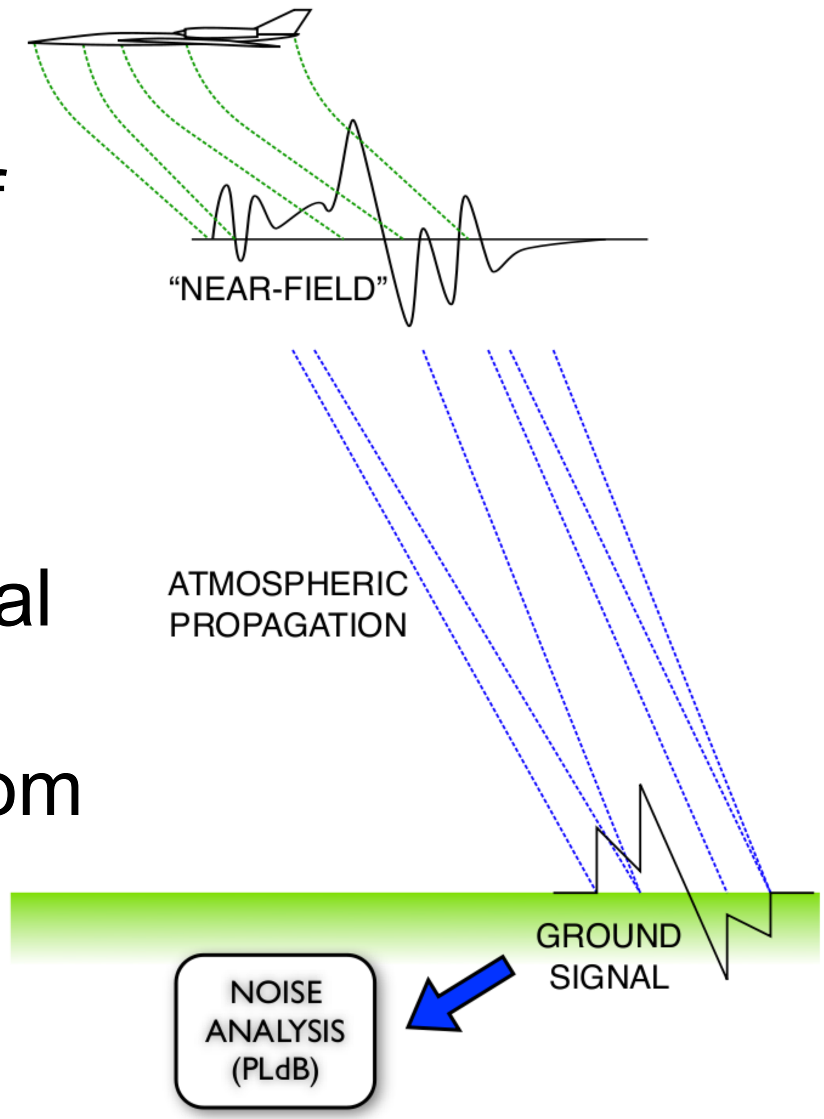
Summary of the 2008 NASA Fundamental Aeronautics Program Sonic Boom Prediction Workshop

Michael A. Park, NASA Langley
Michael J. Aftosmis, NASA Ames
Richard L. Campbell, NASA Langley
Melissa B. Carter, NASA Langley
Susan E. Cliff, NASA Ames
Linda S. Bangert, NASA Langley

2008 FAP Workshop

- Sponsored by the Supersonics Project of the Fundamental Aeronautics Program (FAP)
- Evaluate Computational Fluid Dynamics (CFD) for near-field sonic boom prediction



2008 FAP Workshop Goals

- Understand existing capability
  - Range of configuration complexity
- Identify any needs for future investment
- Reasonable scope
  - NASA only
  - Inviscid analysis

2008 FAP Workshop Structure

- Single 2008 FAP Annual Meeting session self organized by participants in about 6 months
- Oral presentations
  - Introduction and case descriptions
  - Four participant method descriptions and details of individual results
  - Summary and comparison of signatures and computational resources

Motivation

- Share experience to aid AIAA 1st Low Boom Prediction Workshop (LBPW)
- Documentation of the 2008 FAP Workshop
  - Integrate presentations into a single document
  - Capture participant impressions and discussions

Overall Impressions

- Differences between the multiple predictions were less then expected
- Differences between the predictions and the measurements were less than expected
- All methods were sufficiently accurate, fast, and automated for use in a design context
  - New needs have been identified

Overall Impressions

- Grid alignment and anisotropy key ingredients
- Preparing for the workshop streamlined methods in development
- Forum facilitated future collaboration

Near-field CFD

- Includes nonlinearity and three dimensional effects
- Accurate prediction requires the propagation of weak signals significant distances
- Dissipation required for shock capturing rapidly destroys these signals

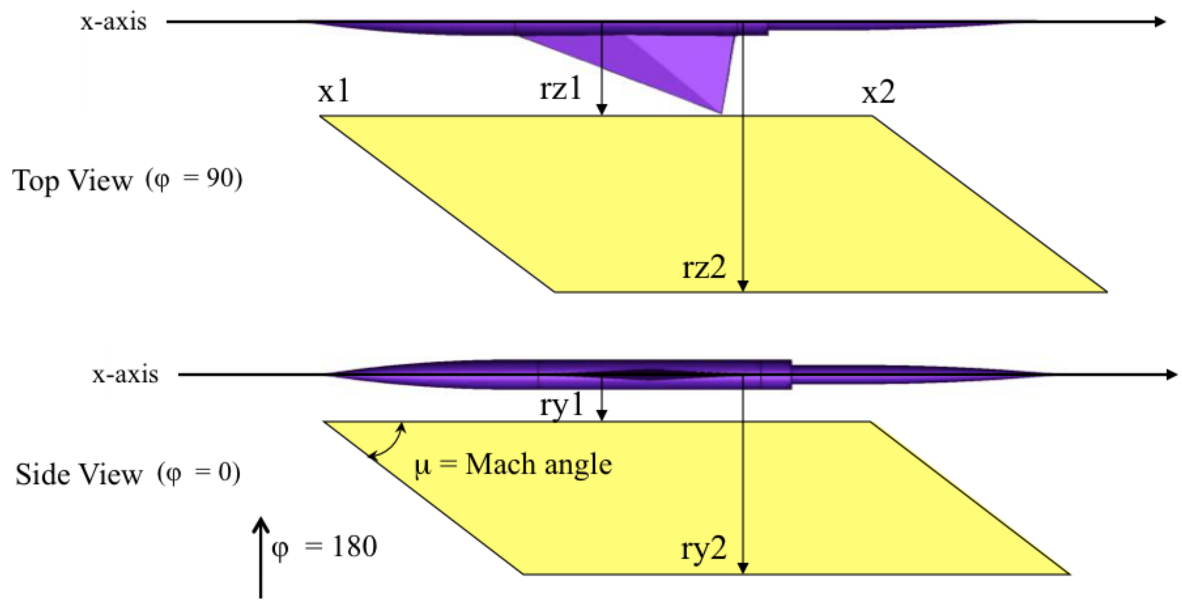
Methods

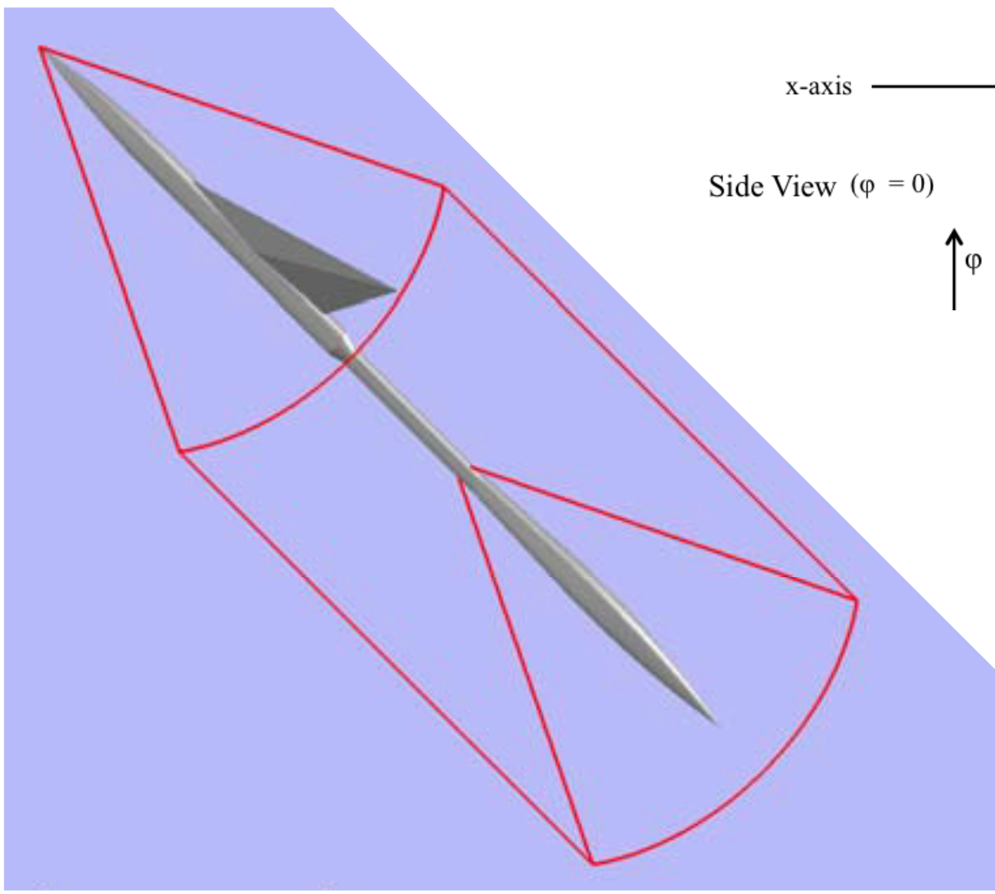
- Required specialized grid techniques
  - Refinement in important propagation regions
  - Alignment to the local or freestream Mach angles
  - Adjoint-based adaptation
- Extracting the signal very near the body and propagating signals within the near-field region
  - Assumption that the 3D effects and nonlinearities are small

Method Overview

- Cart3D-ANET and AIRPLANE-ANET
  - Manual refinement region specification
  - Extracted very near body, ANET propagation
- Cart3D-Adjoint and FUN3D-Adjoint
  - Goal-oriented adaptation (adjoint) to sensor
- USM3D-SSGRID
  - A priori alignment to freestream Mach angle and stretching parallel to Mach angle

Cart3D-ANET and AIRPLANE-ANET





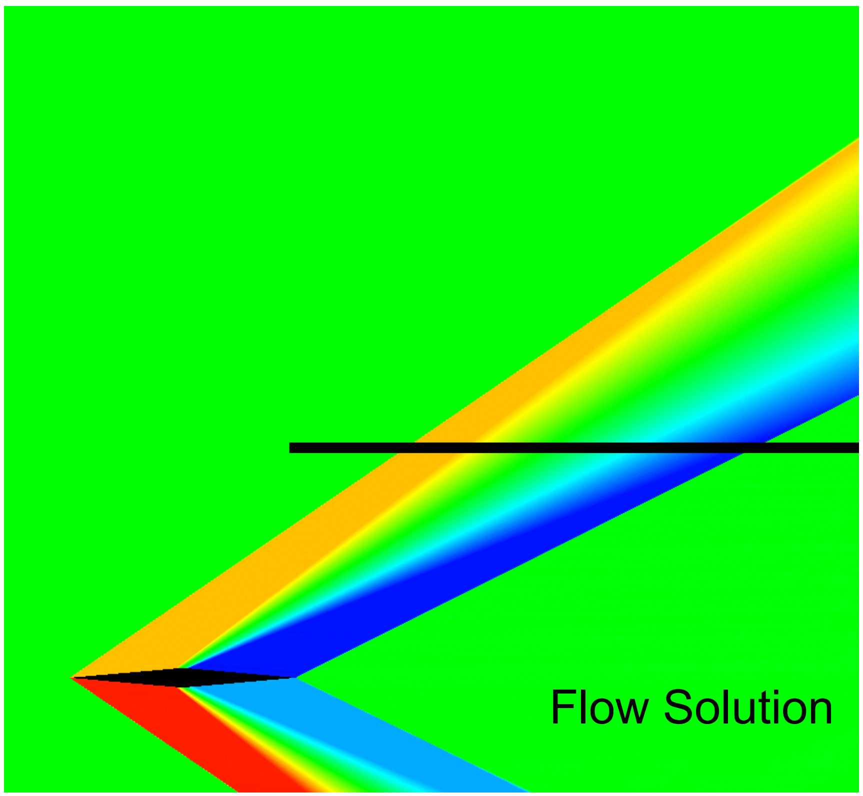
- Elliptical/Annular Swept Sector (EASS)
- Specified isotropic refinement

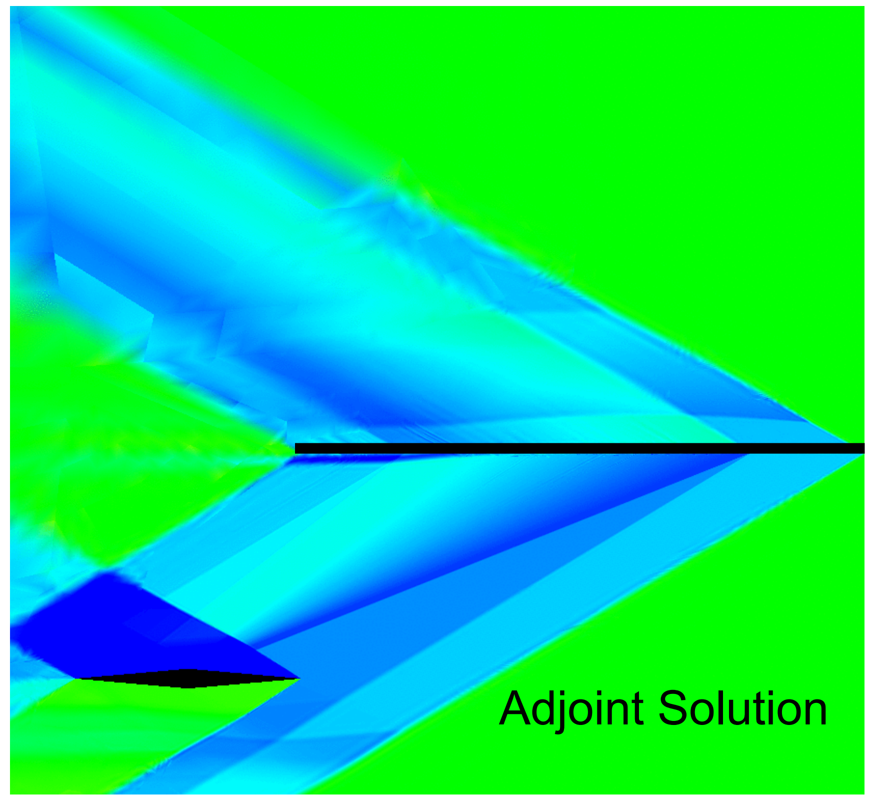
Cart3D-ANET and AIRPLANE-ANET

- ANET is a parameterized waveform propagation tool developed by Thomas
- Signature is extracted at 0.4 body lengths (BL) and propagated to the experimental measurement location at 1-10 BL via ANET with a uniform atmosphere model
  - Except the intermediate Delta Wing Body locations where Cart3D and AIRPLANE are used with EASS only

Cart3D-Adjoint and FUN3D-Adjont

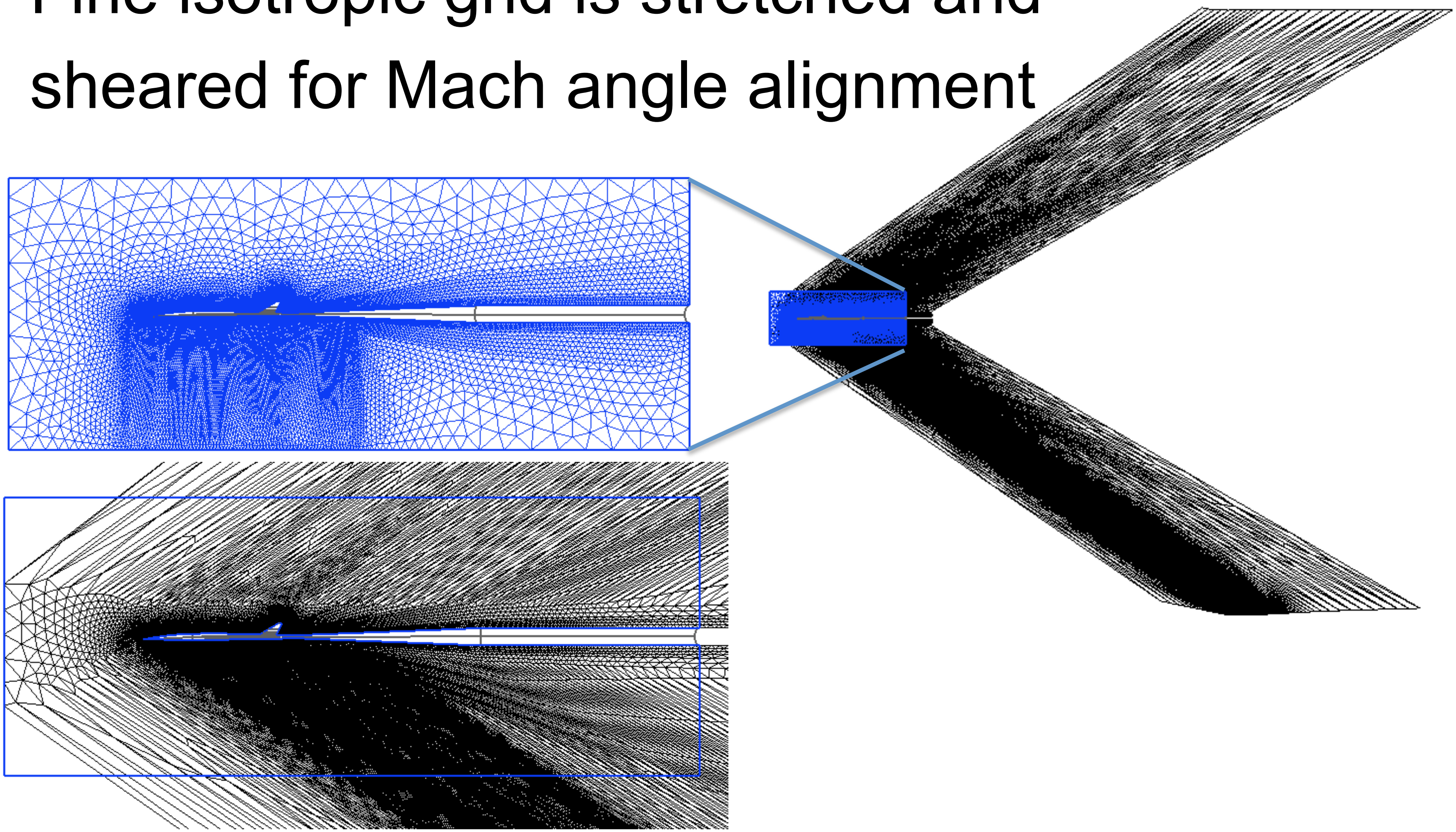
- Flow and adjoint solutions are combined to estimate error that grid adaptation reduces





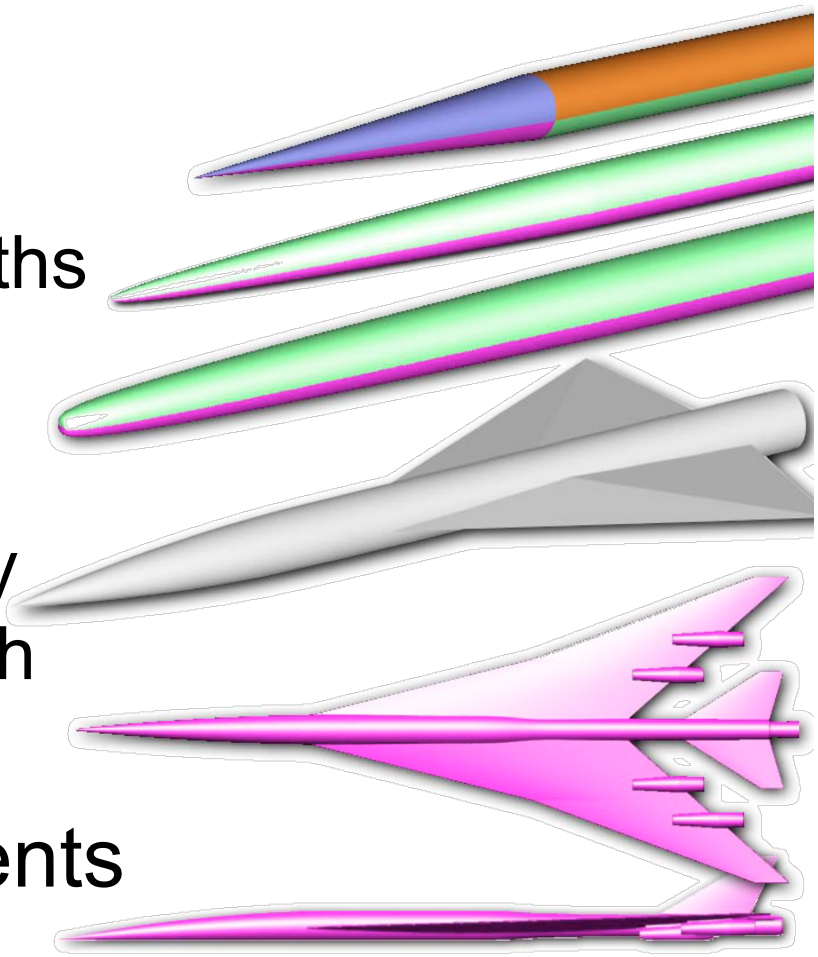
USM3D-SSGRID

Fine isotropic grid is stretched and sheared for Mach angle alignment



Configurations

- Increasing complexity
  - Shocks of various strengths and standoff distances
  - Simple lifting wing body
  - Complex lifting wing body with tails and flow-through nacelles
- Wind tunnel measurements



Comparisons Between Methods

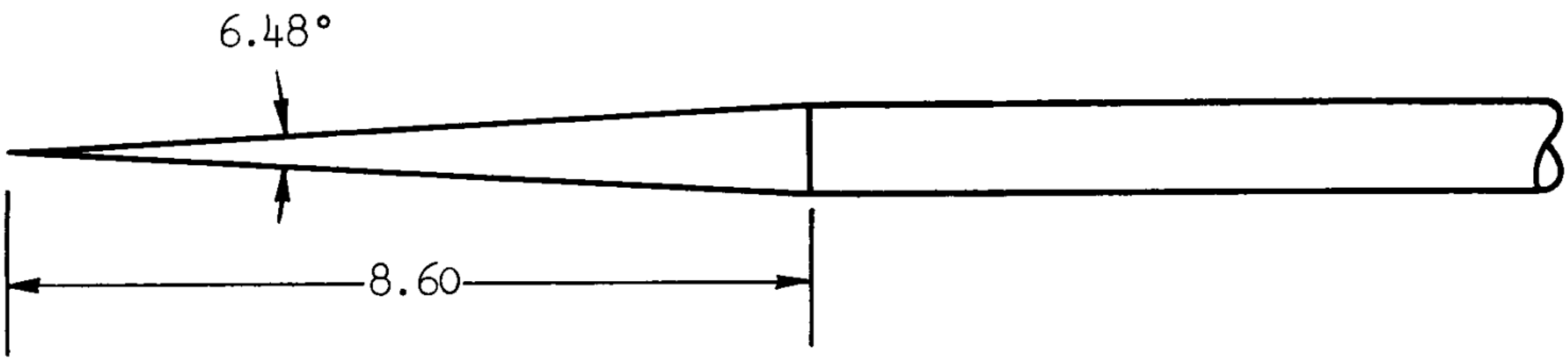
- Need to look closely to find differences with the possibility of being overly critical
- Significance of the difference is not well understood or qualified
  - What is the ideal prediction at extrema
- Evaluating the signatures on the ground with a propagation method could provide significance of the differences

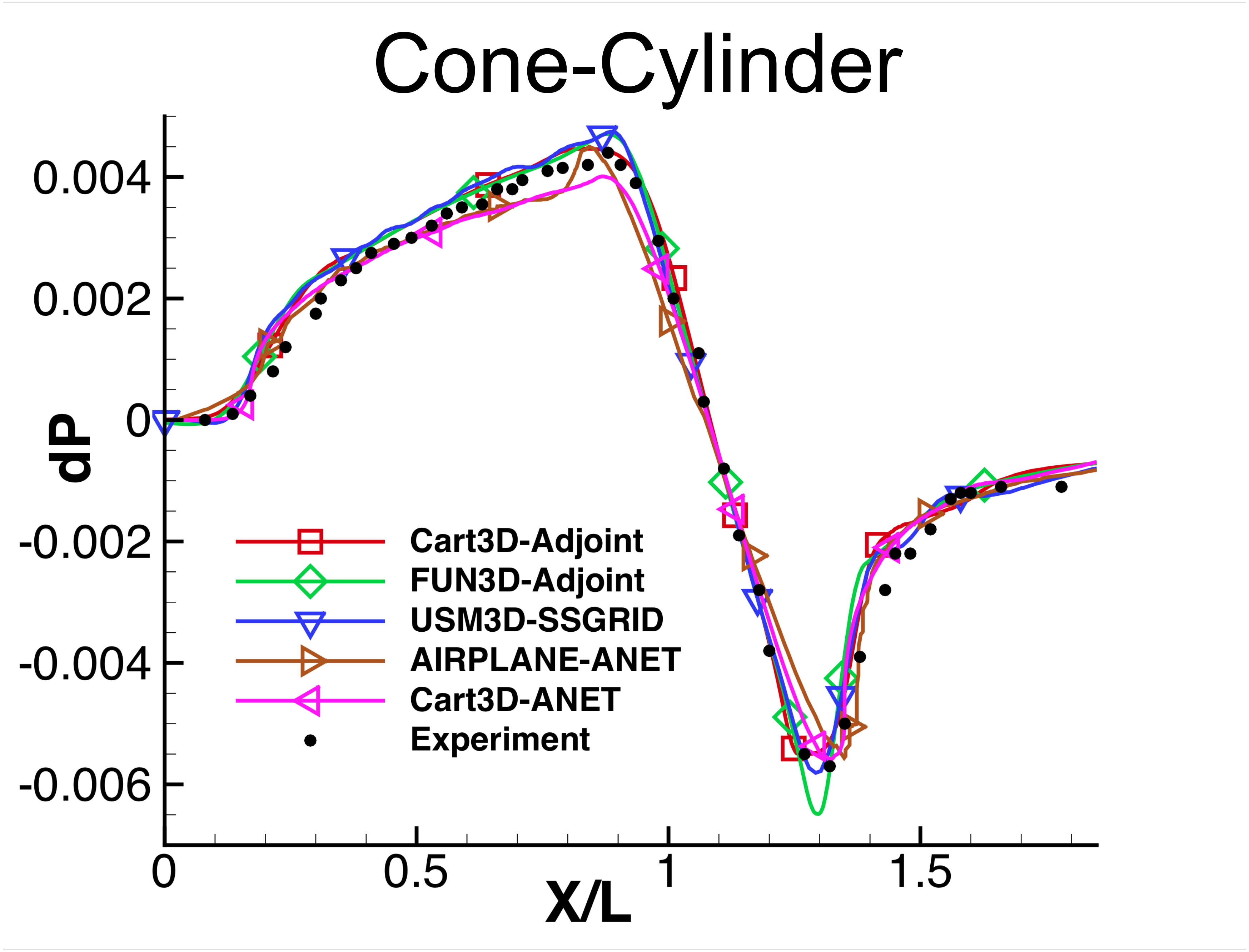
Comparisons to Measurements

- Unknown measurement uncertainty
  - Old tests with limited documentation
  - Known and unknown geometry differences
- Nonuniform wind tunnel test section flow
  - Distorts signals
  - Complicates lift measurement and angle of attack determination
- Viscous effects

Cone-Cylinder

- Attached bow shock with finite rise time in near-field,1.68 Mach, 10 body lengths (L)
- NASA TM X-2219 (1971)





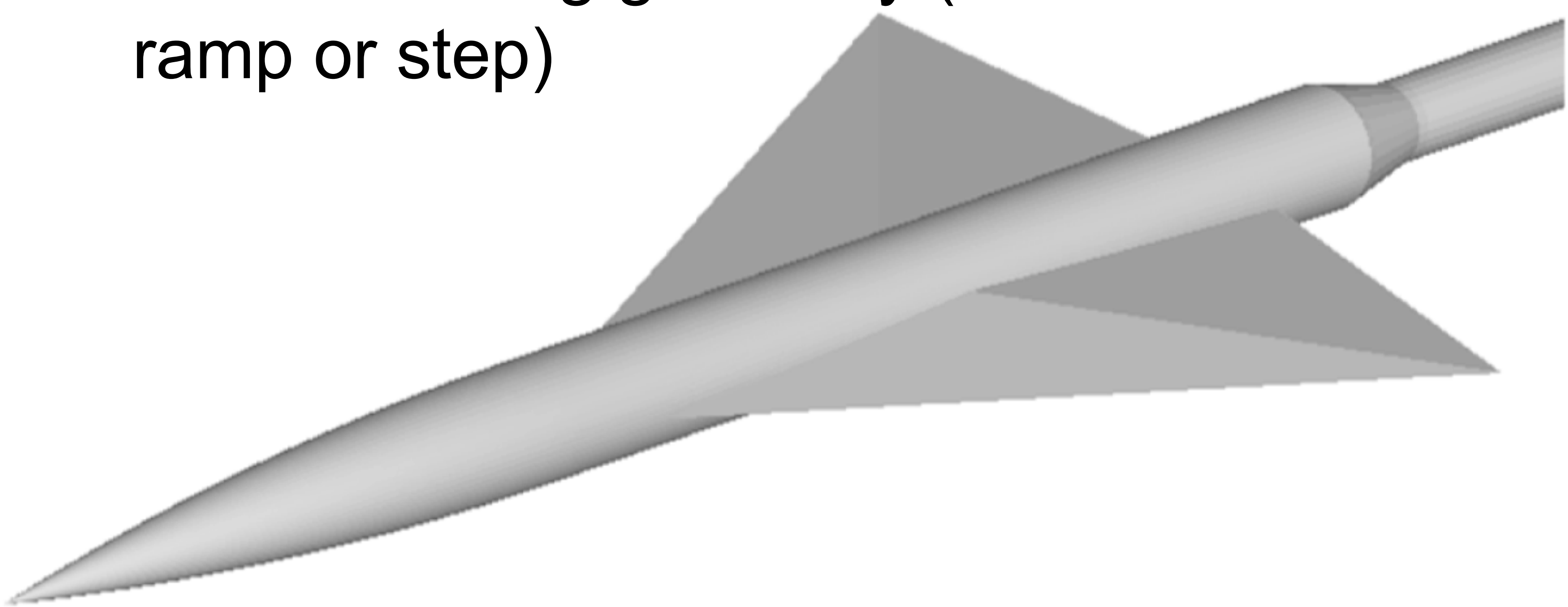
Cone-Cylinder
dP
X/L
0.004
0.002
0
-0.002
-0.004
-0.006
0
0.5
1
1.5
Cart3D-Adjoint
FUN3D-Adjoint
USM3D-SSGRID
AIRPLANE-ANET
Cart3D-ANET
Experiment

Axisymmetric Bodies

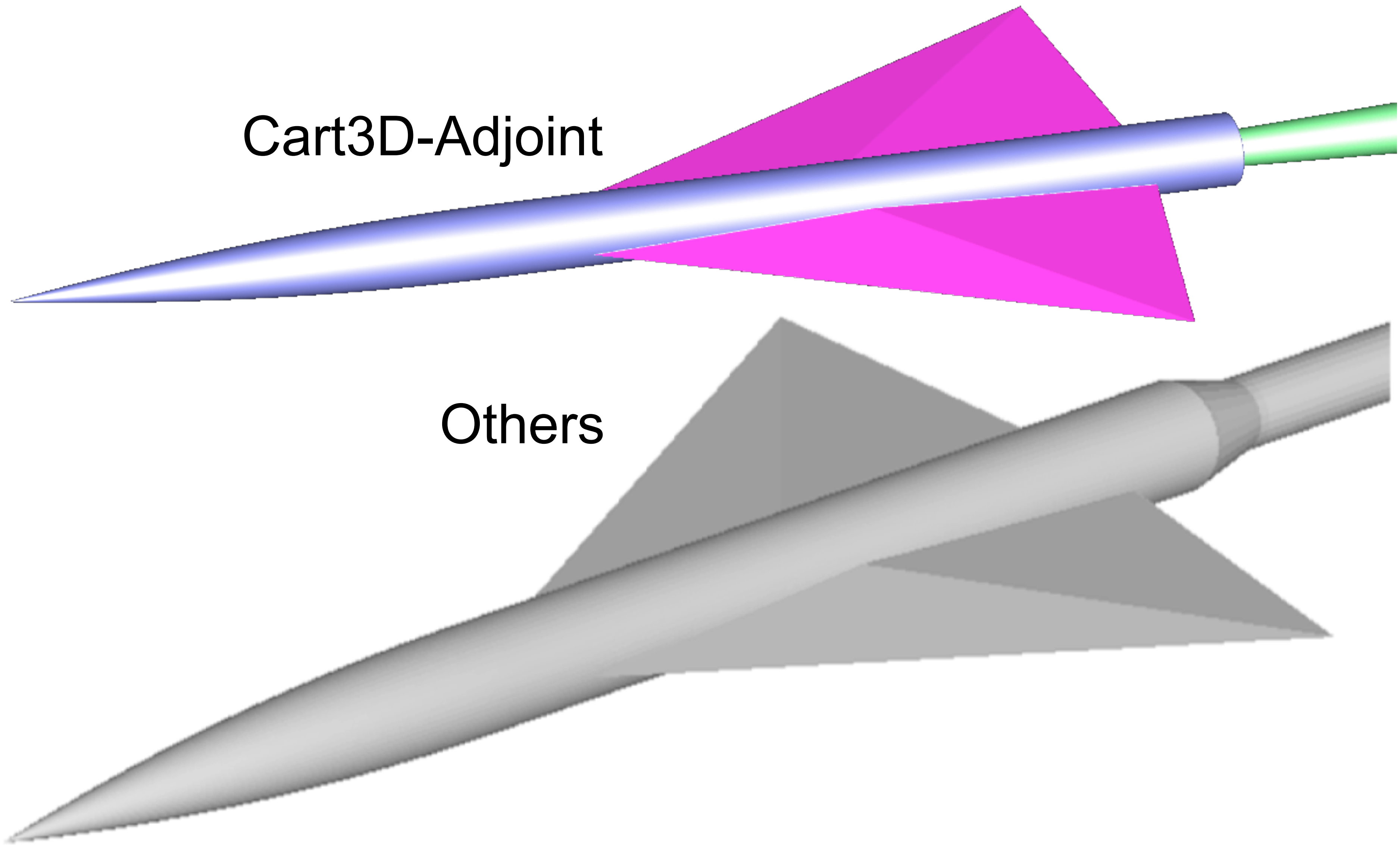
- Bow shocks and expansions of increasing strength, 1.41 Mach, 10 L
- Analytic description $r = f(x^{1/2})$, $r = f(x^{1/4})$
- NASA TN D-3106 (1965)
- Comparison in paper

Delta Wing Body

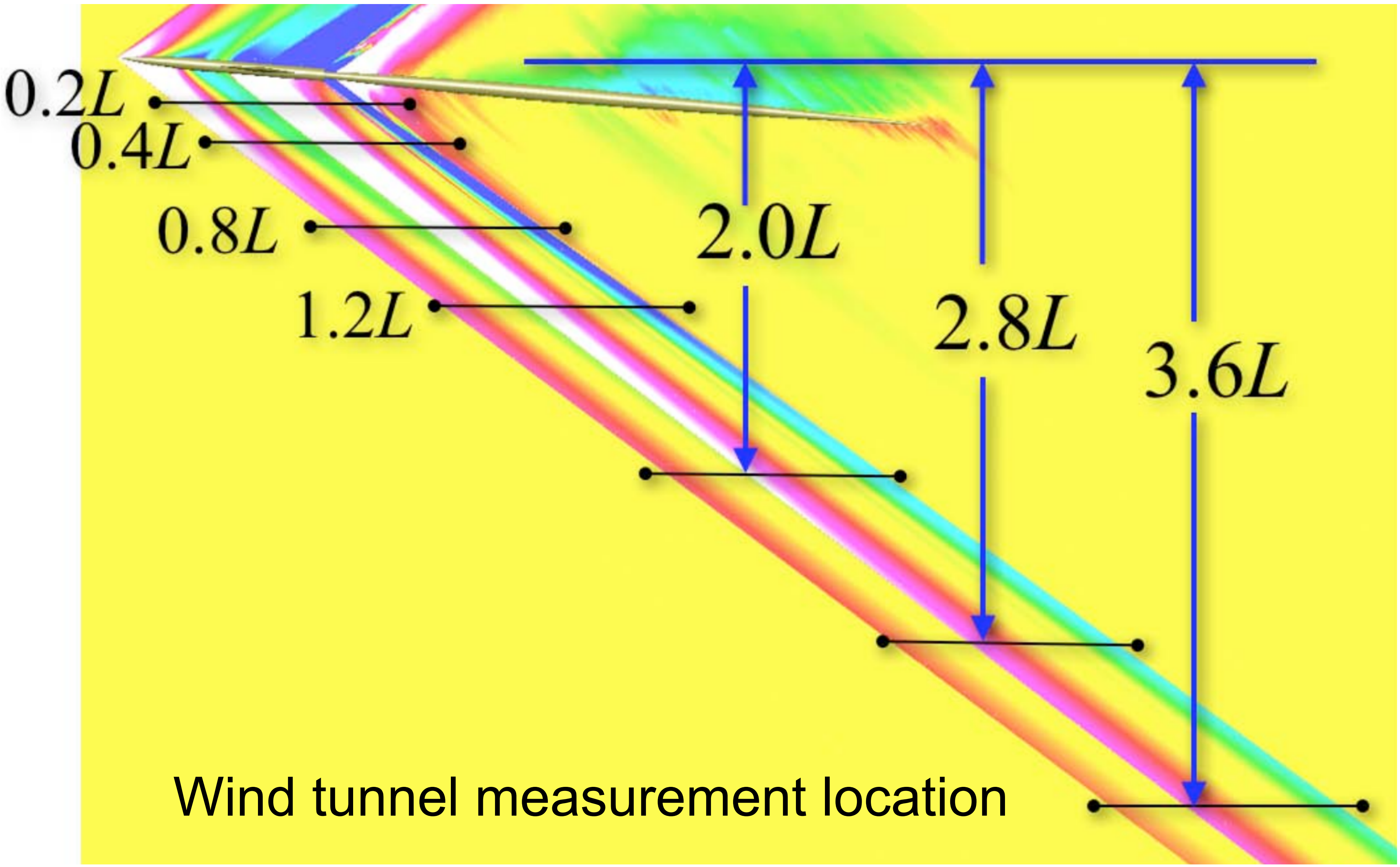
- Simple lifting configuration, 1.68 Mach
- NASA TN D-7160 (1973)
- Unknown sting geometry (modeled as ramp or step)



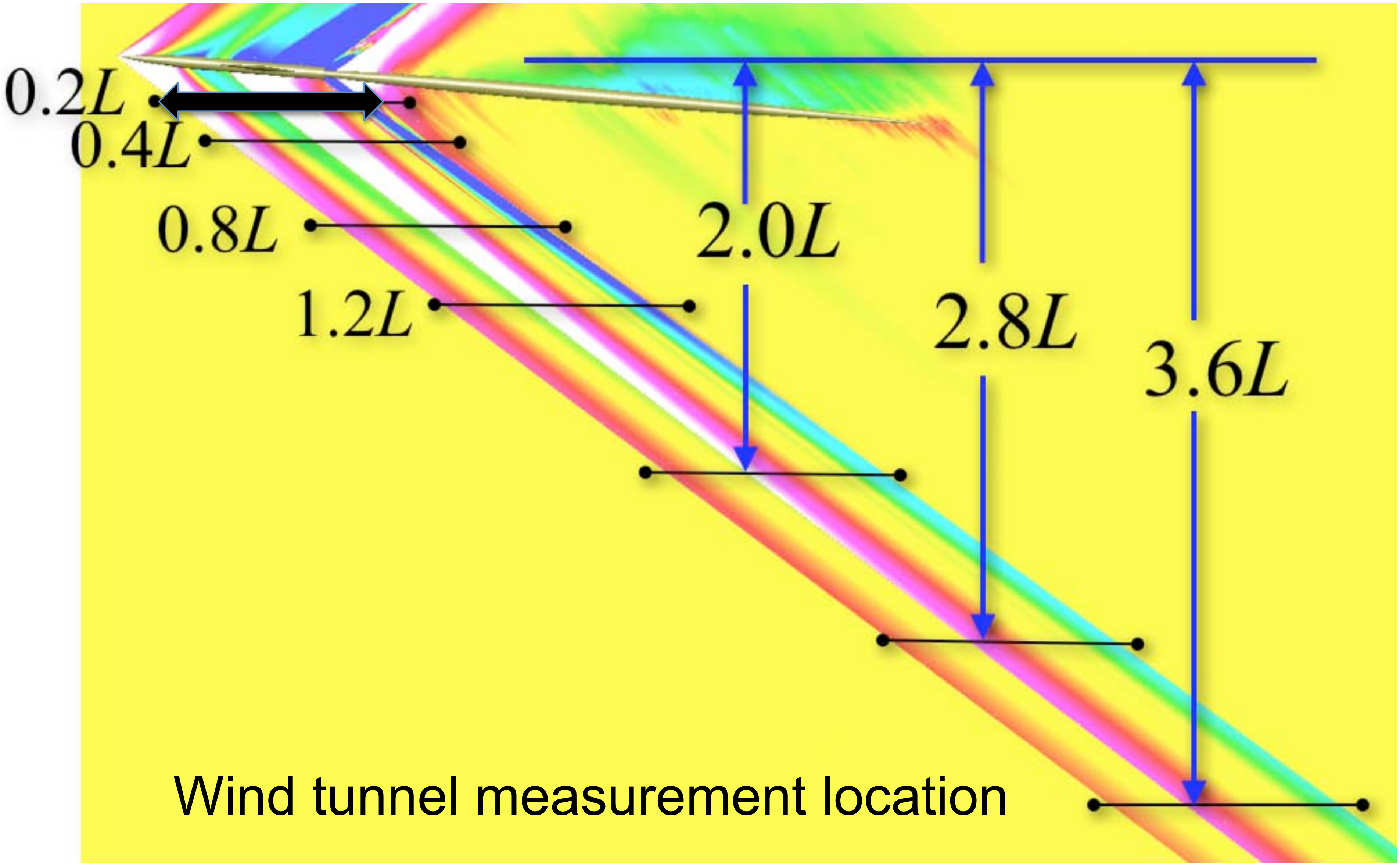
Delta Wing Body

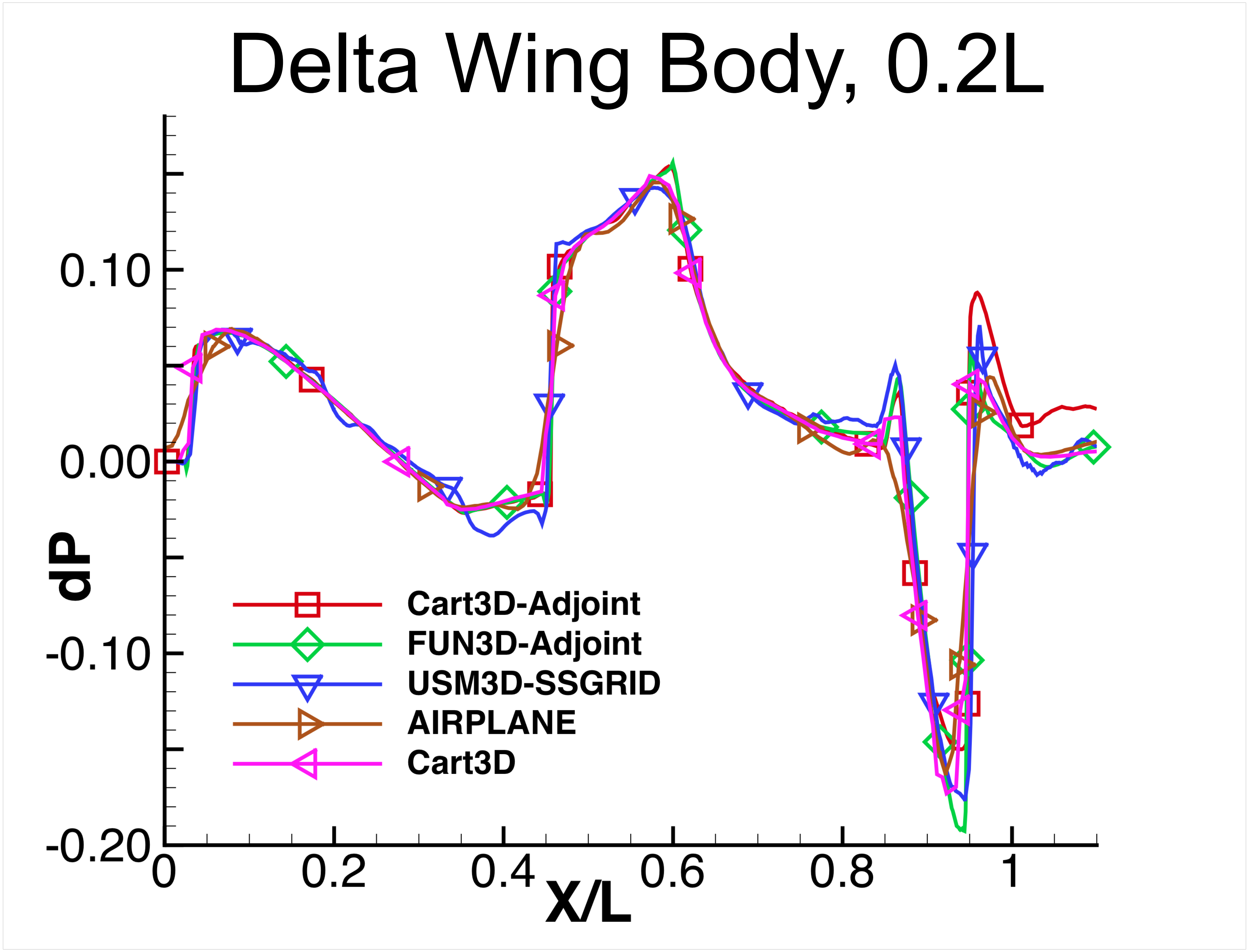


Delta Wing Body



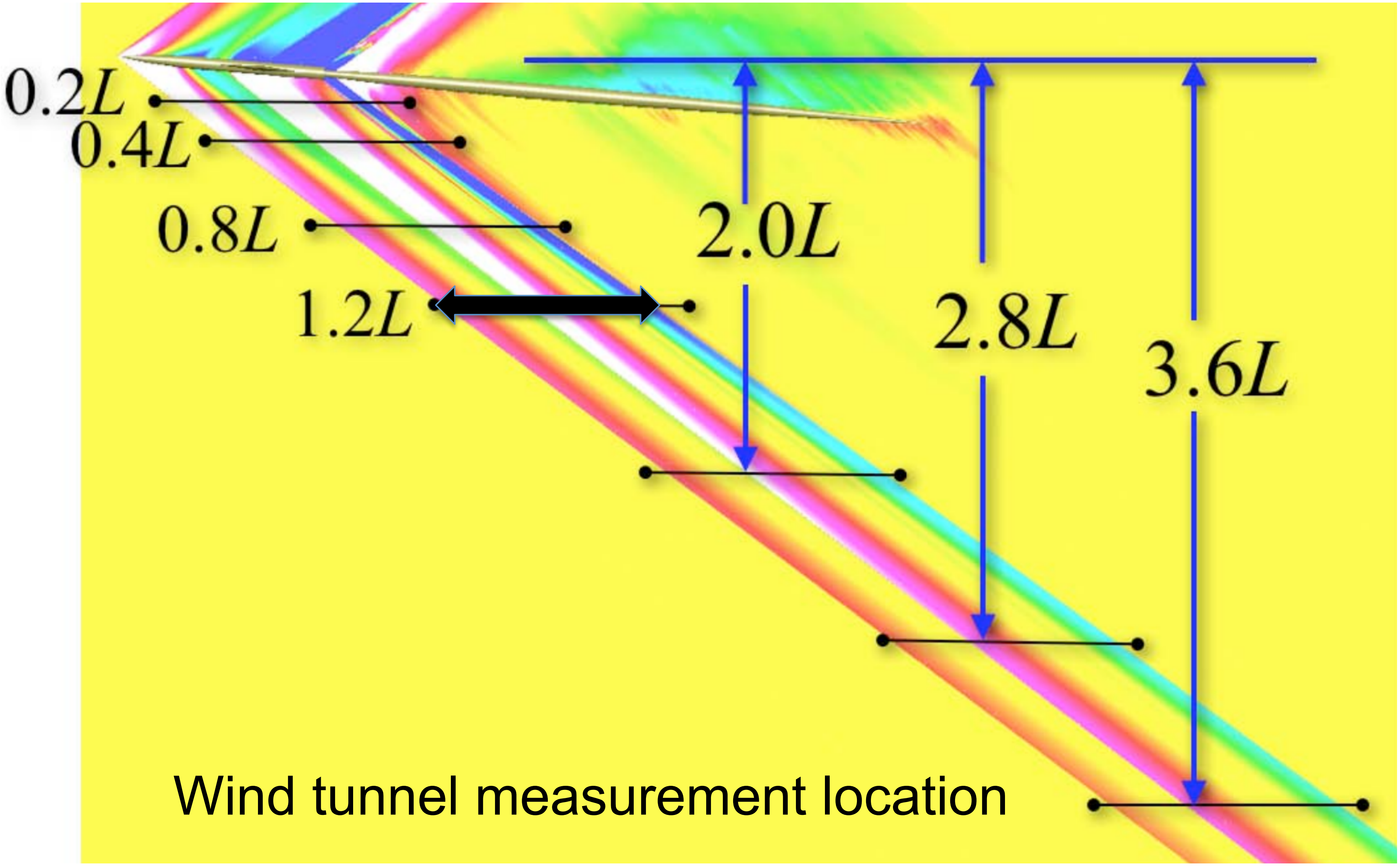
Delta Wing Body

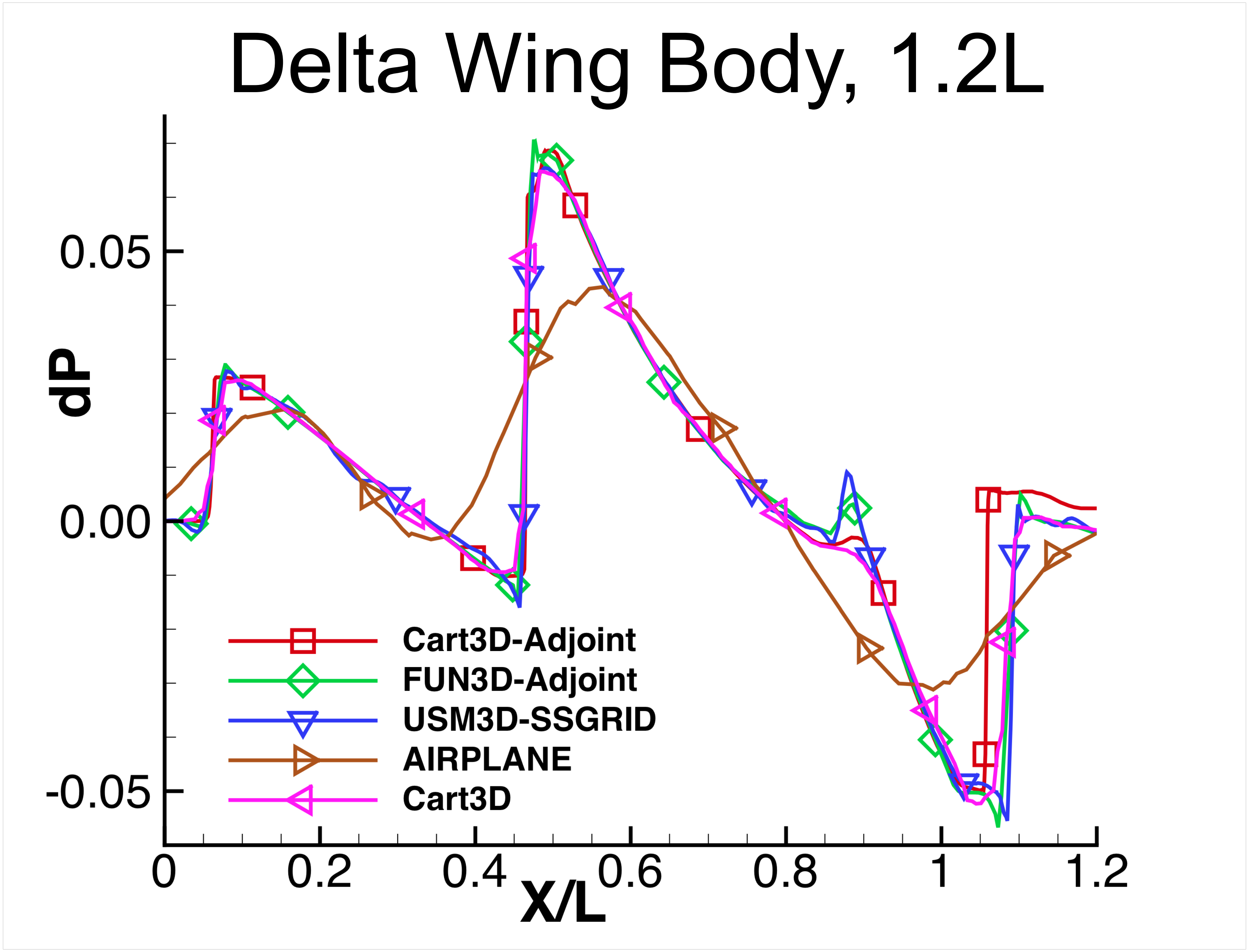




Delta Wing Body, 0.2L
dP
X/L
0.10
0.00
-0.10
-0.20
0
0.2
0.4
0.6
0.8
1
Cart3D-Adjoint
FUN3D-Adjoint
USM3D-SSGRID
AIRPLANE
Cart3D

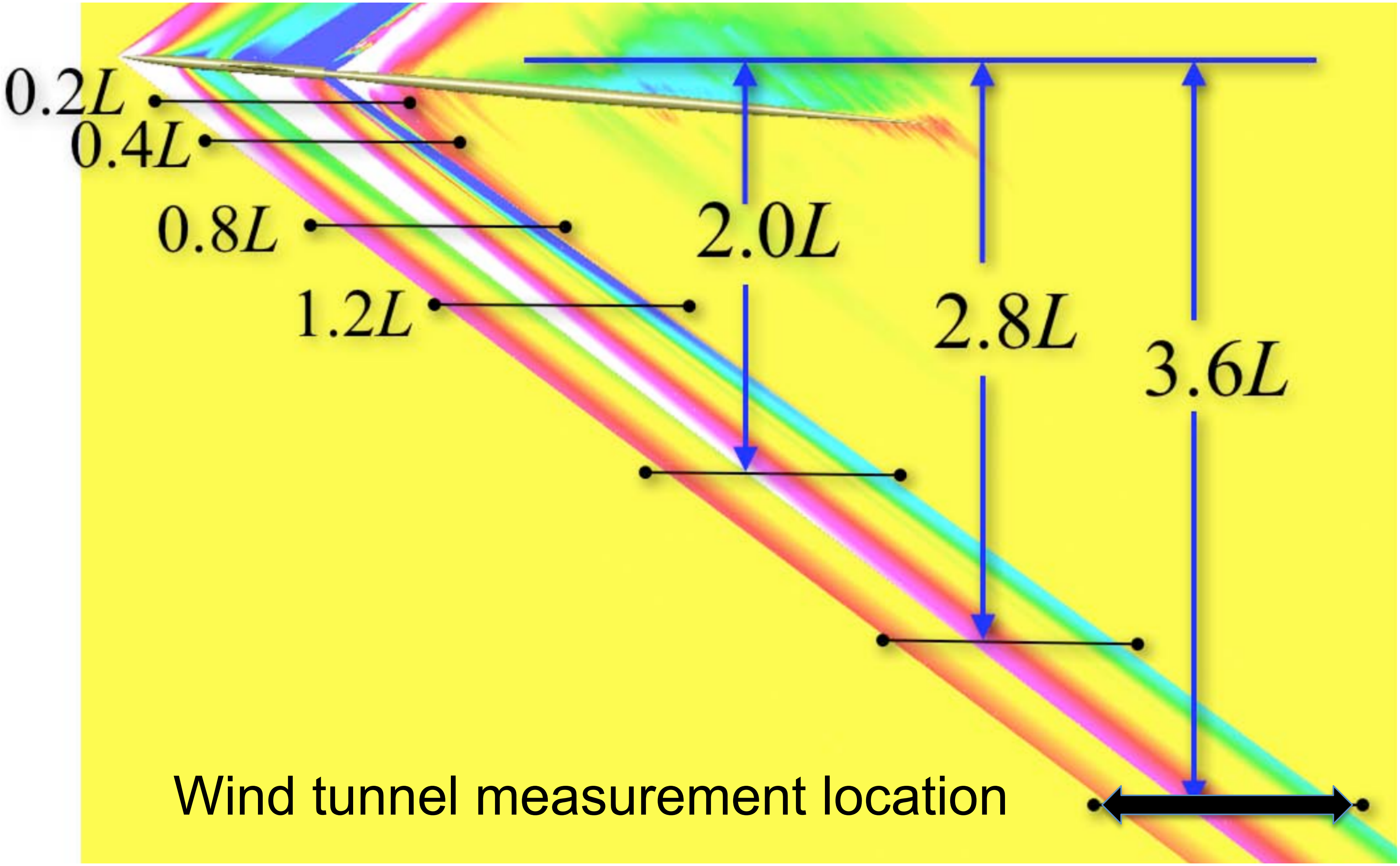
Delta Wing Body

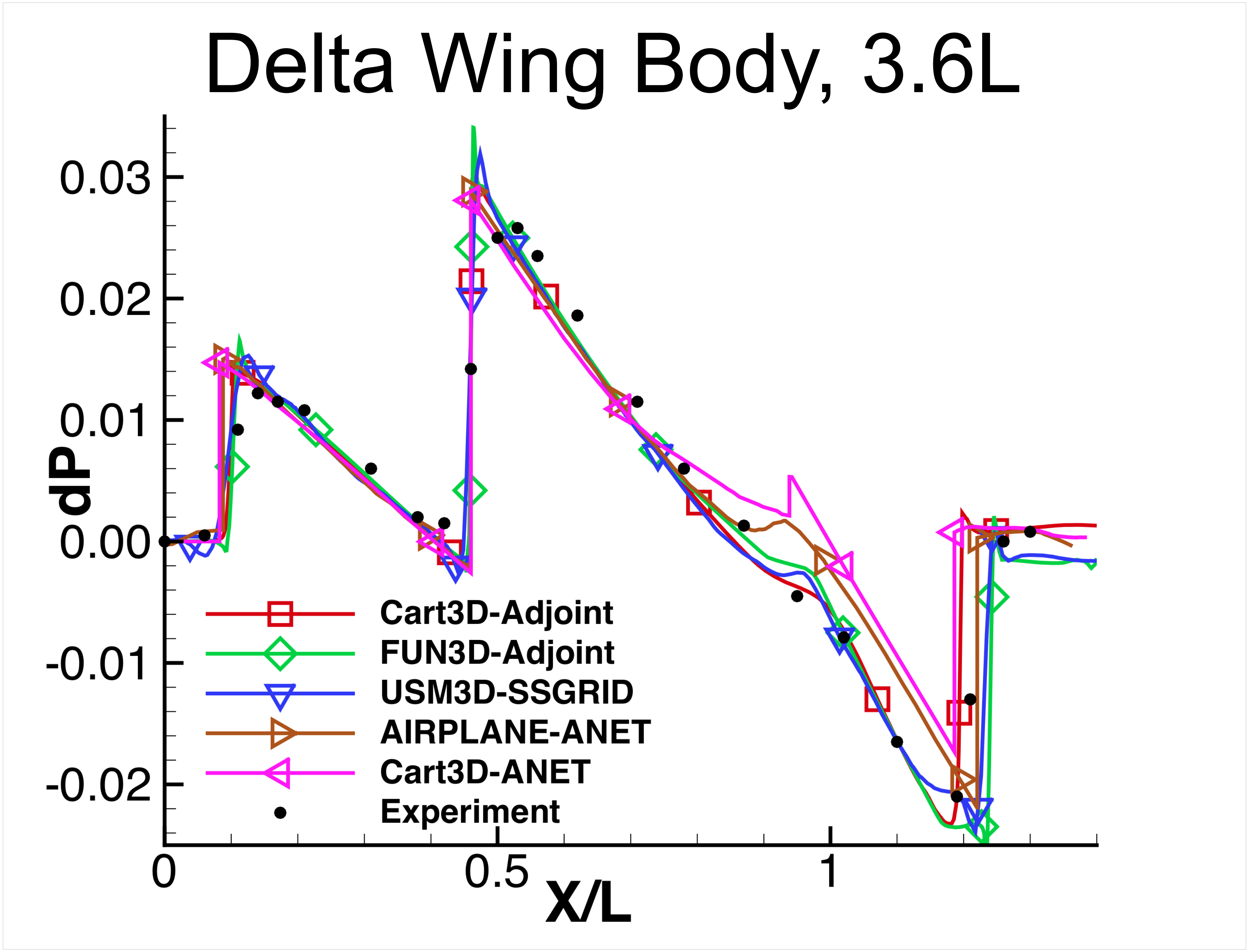




Delta Wing Body, 1.2L
dP
X/L
0.05
0.00
-0.05
0
0.2
0.4
0.6
0.8
1
1.2
Cart3D-Adjoint
FUN3D-Adjoint
USM3D-SSGRID
AIRPLANE
Cart3D

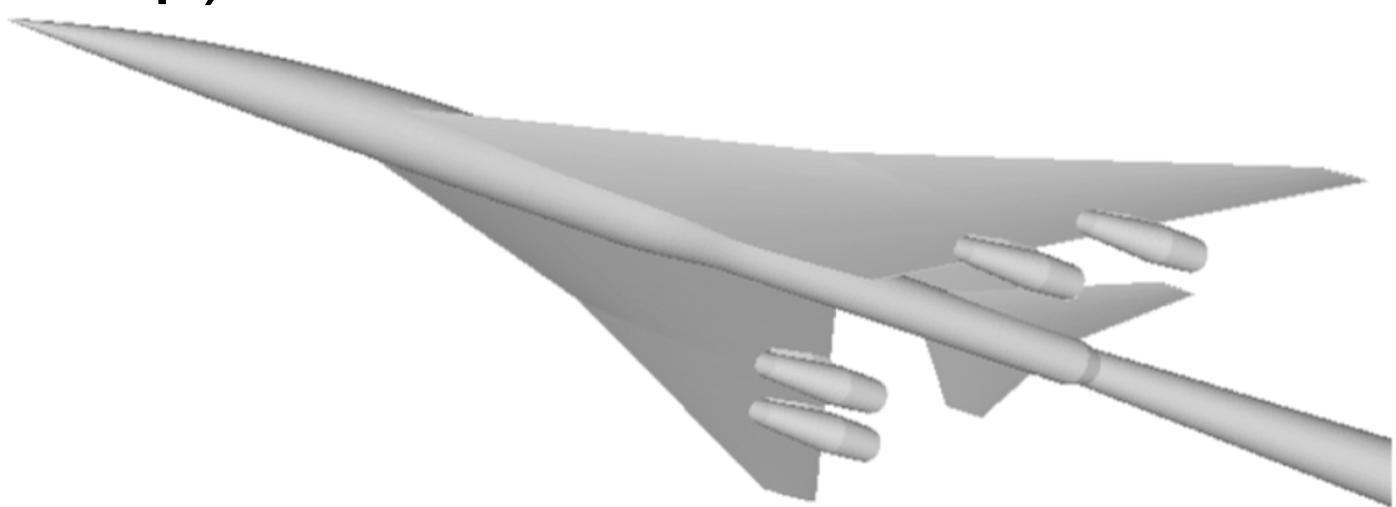
Delta Wing Body




Delta Wing Body, 3.6L
0.03
0.02
0.01
0.00
-0.01
-0.02
dP
0
0.5
1
X/L
Cart3D-Adjoint
FUN3D-Adjoint
USM3D-SSGRID
AIRPLANE-ANET
Cart3D-ANET
Experiment

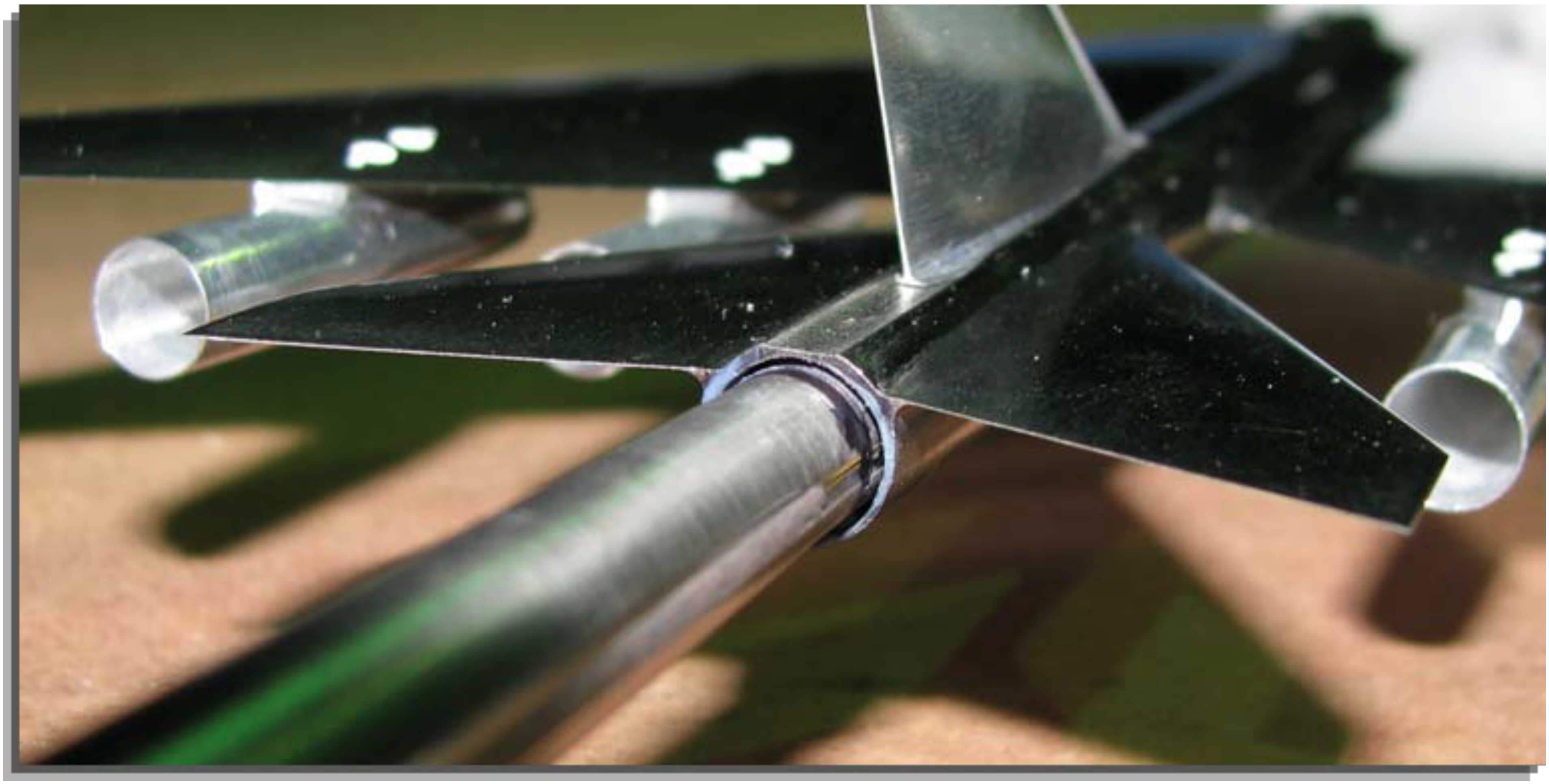
Ames Low-Boom Configuration

- Complex lifting configuration (low boom forebody) 2.0 Mach, H/L=1.167
- NASA CP-1999-209699 (1999)
- Unknown sting geometry (modeled as ramp or step)

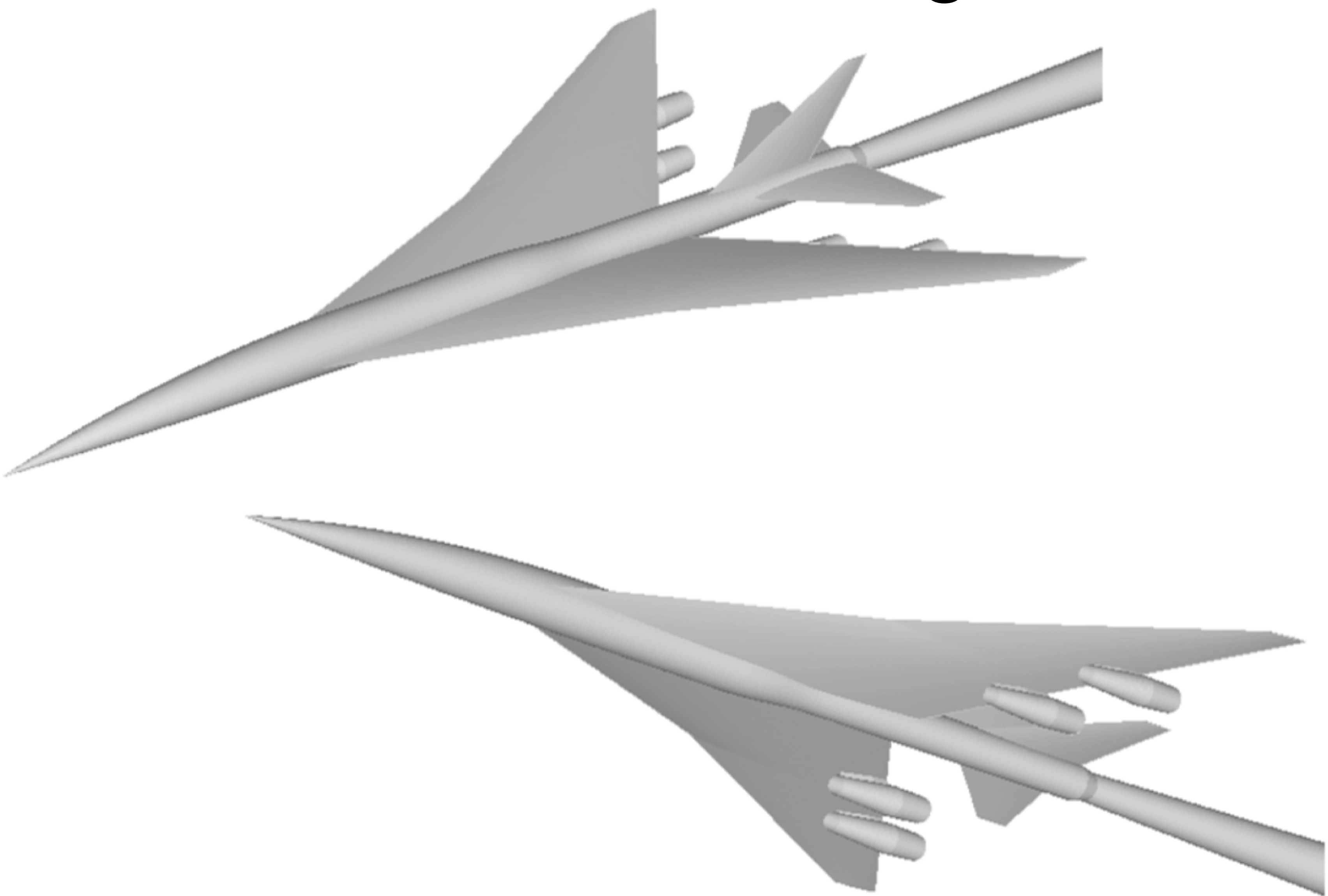


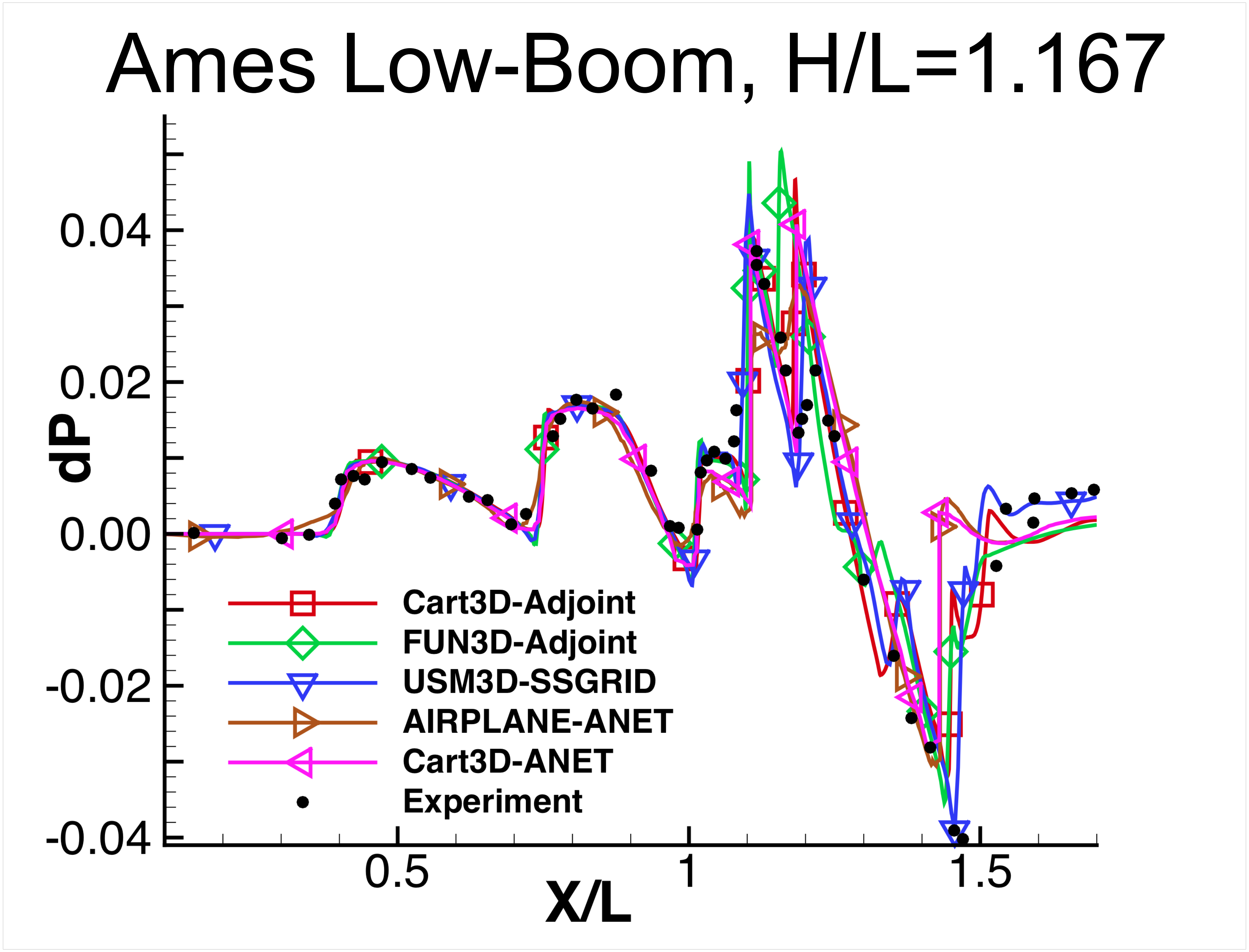
Ames Low-Boom Configuration

- Simplified tail geometry

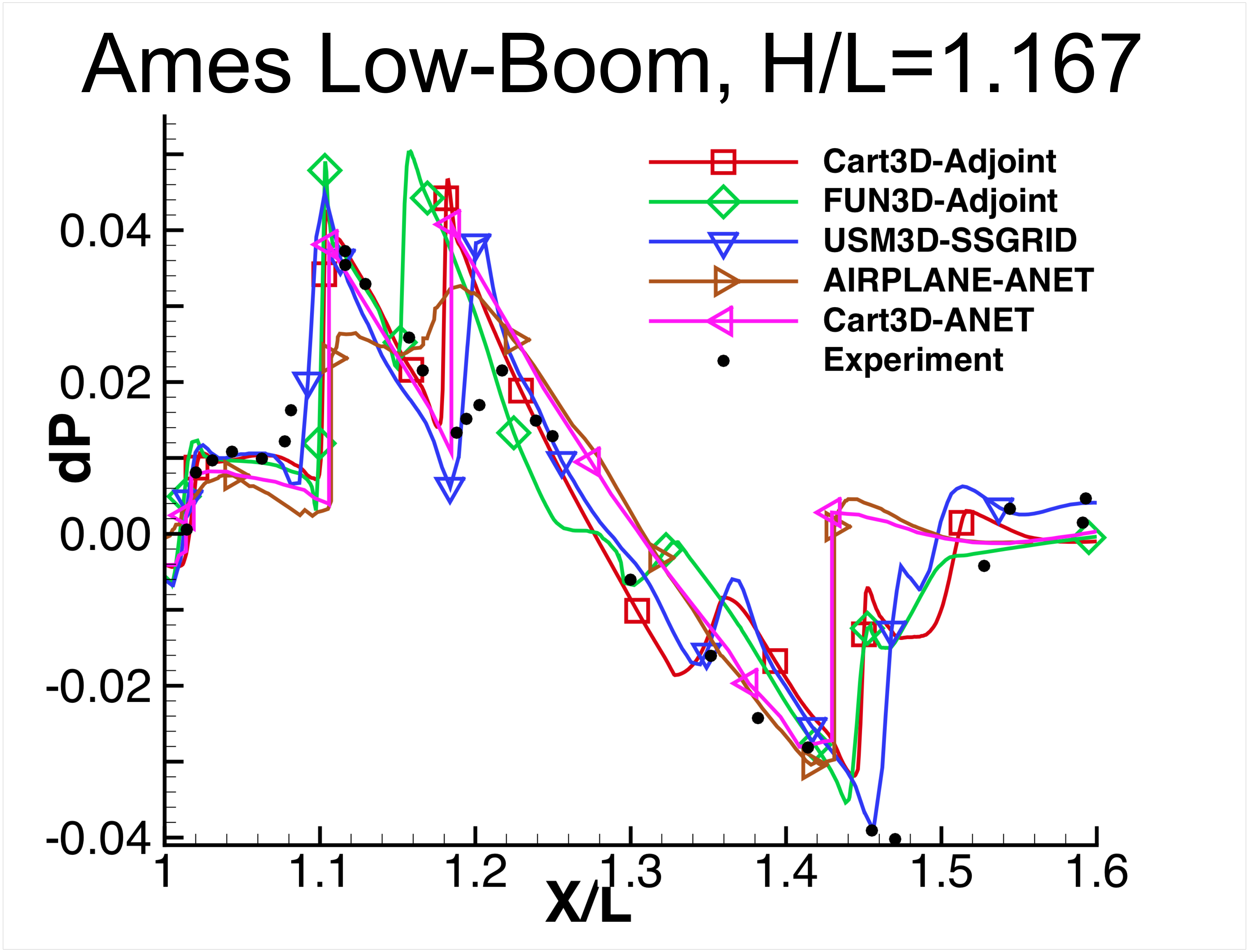


Ames Low-Boom Configuration

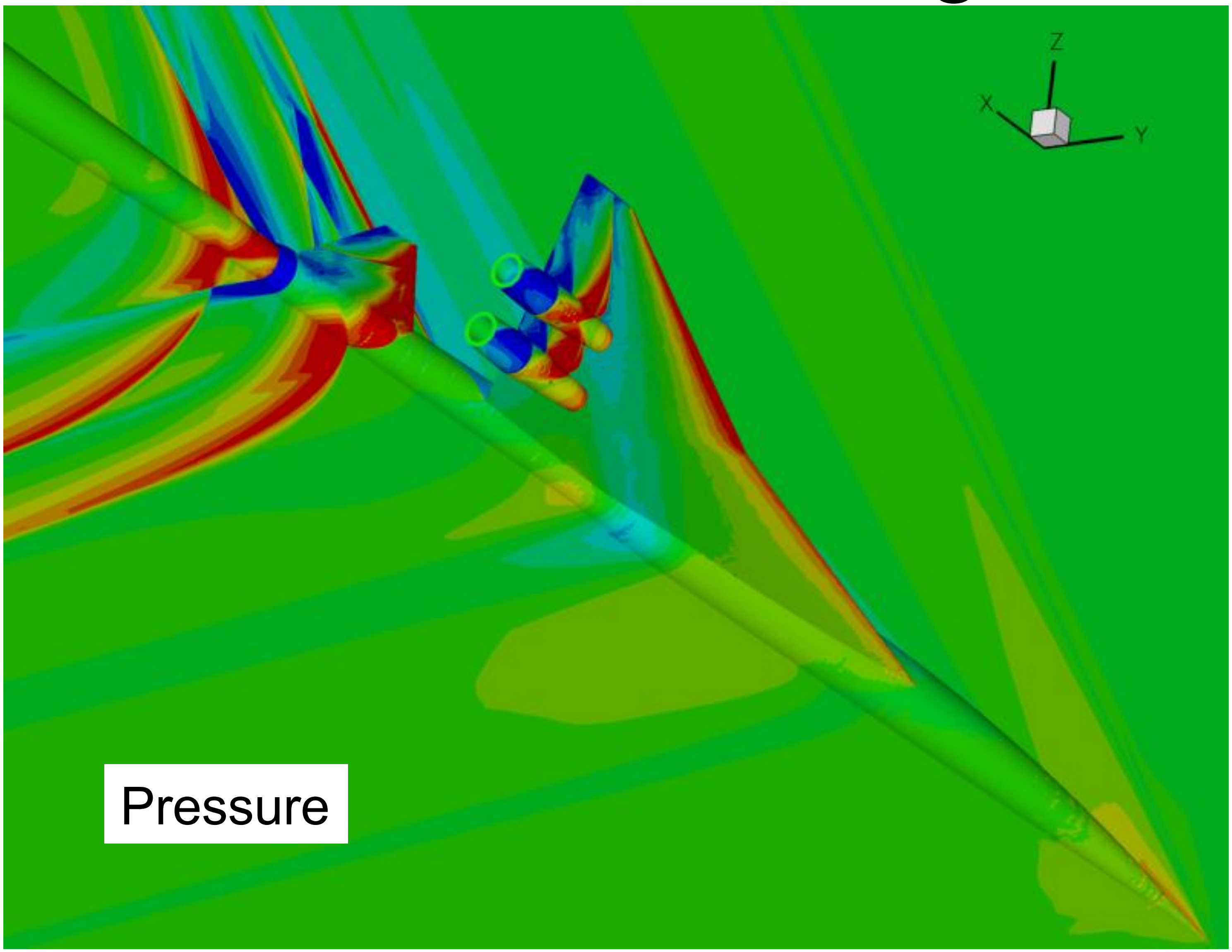




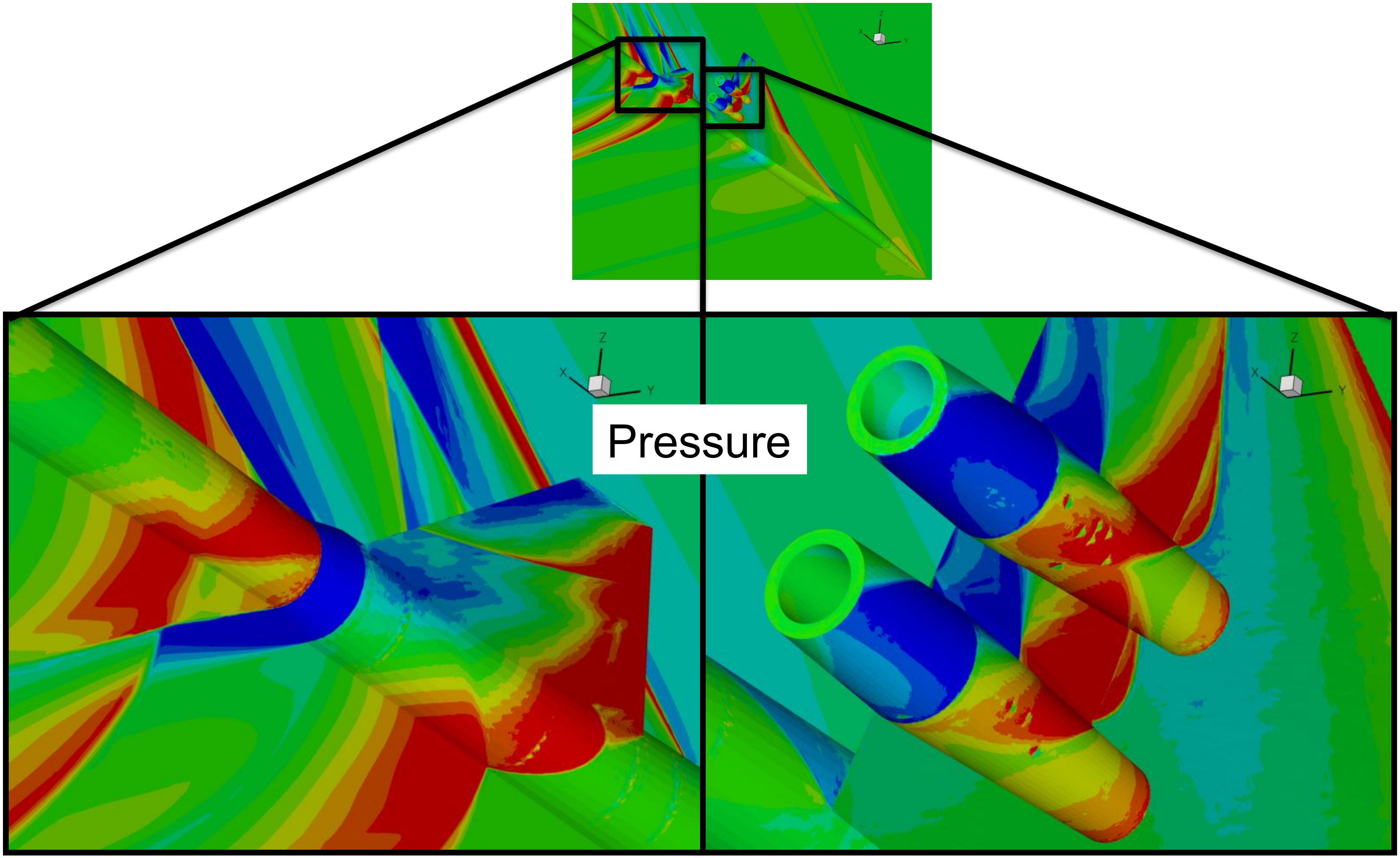
Ames Low-Boom, H/L=1.167
dP
X/L
0.04
0.02
0.00
-0.02
-0.04
0.5
1
1.5
Cart3D-Adjoint
FUN3D-Adjoint
USM3D-SSGRID
AIRPLANE-ANET
Cart3D-ANET
Experiment


Ames Low-Boom, H/L=1.167
Cart3D-Adjoint
FUN3D-Adjoint
USM3D-SSGRID
AIRPLANE-ANET
Cart3D-ANET
Experiment
dP
0.04
0.02
0.00
-0.02
-0.04
1
1.1
1.2
1.3
1.4
1.5
1.6
X/L

Ames Low-Boom Configuration



Ames Low-Boom Configuration



Summary

- Consistent geometry is important
- Propagating signatures extracted from less than a body length yields slightly different results
- Forward portions of the signatures agree
- Largest differences observed in the aft portion of the complex low boom configuration

In Paper

- Review of methods available to NASA before the workshop
- Progress after the workshop
  - CFD, wind tunnel testing, and design
- Resources required by each method
- Details on methods, configurations, and results

Recommendations for LBPW

- Perform propagation on submissions to determine the significance of the differences on the ground
  - Loudness
  - Sensitivities (with adjoint)
- Eliminate geometry differences
- Focus on the aft portion of signatures
  - Complicated by geometry, shock interaction, lift, and boundary layer state

Recommendations for LBPW

- Time and resources required are important to gather but very difficult to compare
- Provide iterative convergence criteria and require reporting (complicated by limiters)

Visit http://lbpw.larc.nasa.gov

- Information on the AIAA 1st Low Boom Prediction Workshop (LBPW)
- 2008 FAP Workshop presentations