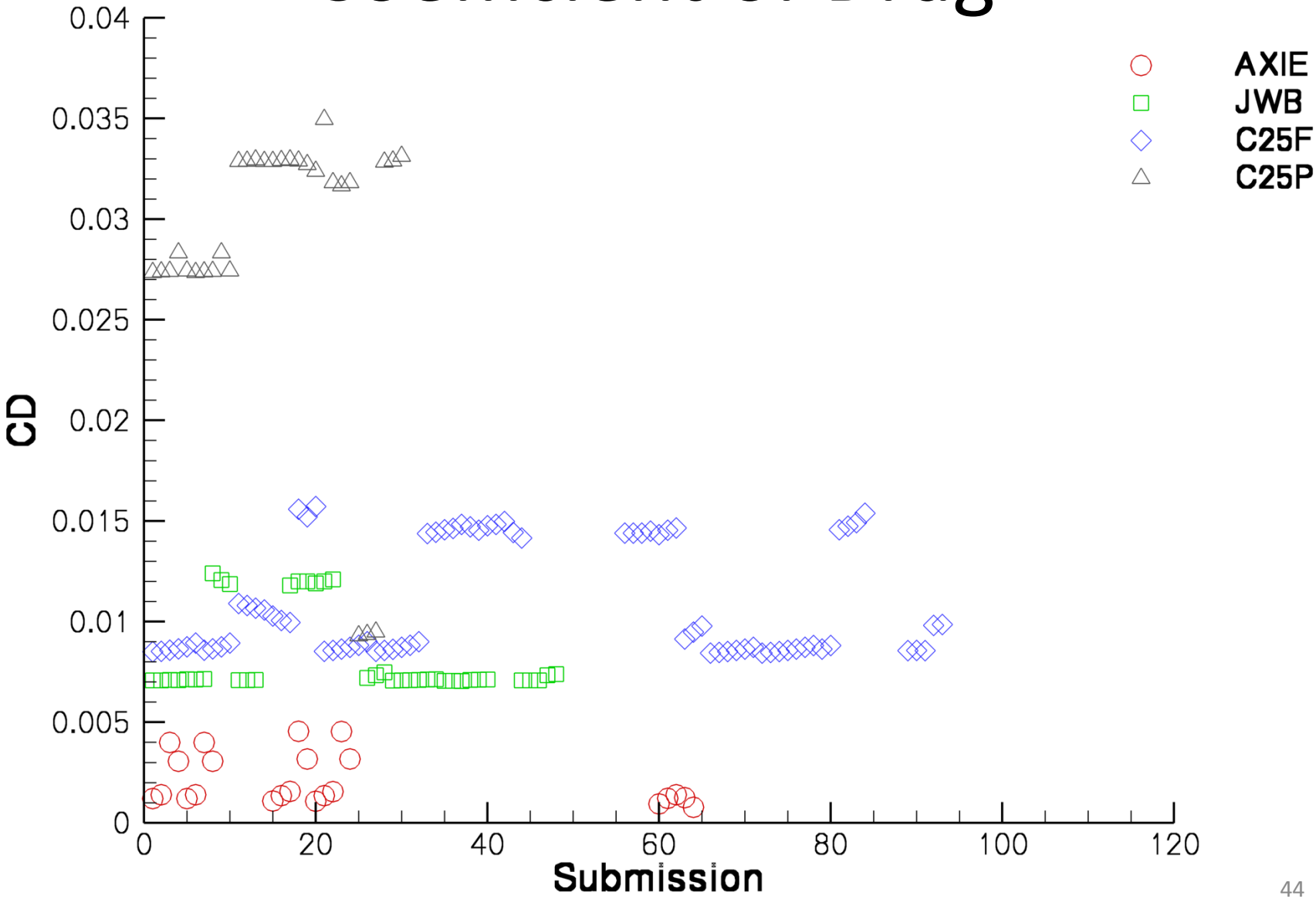
C25F Nearfield R=3, Off-Track



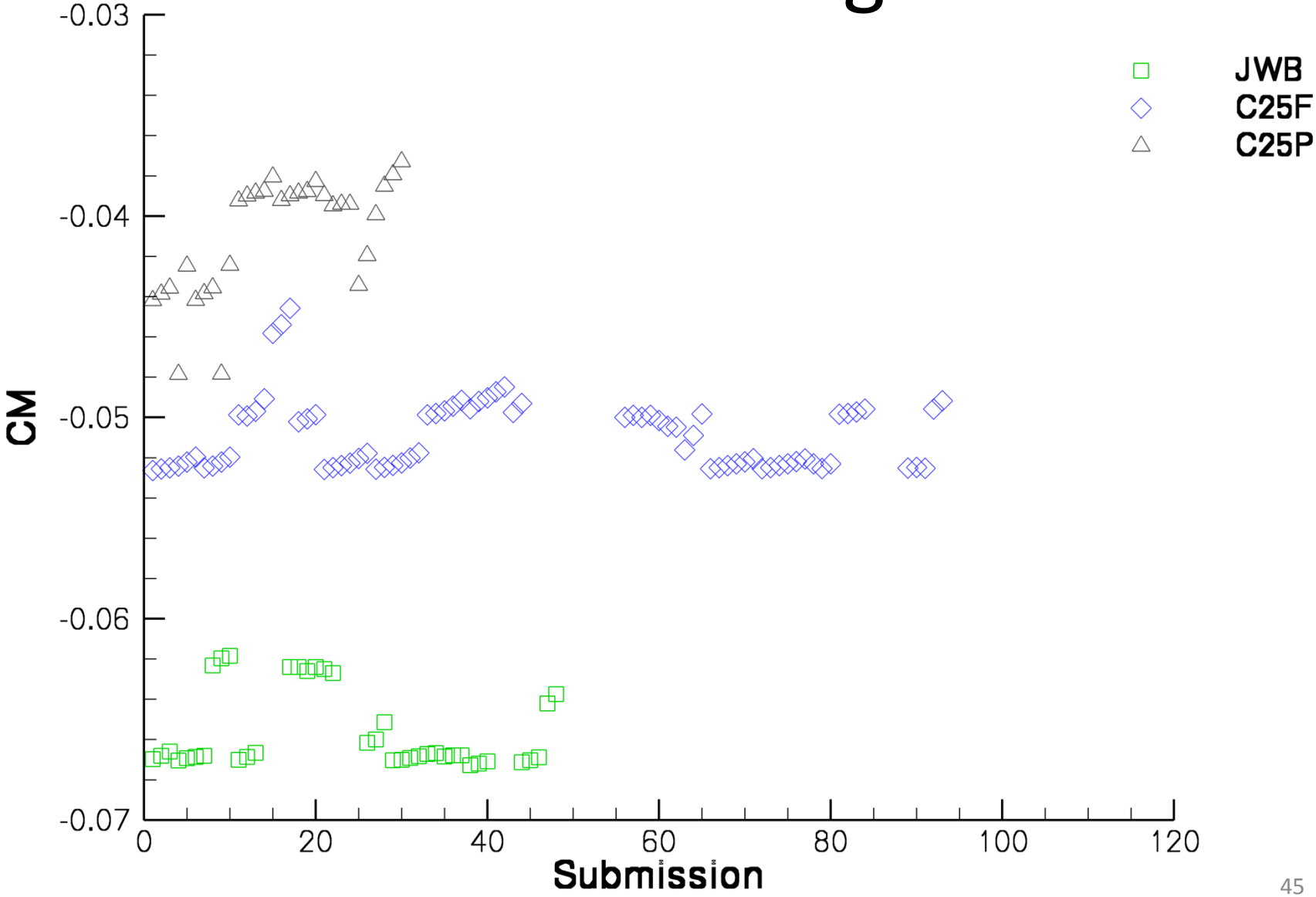
Coefficient of Lift



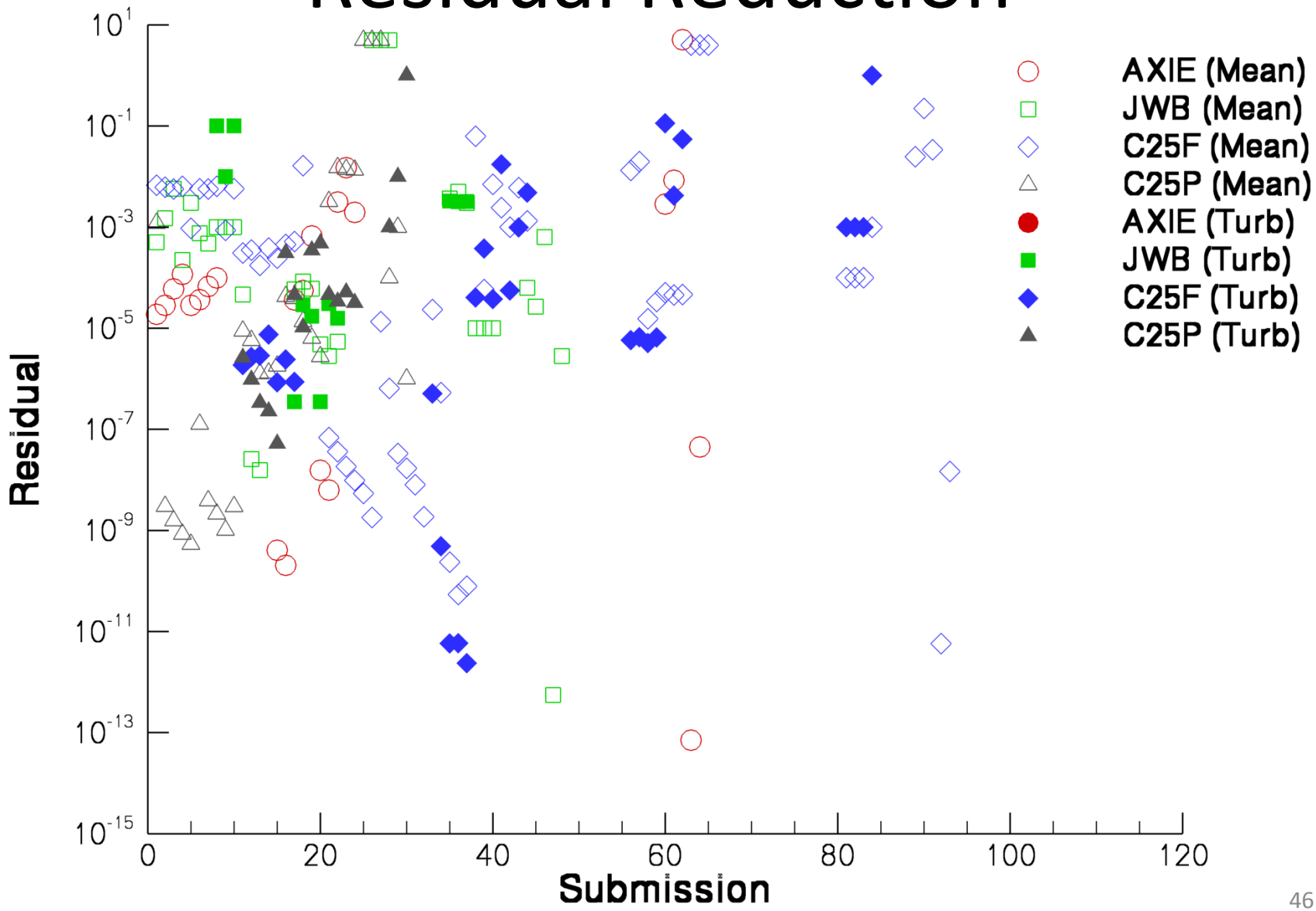
Coefficient of Drag



Coefficient of Pitching Moment



Residual Reduction



Overview

- Described cases and configurations
- Described data extraction and nearfield signature statistics
- Explored trends in nearfield signature variation
  - Model
  - Physics

Acknowledgments

- All participants
- Mathias Wintzer, Irian Odaz, James Fenbert, and Sriram Rallabhandi for C25D flow through and powered designs
- George Anderson and Michael Aftosmis for AXIE design
- JAXA for JWB geometry
- Andrew Clemens for JWB grids
- Marie Denisen, Adrein Loseille, Alaa Elmiligui for grid evaluation and feedback
- Scott Brynildsen, Bill Jones, and Sriram Rallabhandi for geometry preparation
- Joe Derlaga for statistical tools
- NASA Commercial Supersonic Technology Project

Summary

- More to follow after the participant talks
- Propagation
- Loudness measures
- Examination of outliers