THIRD AIAA SONIC BOOM PREDICTION WORKSHOP INTRODUCTION

Lori Ozoroski
NASA Langley Research Center

ORGANIZING COMMITTEE

NASA
- Melissa Carter
- Sriram Rallabhandi
- Mike Park
- Alexandra Loubeau
- Lori Ozoroski
- James Jensen

Boeing
- Todd Magee

DLR
- Jochen Kirz

Gulfstream Aerospace
- Tom Wayman

JAXA
- Yoshi Makino

Lockheed Martin
- John Morgenstern

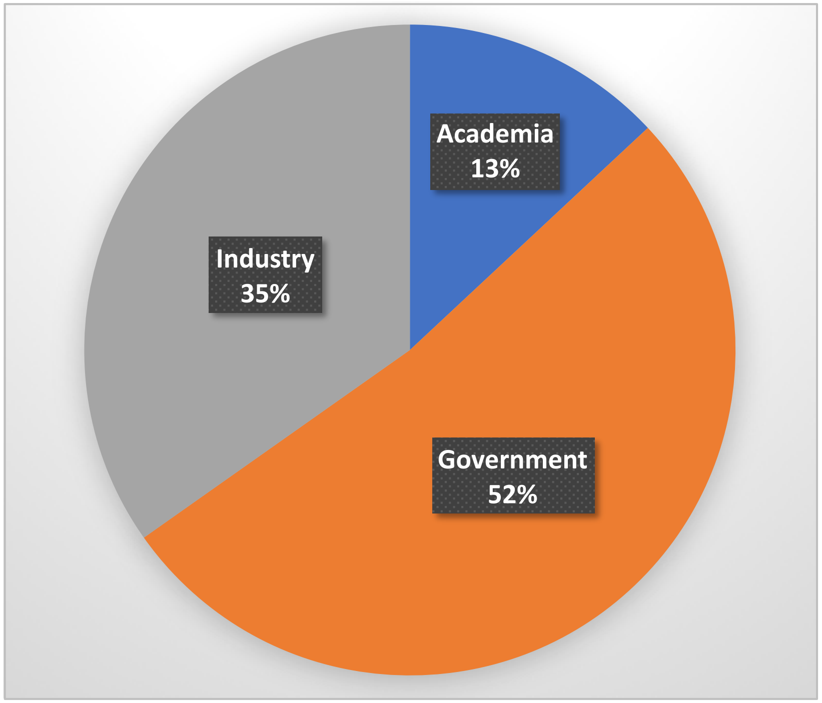
ONERA
- Gerald Carrier

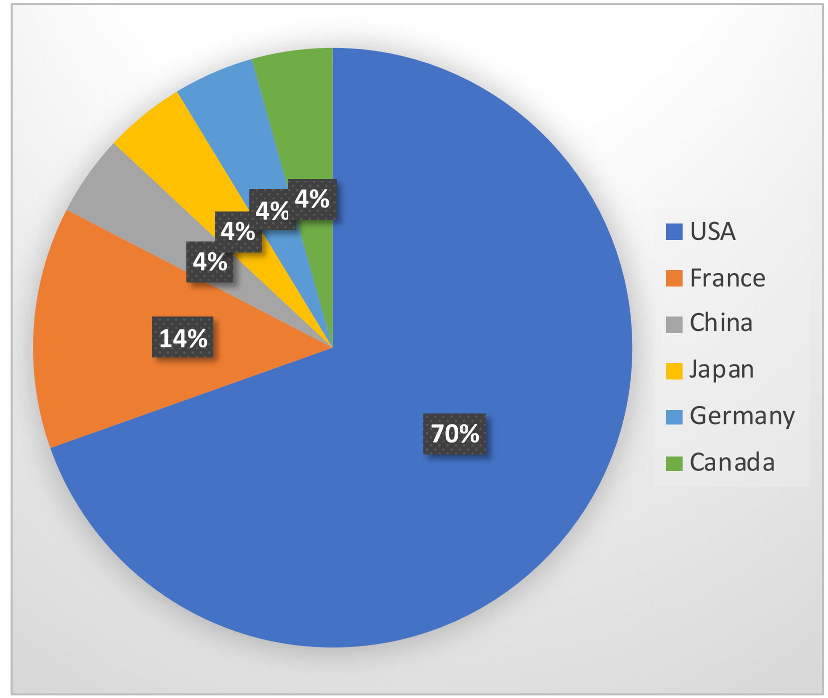
Volpe, US DOT
- Juliet Page

WORKSHOP OBJECTIVE

The objective of the Third Sonic Boom Prediction Workshop is to assess the state of the art for predicting near field signatures with computational fluid dynamics (CFD) and propagation codes used to propagate near field signatures to the ground.

THIRD WORKSHOP: 23 PARTICIPANTS





ANSYS	FAA	Metacomp	Penn State
Boeing	INRIA	NASA	Siemens
Boom Aero	JAXA	Northwestern	Texas A&M
DASSAV	Lockheed	Polytech	Volpe
DLR	Martin	ONERA	

WORKSHOP OVERVIEW

- Saturday, January 4, 2020 (Near Field CFD)
  - CFD to CFD comparison of near field
  - CFD to EXP comparison of near field
  - 2 required configurations
- Sunday, January 5, 2020 (Propagation)
  - Code to code comparison of propagated ground signatures
  - 2 required near field signatures

January 4, 2020: Near Field CFD

7:15 am - 8:00 am	Breakfast	
8:00 am – 8:05 am	Introduction	Lori Ozoroski
8:05 am – 8:30 am	Overview	M. Park & M. Carter
8:30 am - 8:55 am	DLR	Jochen Kirz
8:55 am - 9:20 am	Texas A&M University	Forrest Carpenter
9:20 am - 9:45 am	NASA Langley	Alaa Elmiligui
~~9:45 am - 10:10 am~~	~~ONERA~~	~~Olivier Atinault~~
10:10 am - 10:35 am	Break	
10:35 am - 11:00 am	Boeing	Todd Magee
11:00 am - 11:25 am	NASA Ames	Wade Spurlock
11:25 am - 11:50 am	NASA Ames	James Jenson
11:50 am - 12:15 pm	Northwestern Polytechnical University	Zhijin Lei (University of Miami)
12:15 pm - 1:15 pm	Lunch Provided by AIAA included in the registration fee	
1:15 pm - 1:40 pm	Siemens	Chris Nelson
1:40 pm – 2:05 pm	Boom Aero	Enrico Fabiano
2:05 pm - 2:30 pm	ANSYS	Isik Ozcer
2:30 pm – 2:55 pm	Metacomp	Amarnatha Sarma Potturi
2:55 pm – 3:20 pm	Break	
3:20 pm – 3:45 pm	NASA Langley	Mike Park
3:45 pm - 4:10 pm	INRIA	Adrien Loseille
4:10 pm - 4:35 pm	JAXA	Hiroaki Ishikawa
~~4:35 pm - 5:00 pm~~	~~Lockheed Martin~~	~~John Morgenstern~~
5:00 pm - 6:00 pm	Summary	M. Park & M. Carter
6:00 pm - 6:30pm	Discussion	

January 5, 2020: Propagation		
7:15 am - 8:00 am	Breakfast	
8:00 am – 8:05 am	Introduction	Lori Ozoroski
8:05 am – 8:30 am	Overview	Sriram Rallabhandi
8:30 am – 9:00 am	NASA Ames	Mike Aftosmis
9:00 am – 9:30 am	Dassault	Pierre-Elie Normand
9:30 am – 10:00 am	ONERA	Gerald Carrier
10:00 am – 10:30 am	Break	
10:30 am – 11:00 am	NASA Langley	Sriram Rallabhandi
11:00 am – 11:30 am	Volpe	R. Downs & J. Page
11:30 am – 12:00 pm	Penn State	Luke Wade
12:00 pm – 1:00 pm	Lunch Provided by AIAA included in the registration fee	
1:00 pm – 1:30 pm	NASA Langley	Joel Lonzaga
1:30 pm – 2:00 pm	JAXA	Masashi Kanamori
2:00 pm – 2:30 pm	Boeing	Hao Shen
2:30 pm – 3:00 pm	Break	
3:00 pm – 3:30 pm	Boom Supersonic	Enrico Fabiano
~~3:30 pm – 4:00 pm~~	~~Lockheed Martin~~	~~John Morgenstern~~
4:00 pm – 4:30 pm	FAA	Sandy Liu
4:30 pm – 5:00 pm	Summary	S. Rallabhandi & A. Loubeau
5:00 pm – 5:30 pm	Discussion	

THIRD AIAA SONIC BOOM PREDICTION WORKSHOP NEAR FIELD CFD INTRODUCTION

Melissa Carter & Mike Park
NASA Langley Research Center

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

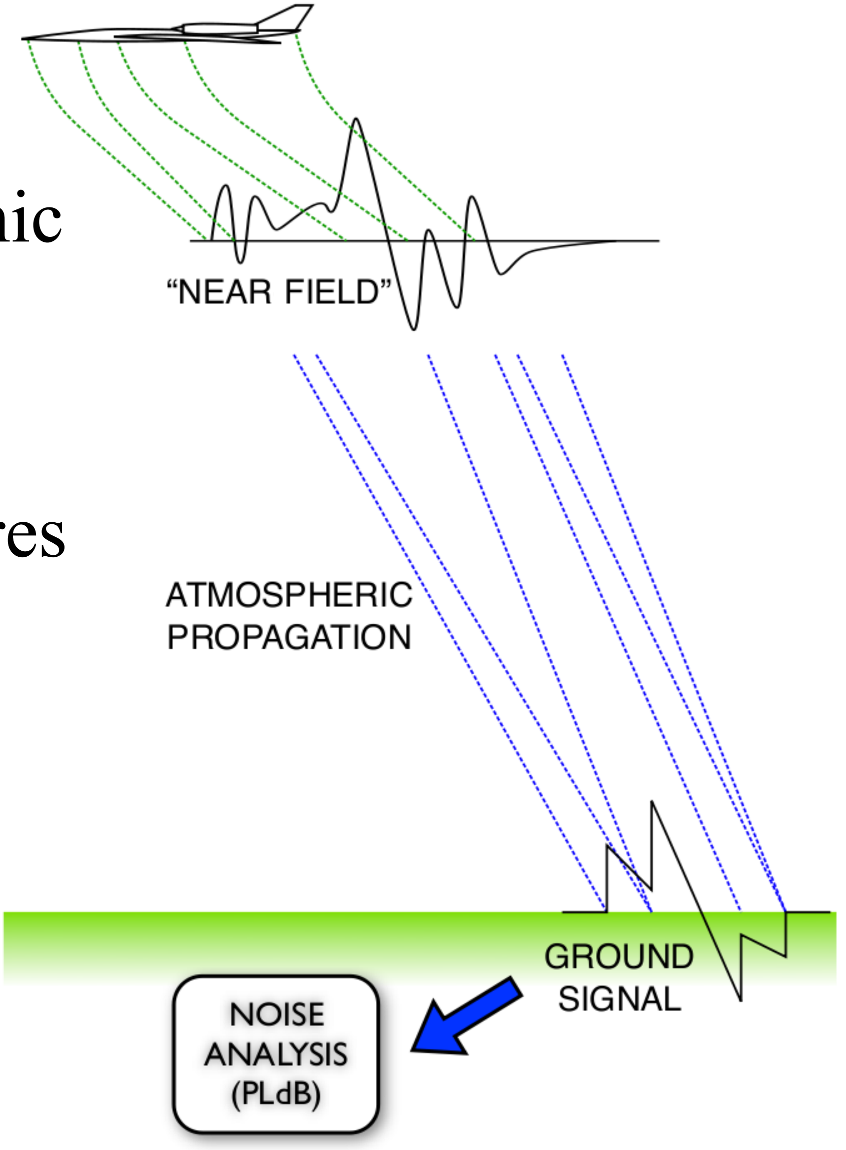
MOTIVATION

Near field CFD is part of sonic boom prediction

Explore the issues

Impartially compare signatures by uniform application of

- Near field statistics
- Propagation
- Loudness measures



WORKSHOP CULTURE

Adjectives such as good, bad, right, and wrong oversimplify issues and should be avoided

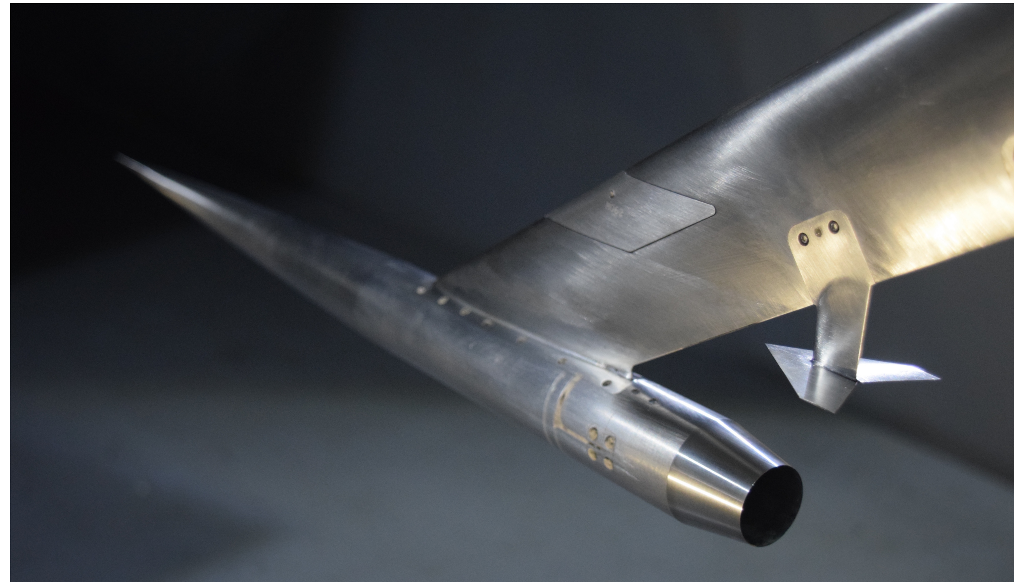
Focus on describing observed differences and communicate why things are different

MODELS AND CASES

Ames 9’x7’ Biconvex Plume-Shock Interaction Case

C608, an early X-59 Prototype

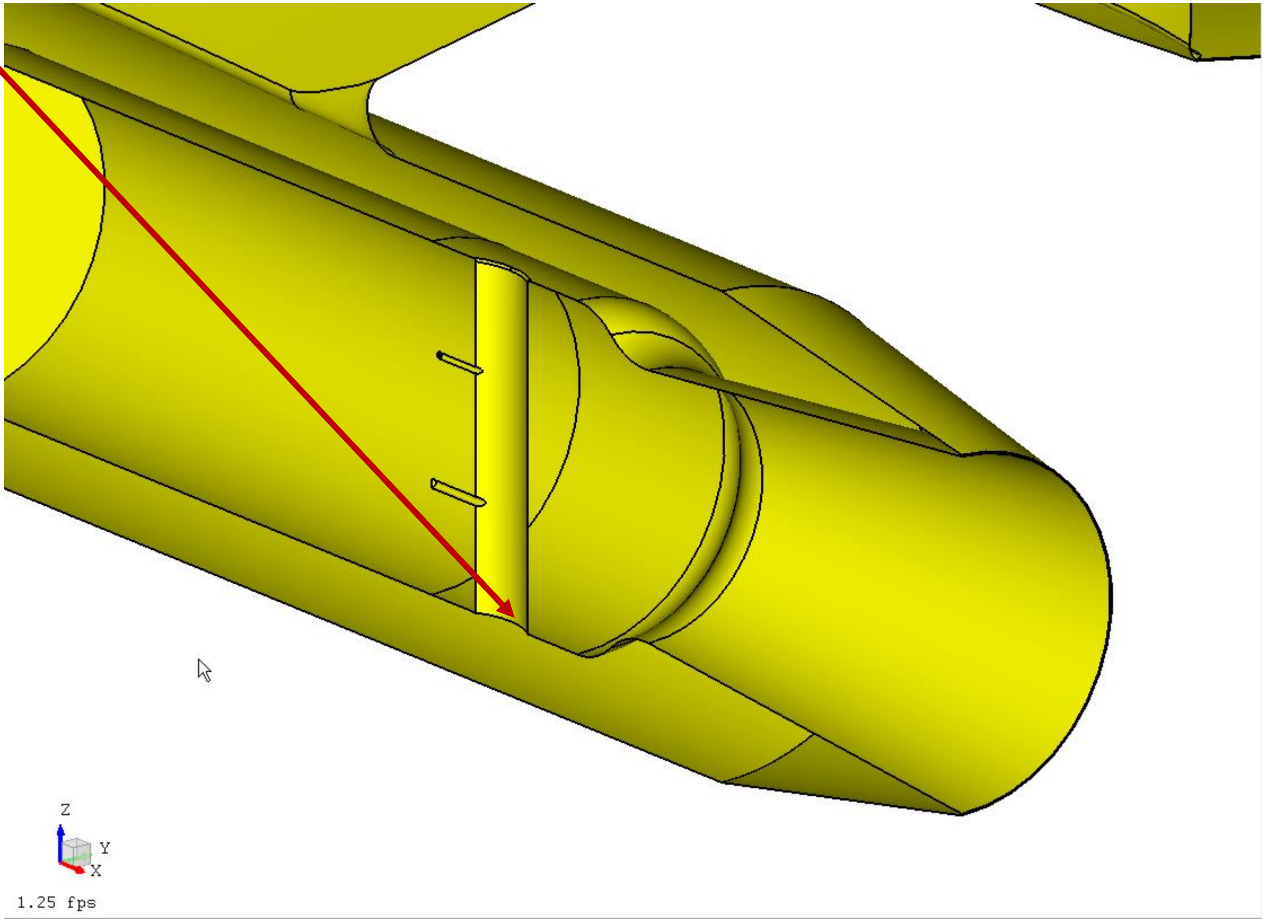
IGES and STEP geometry files along with workshop generated grids provided



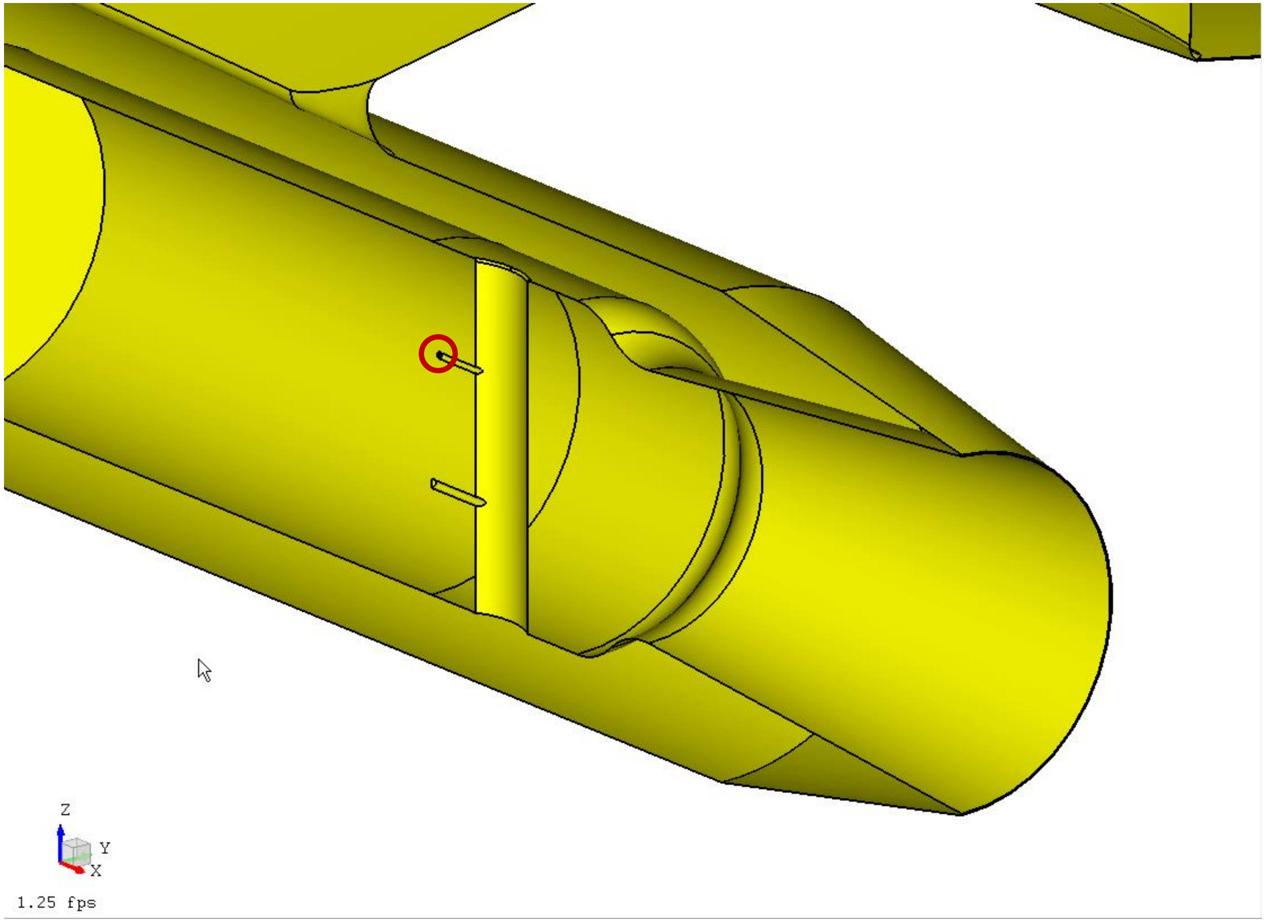
BICONVEX GEOMETRY ASSESSMENT

3.5e-5 inch edge

Mark Gammon (CADfix)



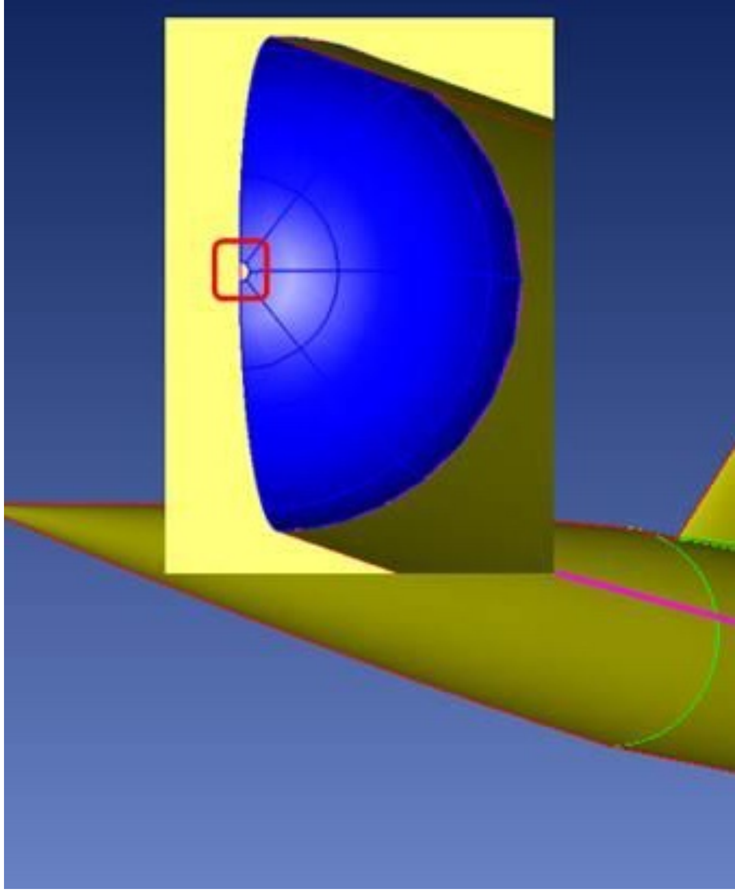
BICONVEX GEOMETRY ASSESSMENT

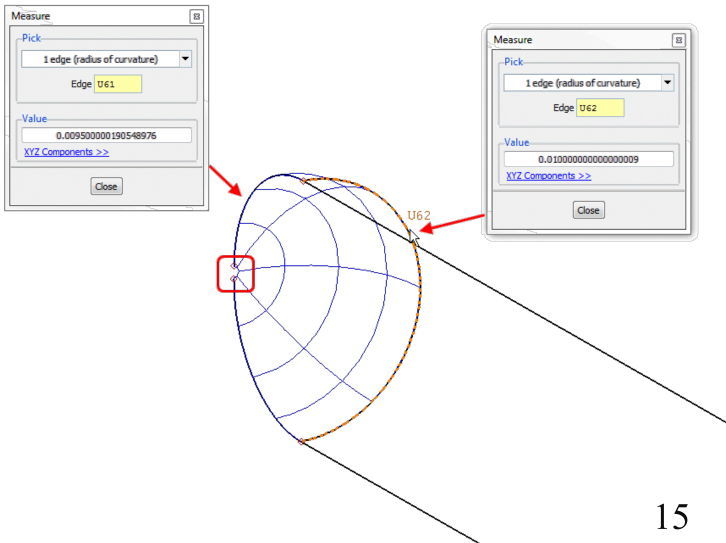


BICONVEX GEOMETRY ASSESSMENT

IGES (from OpenCASCADE) has a spherical cap on cylinder with a slightly smaller radius resulting in a torus surface and a gap at the pole. Face topology is not closed.

STEP (from NX) has closed the loop by merging the vertices but the underlying NURBS curves/surfaces are the same as in IGES



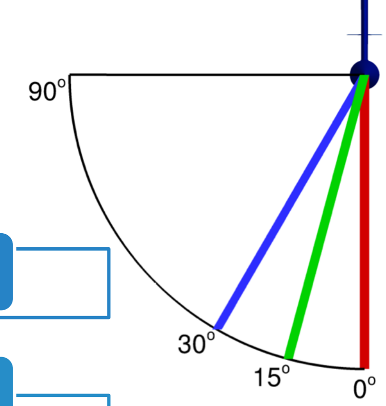


C608 GEOMETRY ASSESSMENT

- Less detailed examination
- Geometry is well-formed, with some inconvenient sliver faces (some curved)
- Both configurations had internal revisions through iterating with Geolab
- Participants are asked to report any geometry issues or modifications required for meshing

BICONVEX INTRODUCTION

SIMULATION CONDITIONS



1.6 Mach

0.0° angle of attack

Geometry and grid provided in correct orientation

22.4-inch-long model

374 Rankine temperature

376,850 Reynolds number per inch

- 8.4 million Reynolds number based on model length

8.0 Engine plenum pressure ratio, P_T/P_∞

1.768 Engine plenum temperature ratio, T_T/T_∞

Data extracted at Z=15.0 inches, at 3 Phi angles

- Phi angles of approx. 0°, 15° and 30°

GRID DETAILS

Tetrahedral Grids

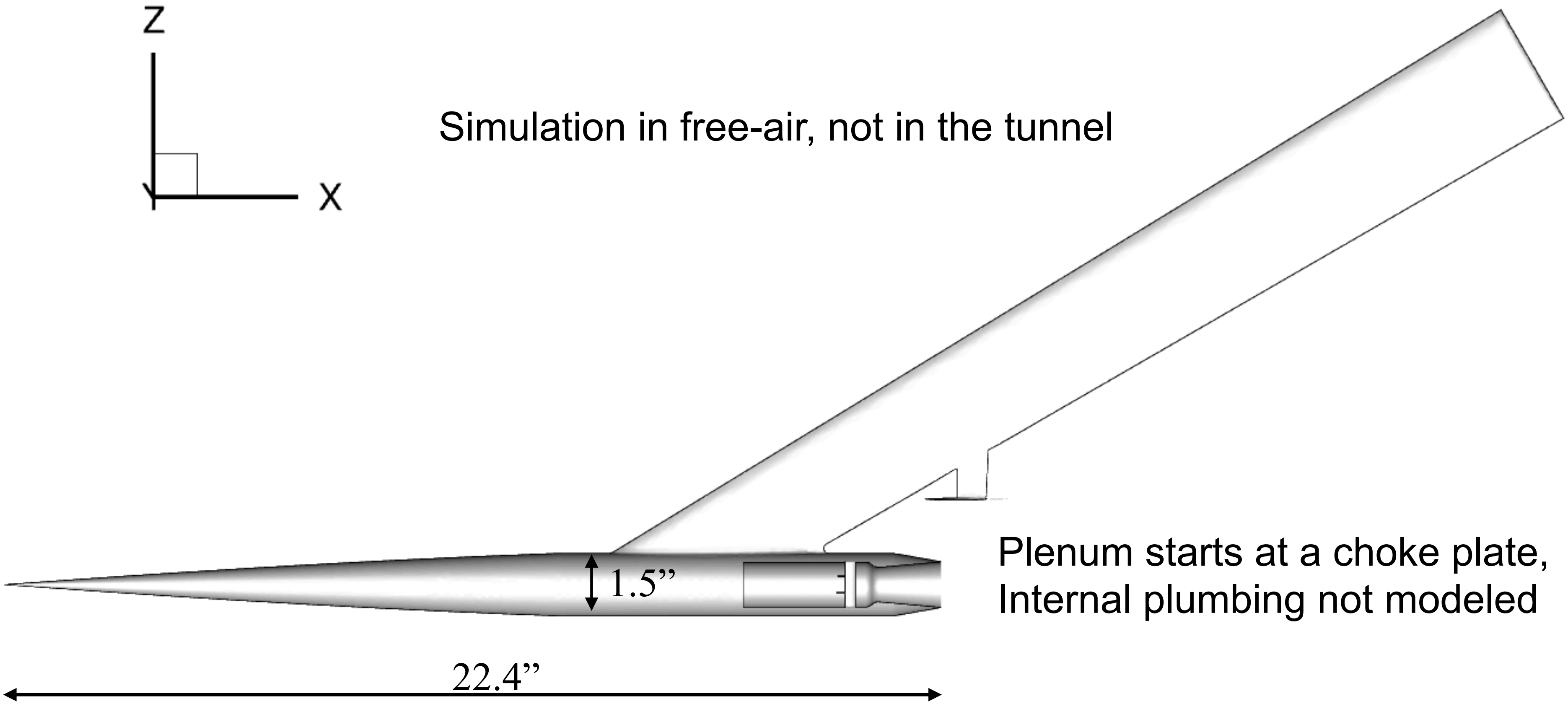
Scale	Nodes	Tetrahedral
1.57	846,227	4,785,786
1.28	1,576,352	8,977,516
1.00	3,286,221	18,815,990

Mixed-Element Grids

Scale	Nodes	Tetrahedral	Prisms
1.57	846,227	2,825,421	650,469
1.28	1,576,352	5,984,989	993,489
1.00	3,286,221	14,627,534	1,388,470

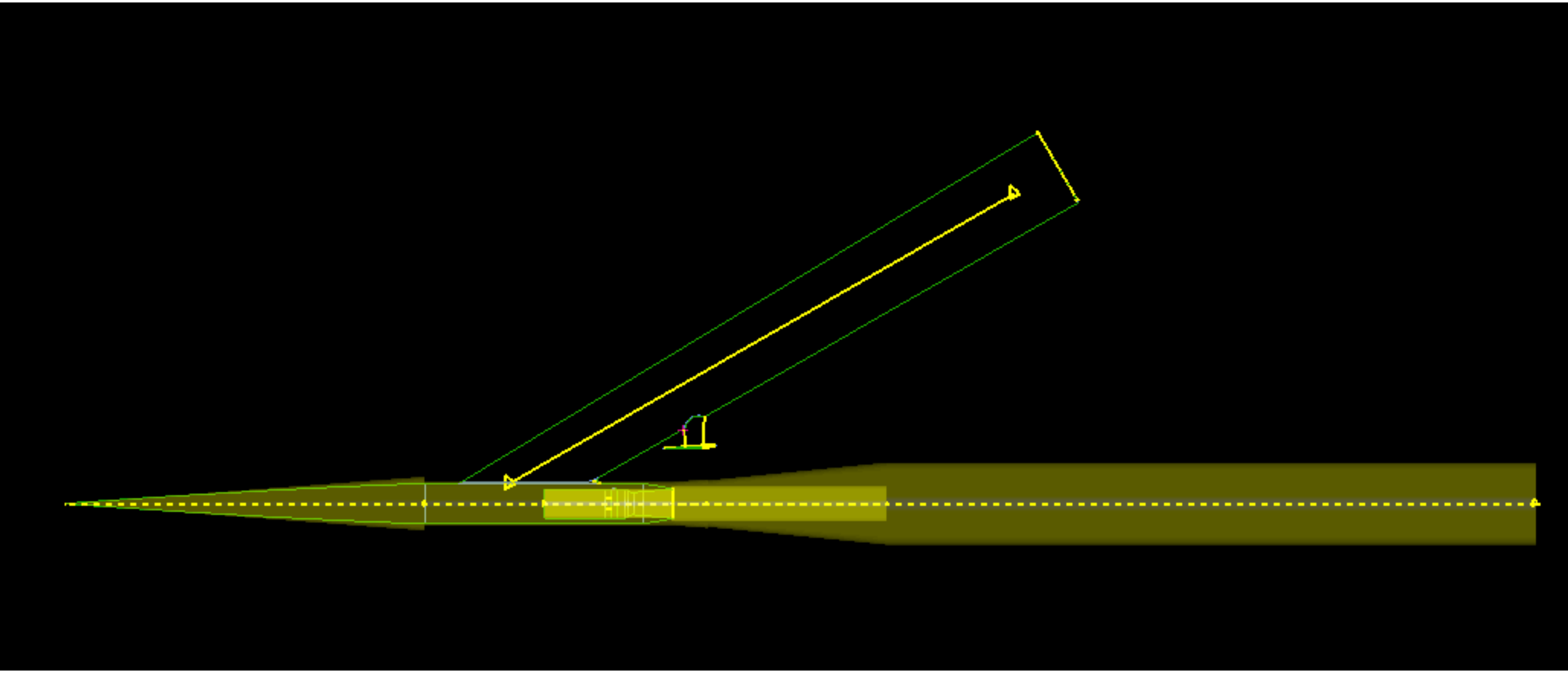
BICONVEX GEOMETRY

Simulation in free-air, not in the tunnel



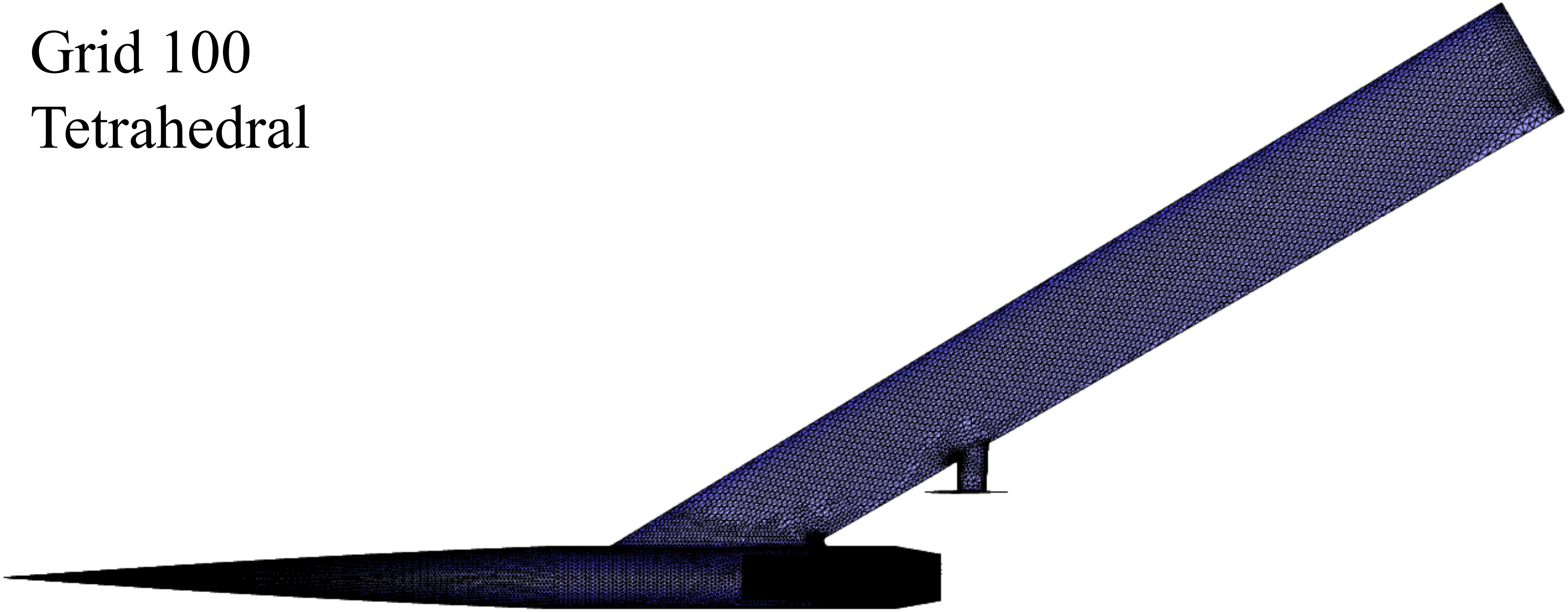
Plenum starts at a choke plate,
Internal plumbing not modeled

BICONVEX SOURCING



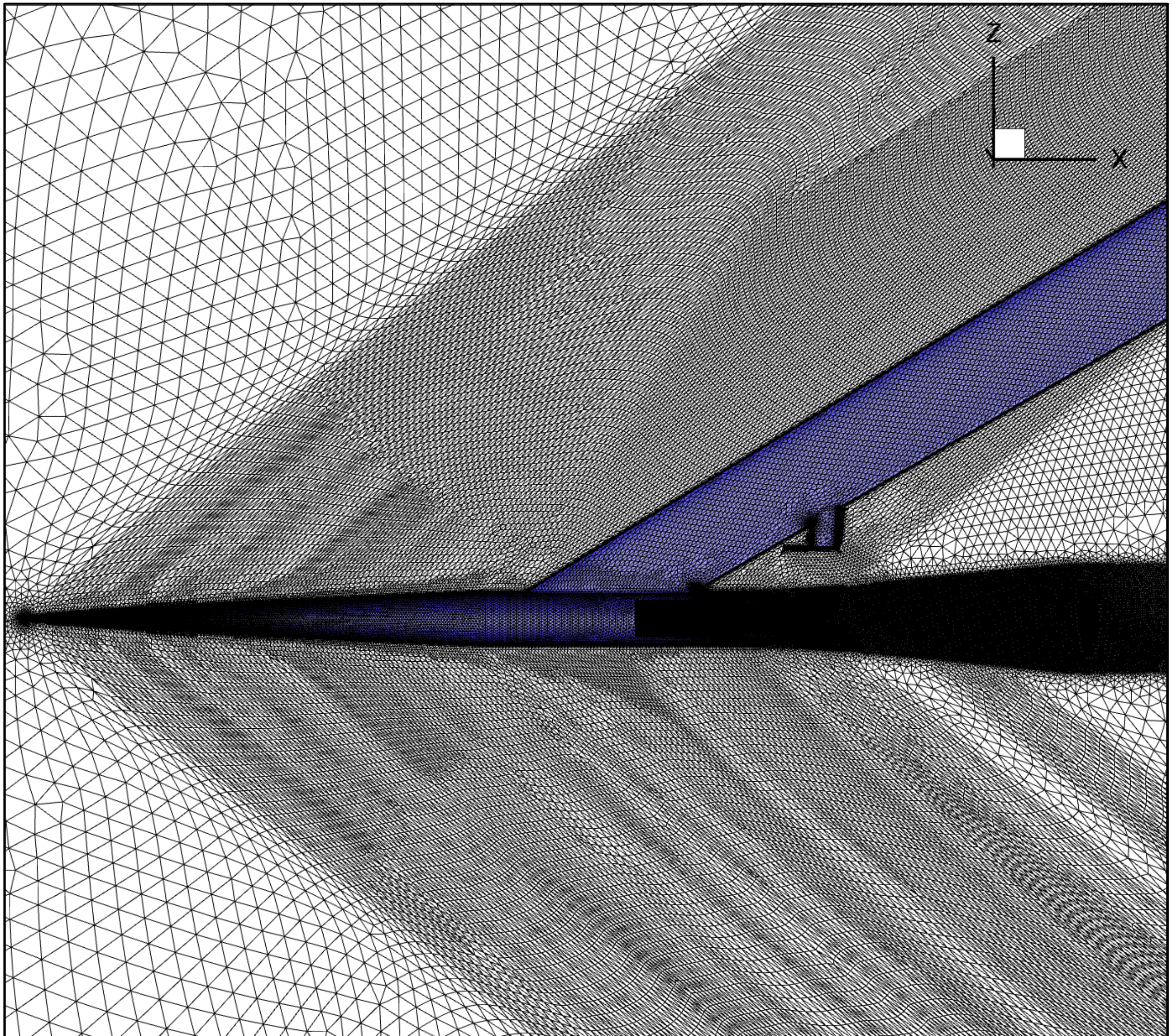
BICONVEX SURFACE GRID

Grid 100
Tetrahedral



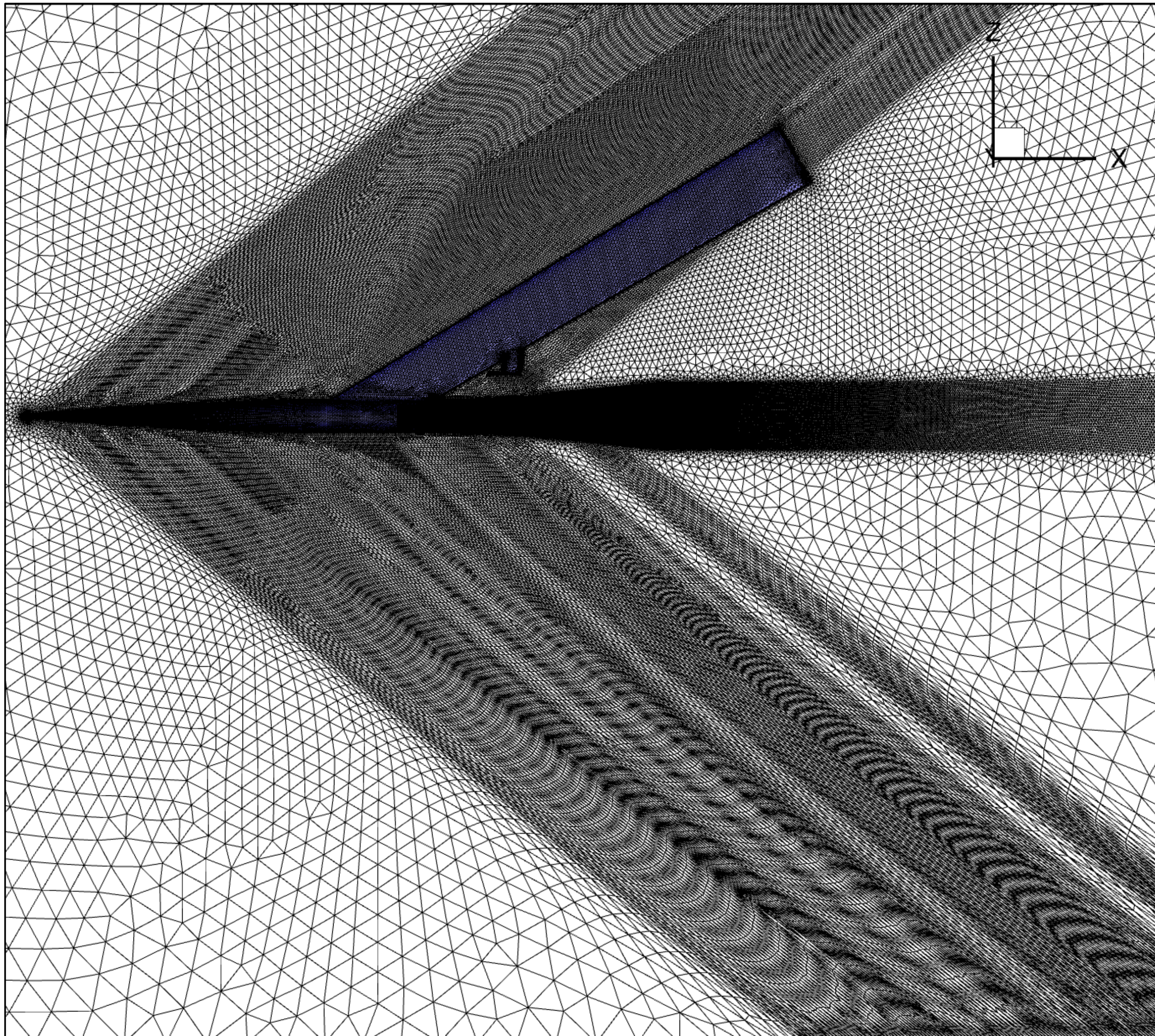
BICONVEX SYMMETRY PLANE GRID

Grid 100
Tetrahedral
Prescribed

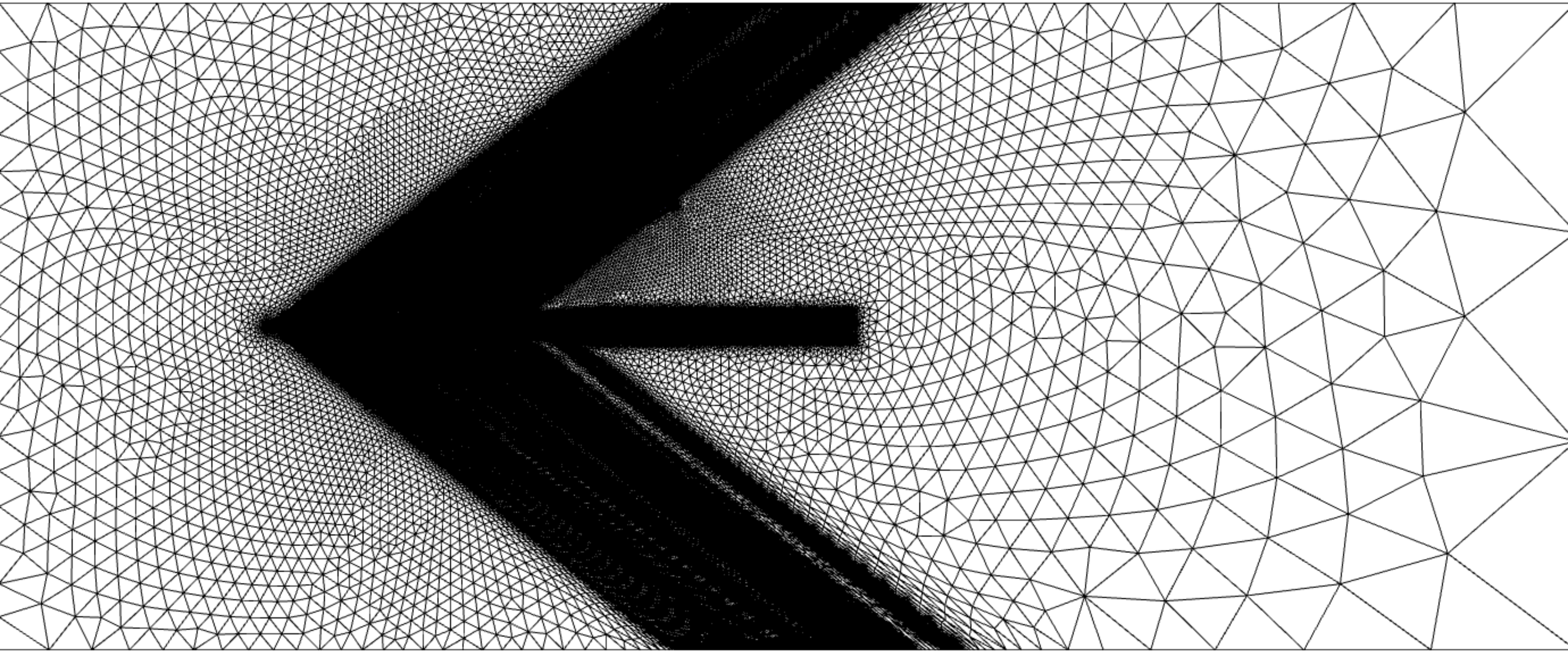


BICONVEX SYMMETRY PLANE GRID

Grid 100
Tetrahedral
Prescribed



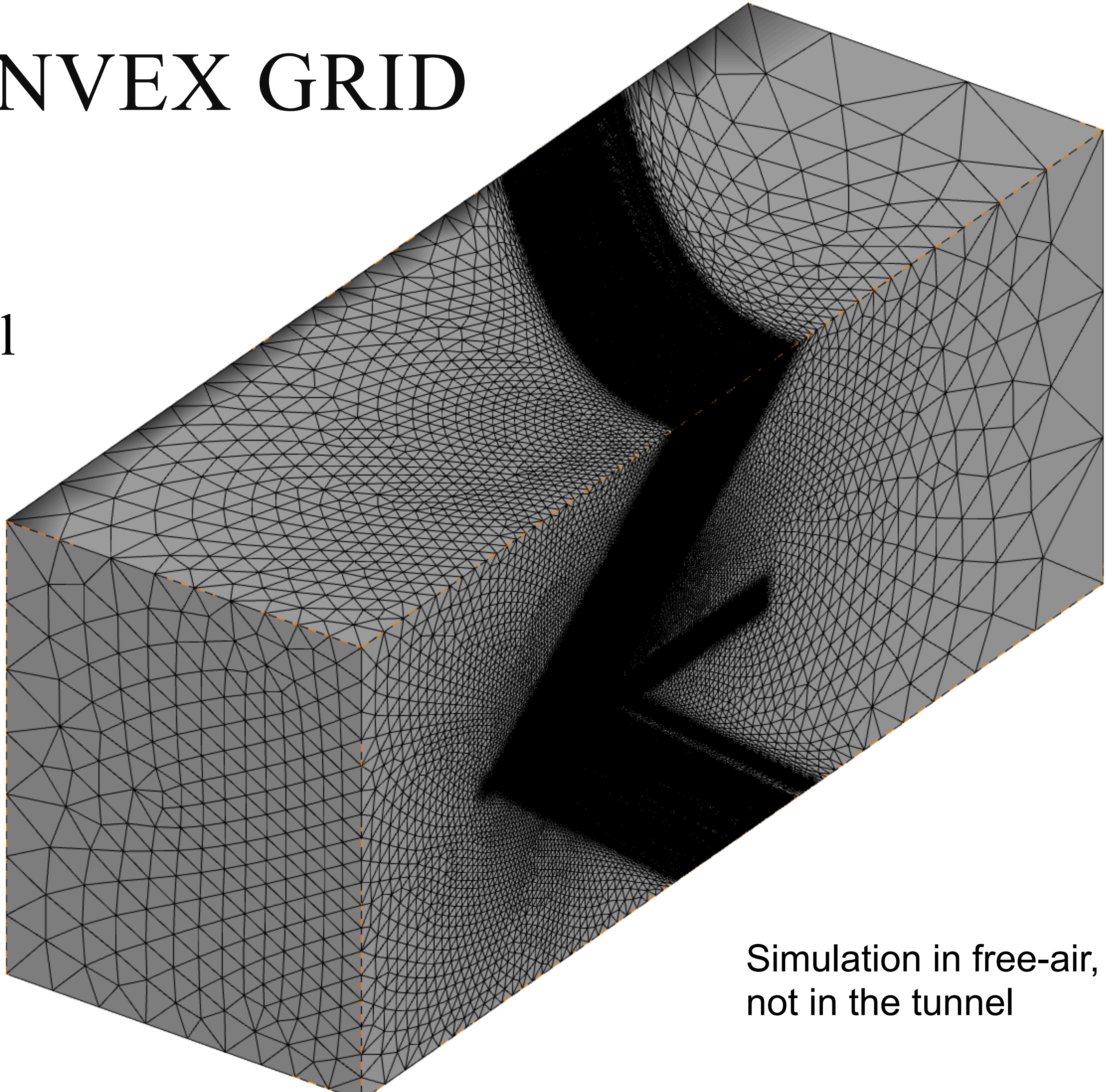
BICONVEX SYMMETRY PLANE GRID



Grid 100
Tetrahedral
Prescribed

BICONVEX GRID

Grid 100
Tetrahedral
Prescribed



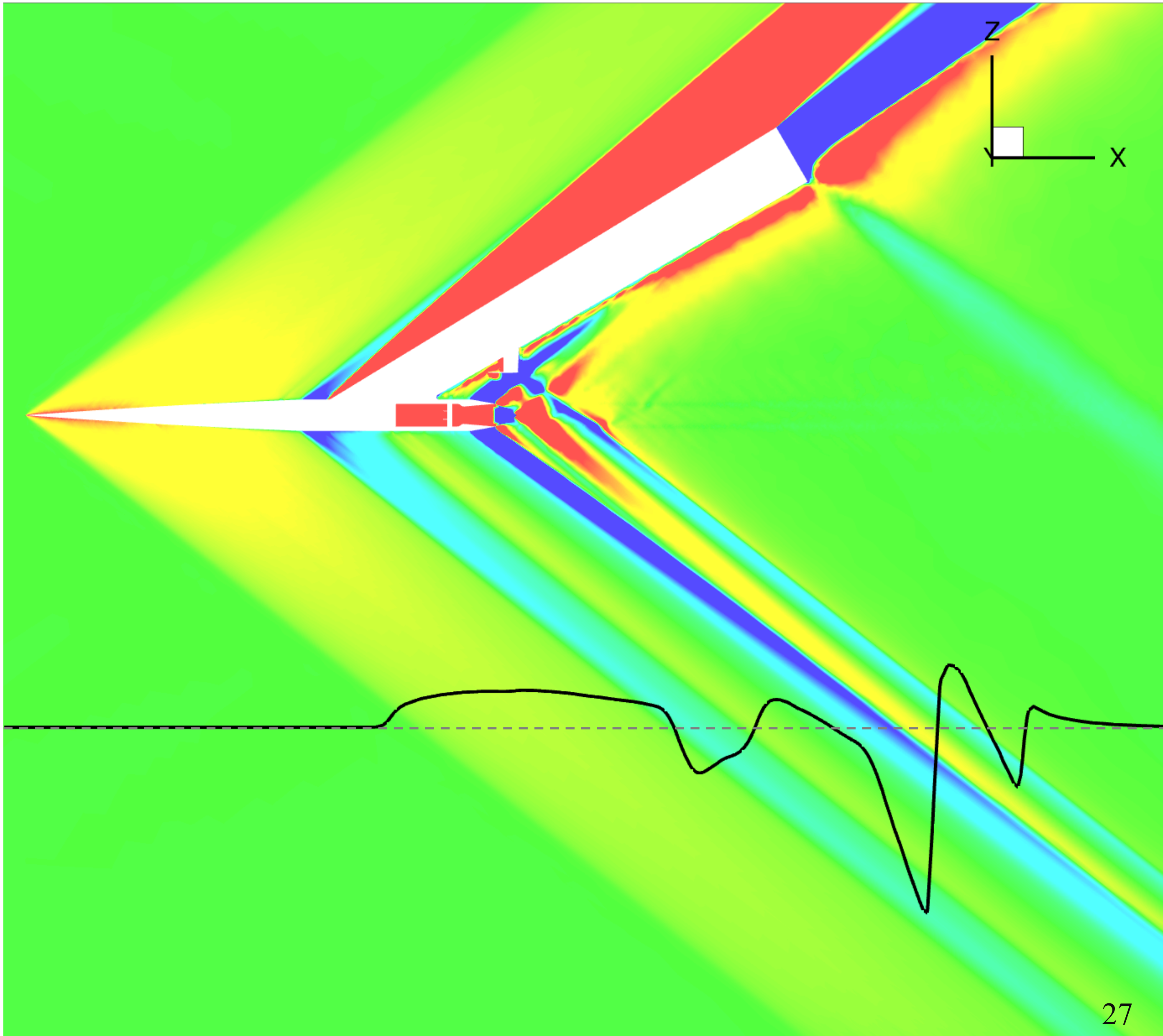
Simulation in free-air,
not in the tunnel

BICONVEX dp/p_{INF}

Grid 100
Tetrahedral

USM3D
Production
code

dp/p_{∞} which is the pressure disturbance normalized by freestream pressure

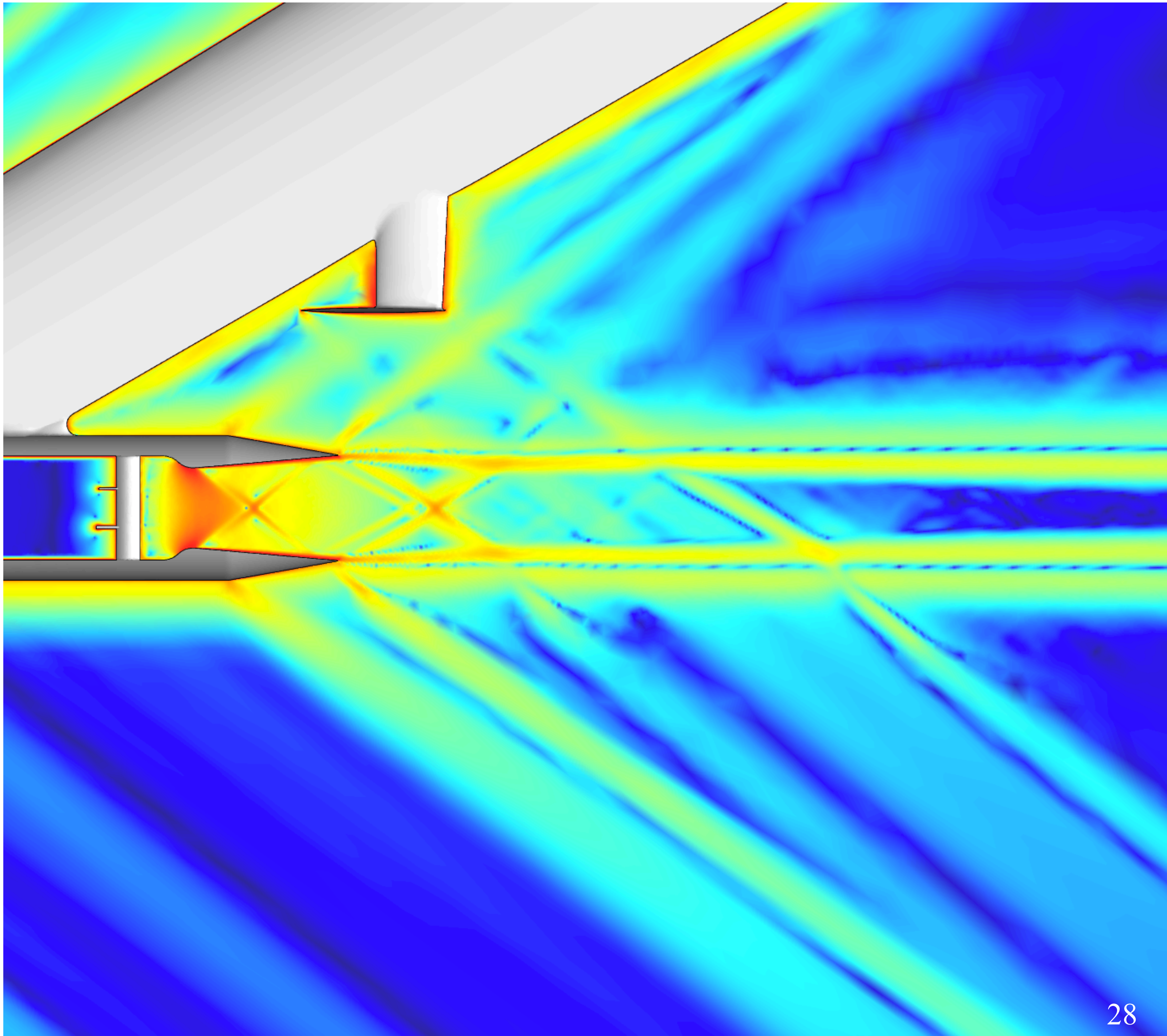


BICONVEX DENSITY GRADIENT

Grid 100
Tetrahedral

USM3D
Production
code

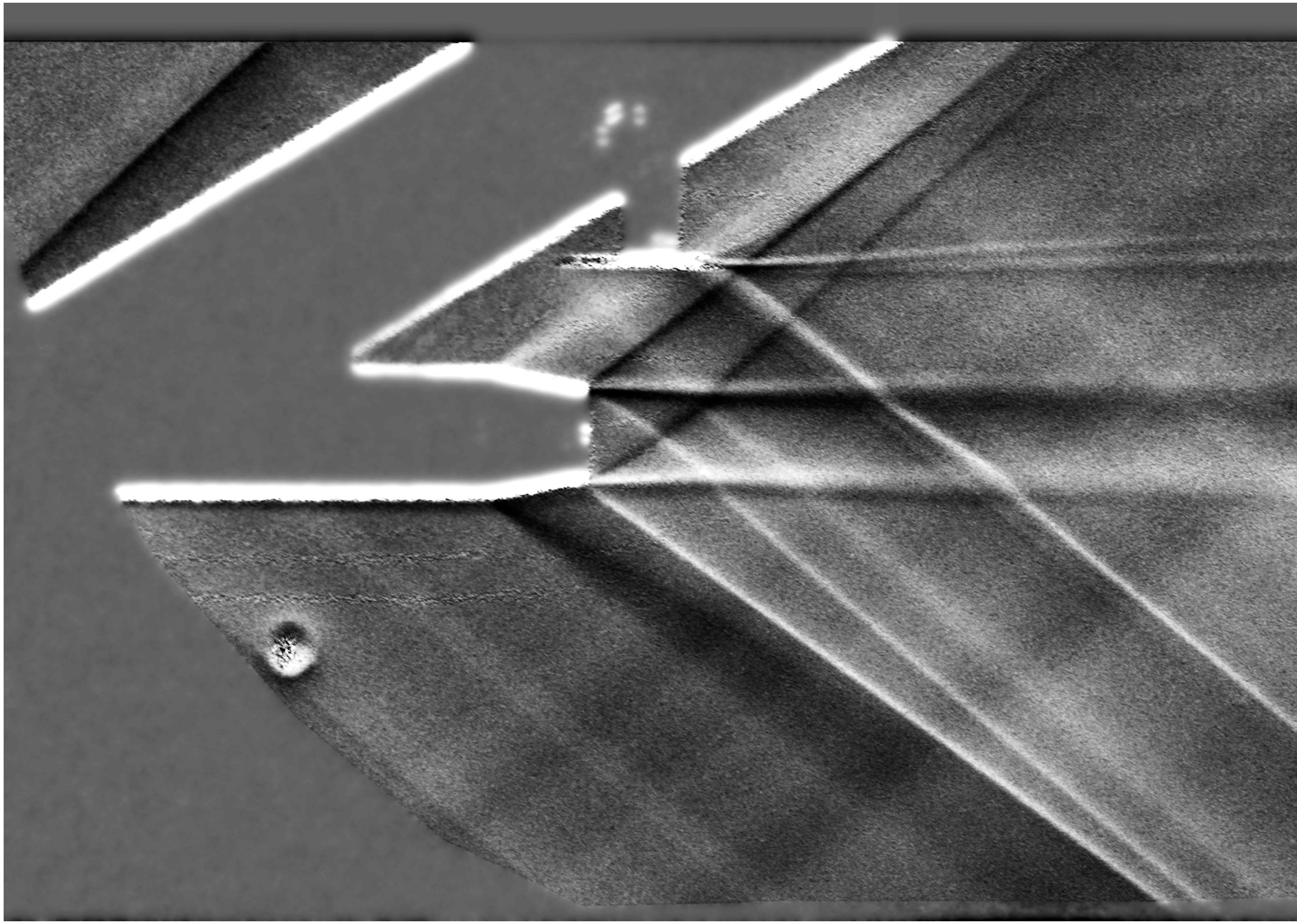
Density
gradient
(numerical
schlieren)



BICONVEX RETROREFLECTIVE BACKGROUND ORIENTED SCHLIEREN (RBOS)

Ames 9’ x 7’ Wind Tunnel RBOS data

Contrast was increased from original photo



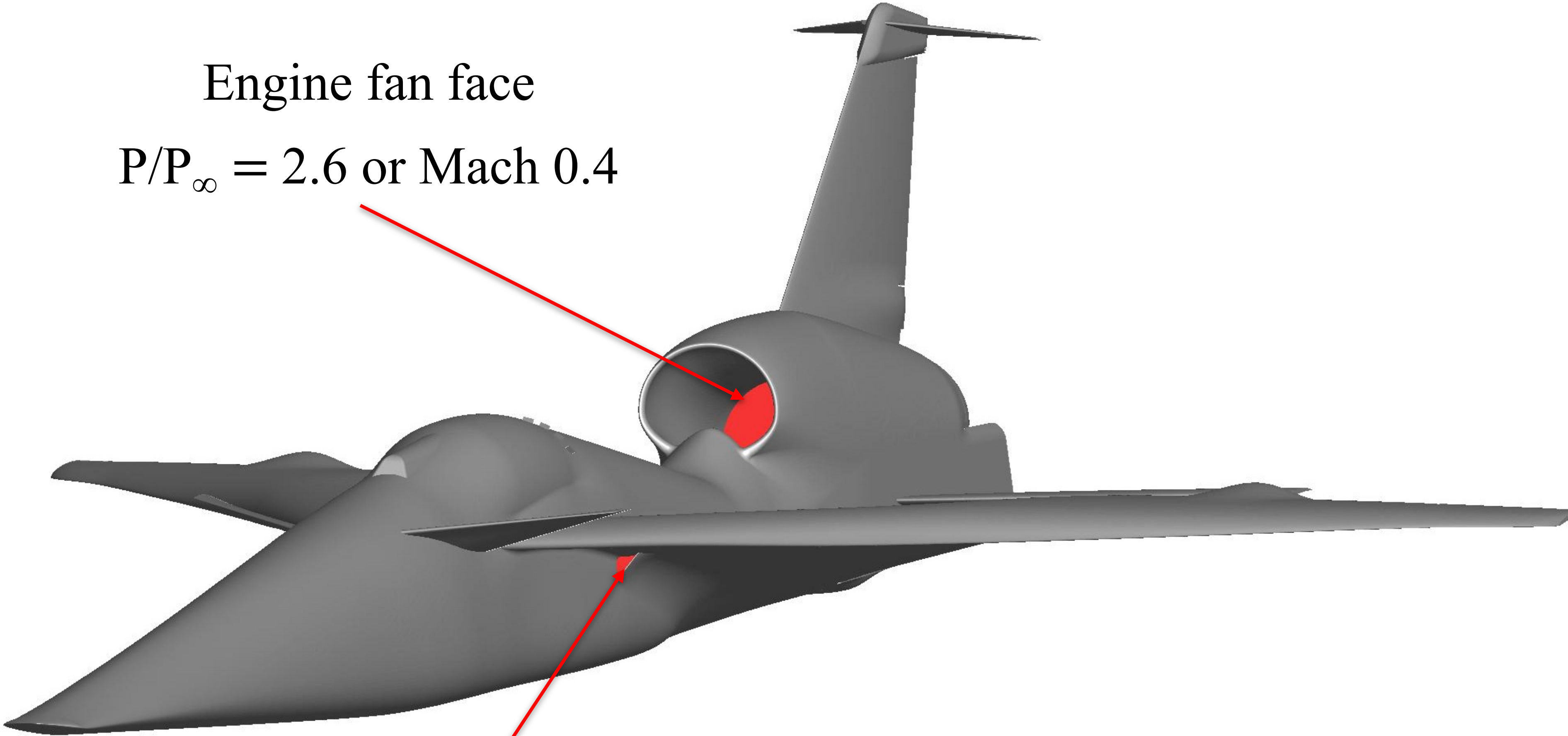
C608, AN EARLY X-59 PROTOTYPE, INTRODUCTION

SIMULATION CONDITIONS

- 1.4 Mach
- 0.0° angle of attack
  - Geometry and grid provided in correct orientation
- 1,080 inch-model length
- 389.9 Rankine temperature
- 109,776 Reynolds number per inch
  - 118.5 million Reynolds number based on model length
- 10.0 Engine plenum pressure ratio, P_T/P_∞
- 7.0 Engine plenum temperature ratio, T_T/T_∞
- 2.6 pressure ratio, P/P_∞ at engine fan face
  - Alternate: 0.40 Mach number at engine fan face
- 1.4 pressure ratio, P/P_∞ at ECS inlet face
  - Alternate: 0.35 Mach number at ECS inlet face
- 2.4 Bypass pressure ratio, P_T/P_∞
- 2.0 Bypass temperature ratio, T_T/T_∞
- Data extracted at 3 body lengths below the model
  - Phi from 0°-180°, 2° increments

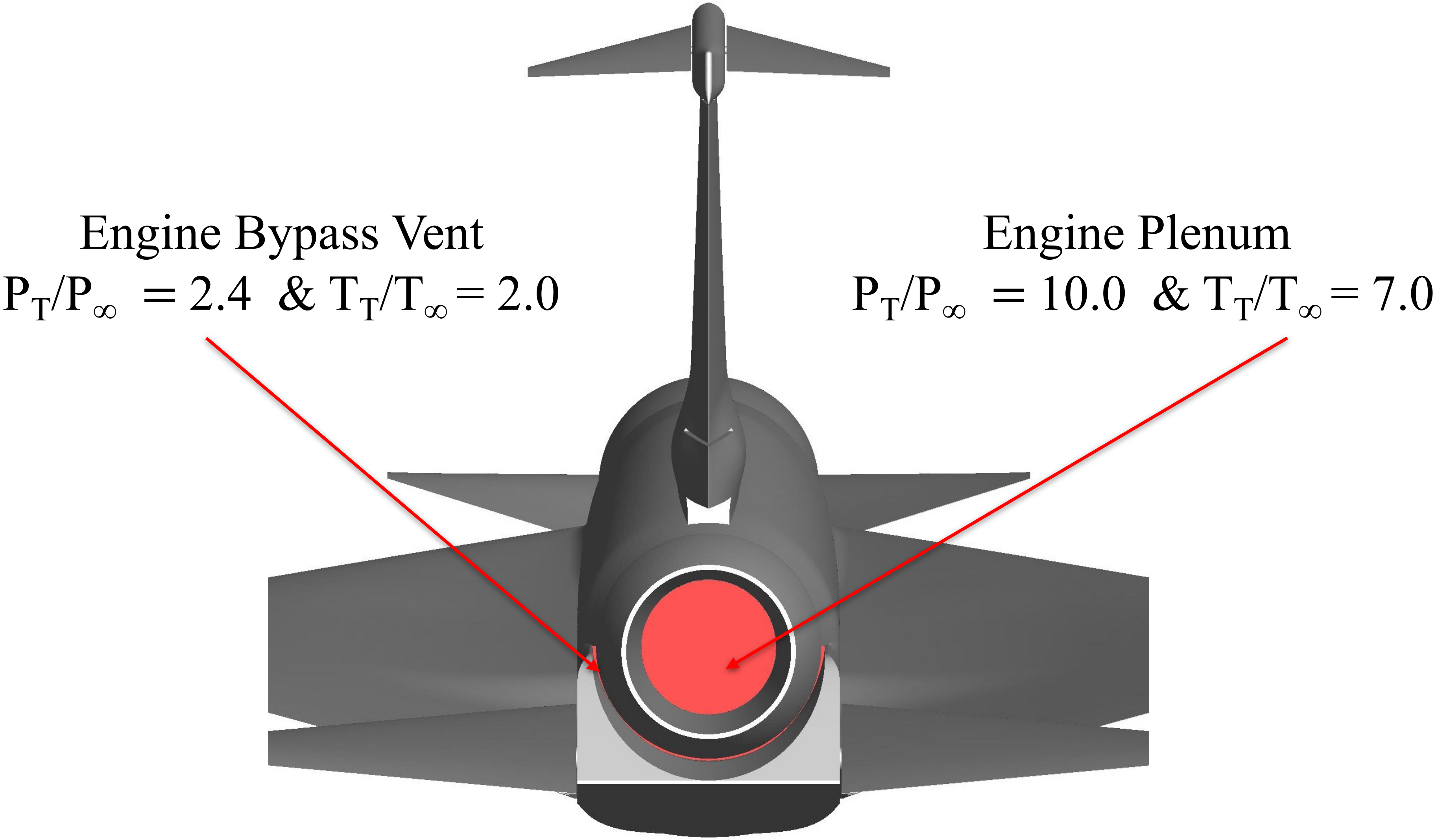
Engine fan face

$P/P_{\infty} = 2.6$ or Mach 0.4



Environmental Control System (ECS) Intake face

$P/P_{\infty} = 1.4$ or Mach 0.35


Engine Bypass Vent
$P_T/P_\infty = 2.4$ & $T_T/T_\infty = 2.0$
Engine Plenum
$P_T/P_\infty = 10.0$ & $T_T/T_\infty = 7.0$

GRID DETAILS

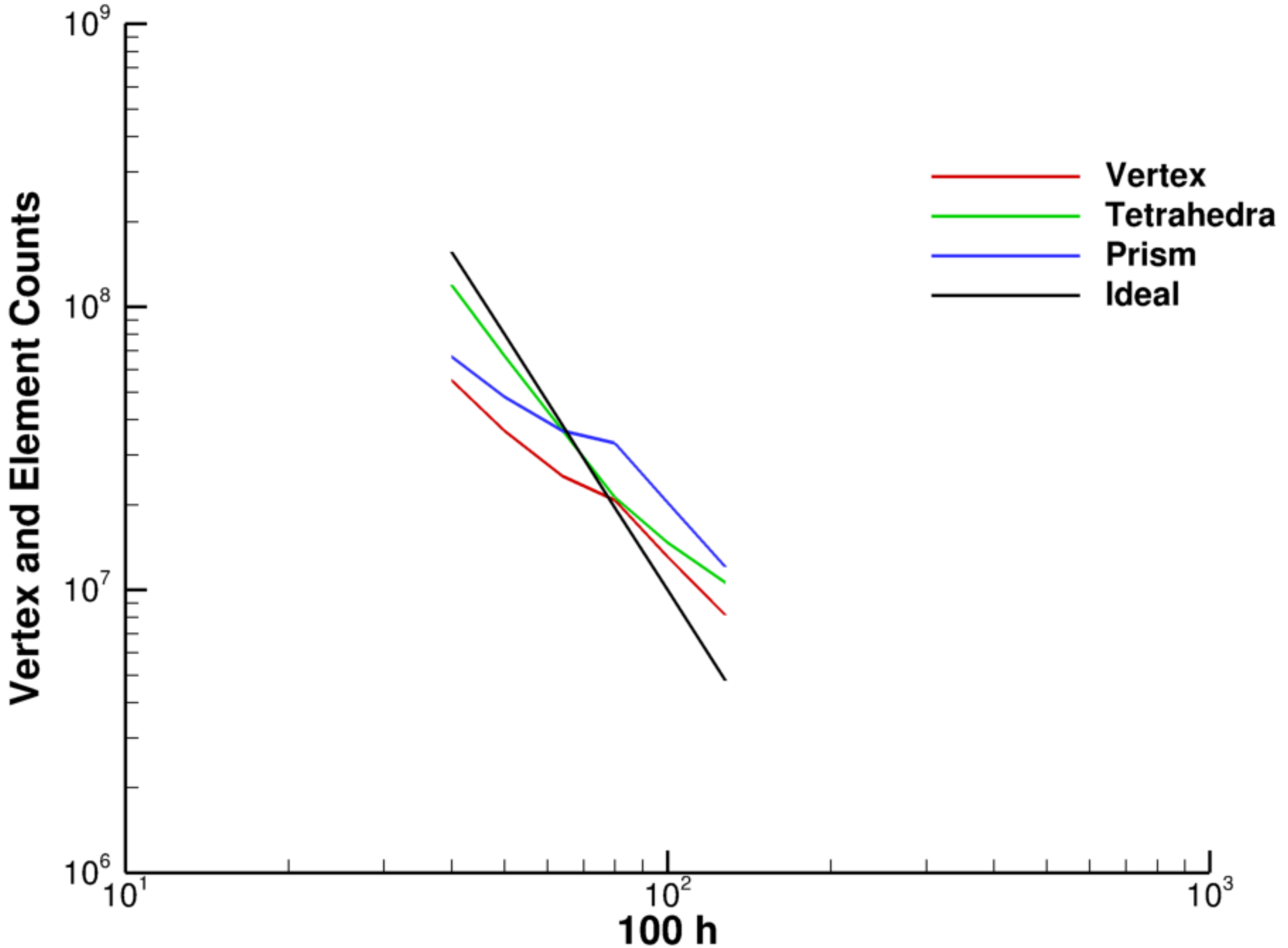
Tetrahedral Grids

Scale	Nodes	Tetrahedral
0.40	162,970,101	964,796,522
0.50	89,458,689	527,864,565
0.64	50,215,130	295,275,952
0.80	34,879,443	204,705,976
1.00	20,701,451	121,014,955
1.28	11,782,783	68,486,582

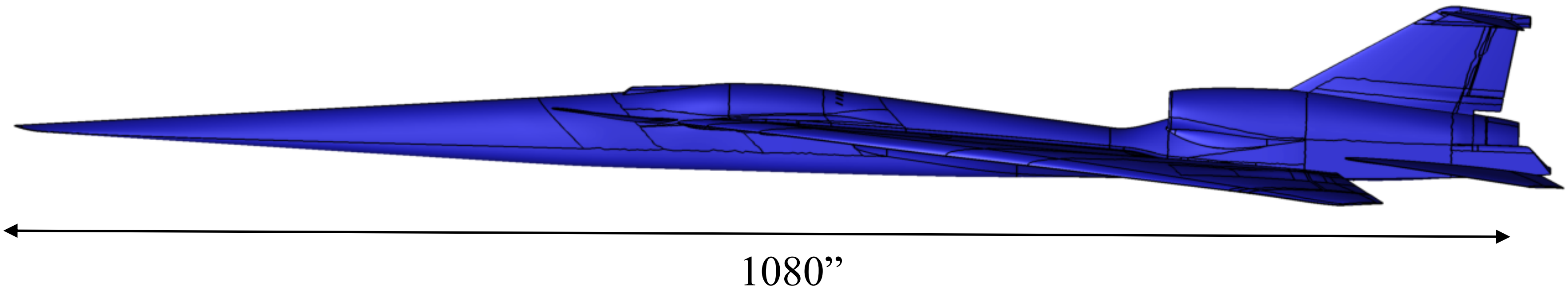
Mixed-Element Grids

Scale	Nodes	Tetrahedral	Prisms
0.40	162,970,101	119,456,686	281,557,286
0.50	89,458,689	67,138,507	153,392,736
0.64	50,215,130	36,567,810	86,083,502
0.80	34,879,443	21,266,609	61,007,871
1.00	20,701,451	14,681,692	35,346,643
1.28	11,782,783	10,599,974	19,224,816

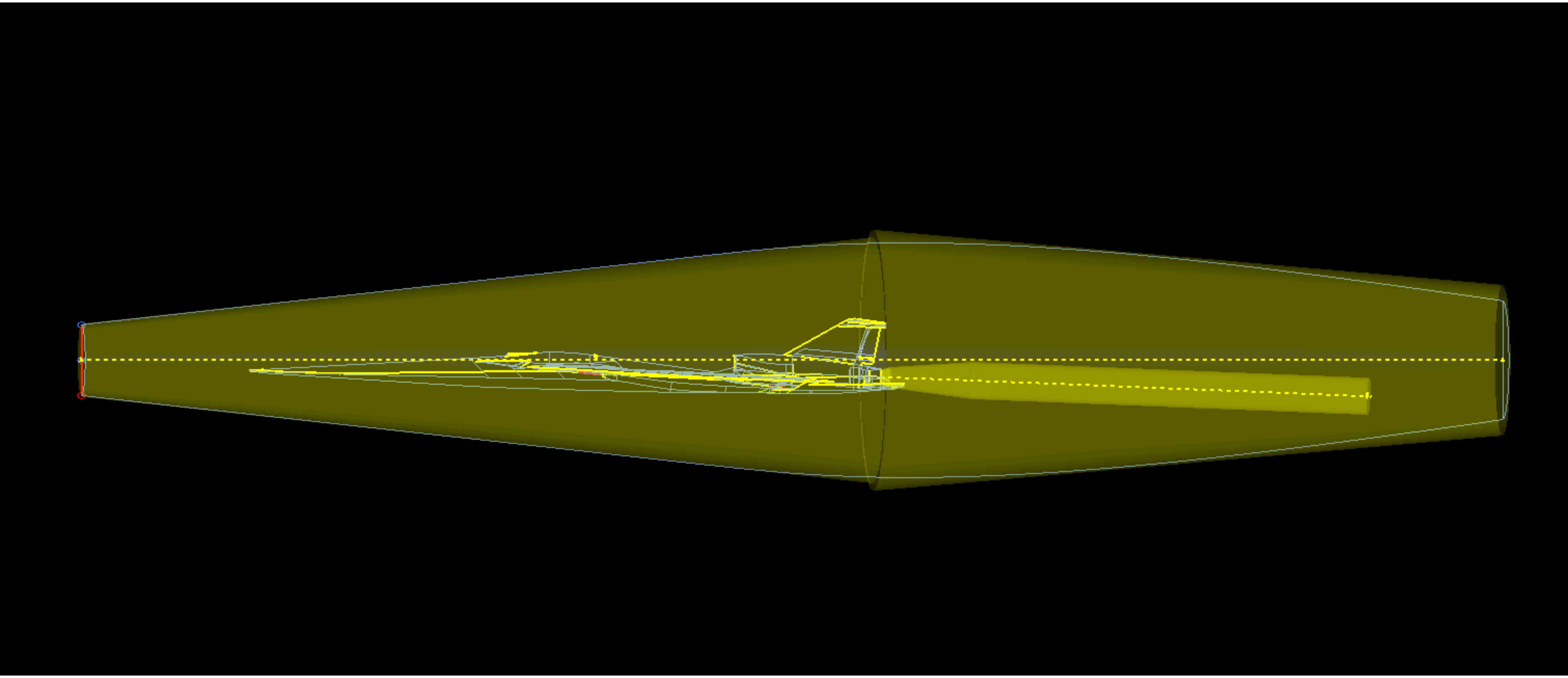
ELEMENT COUNT



C608 GEOMETRY



C608 SOURCING

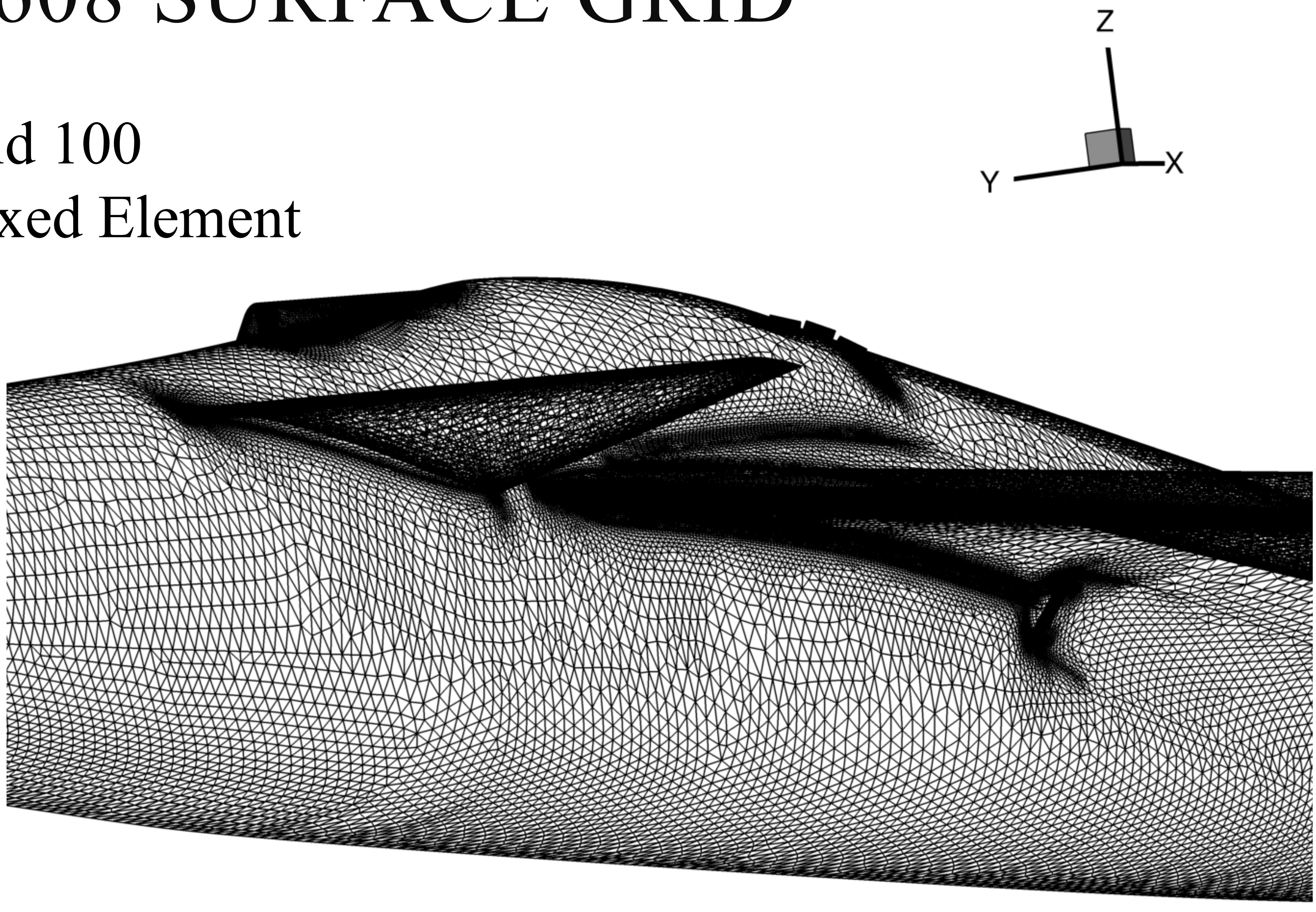


C608 SURFACE GRID

Grid 100
Mixed Element

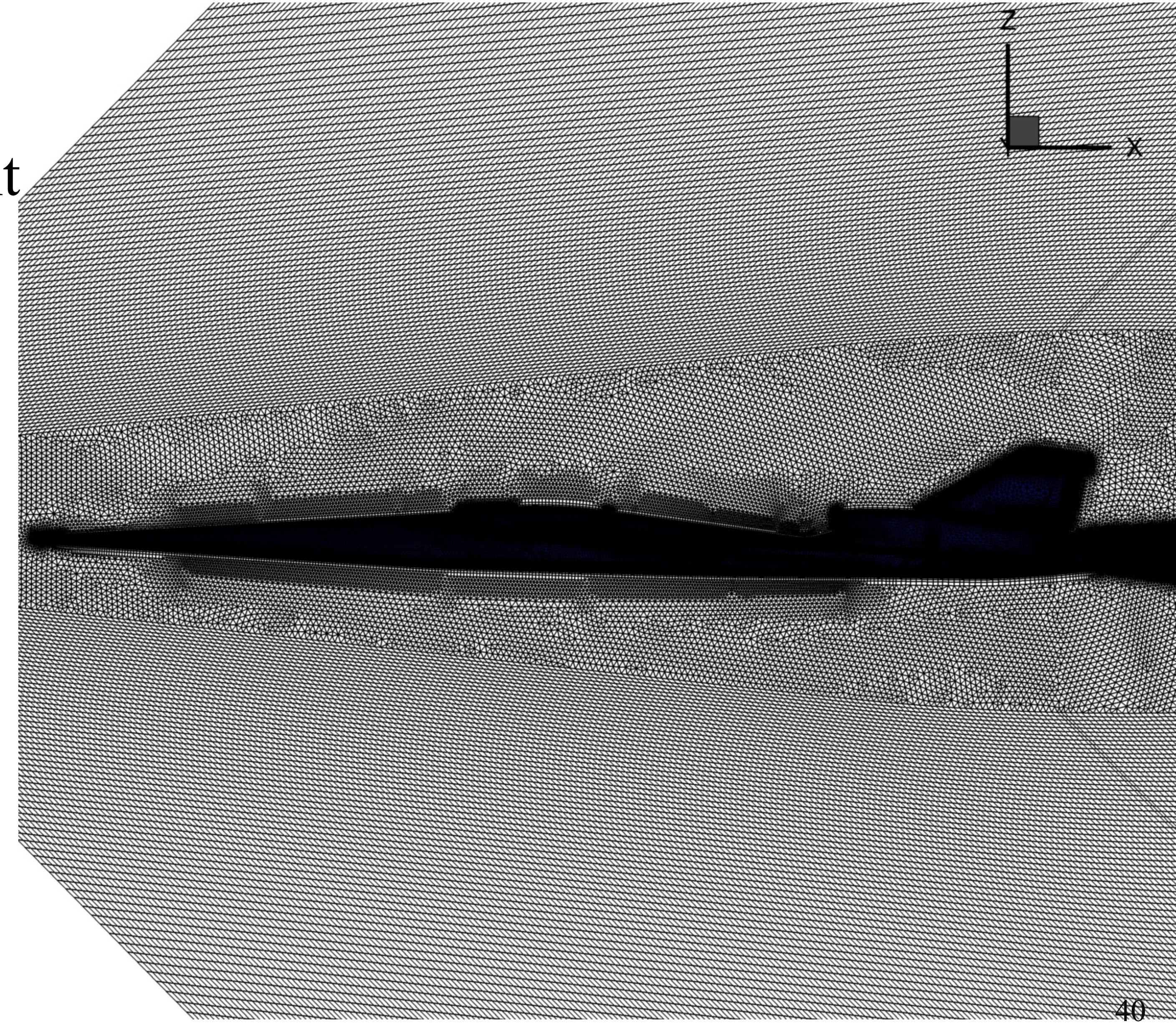
C608 SURFACE GRID

Grid 100
Mixed Element



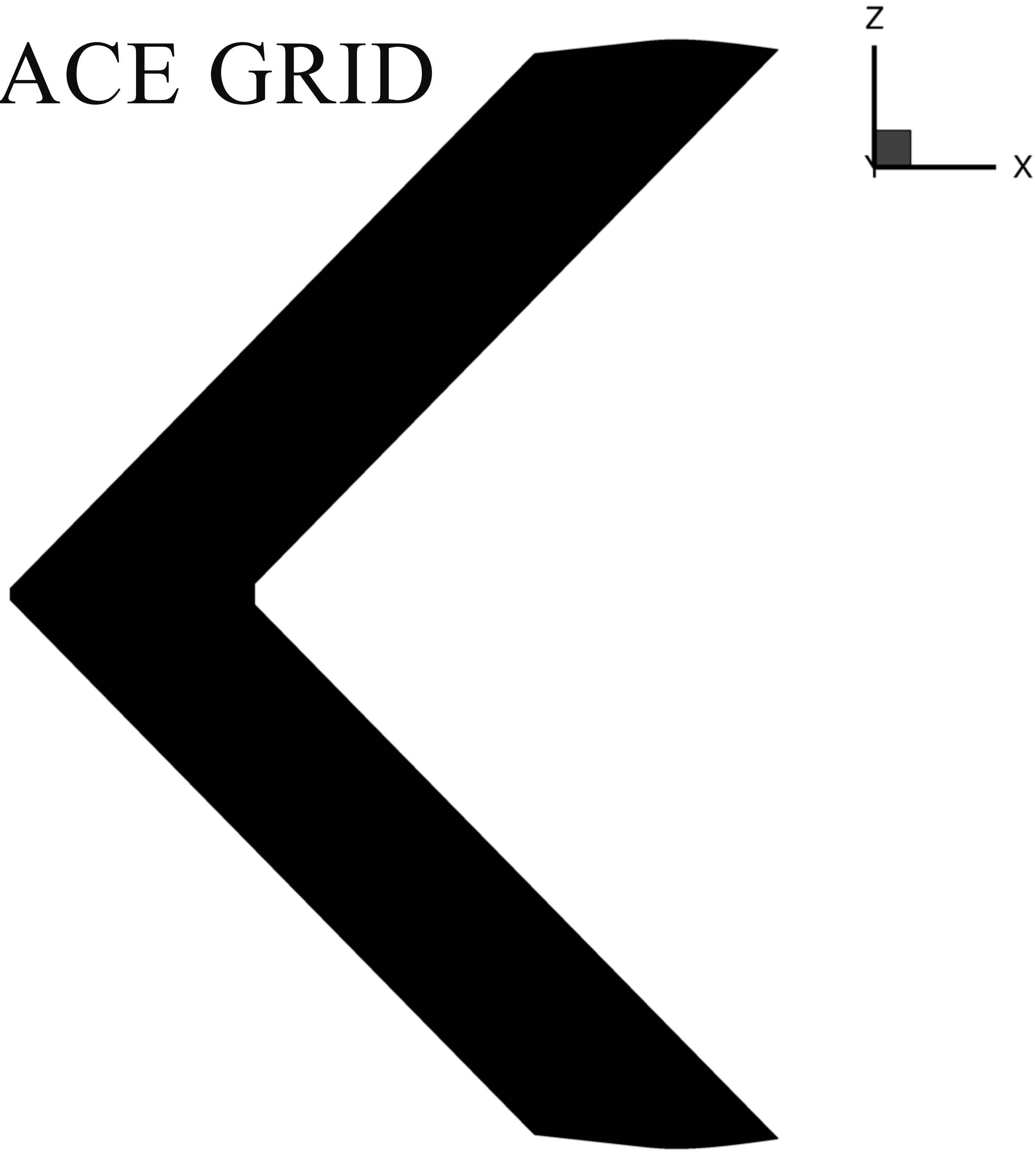
C608 SURFACE GRID

Grid 100
Mixed Element



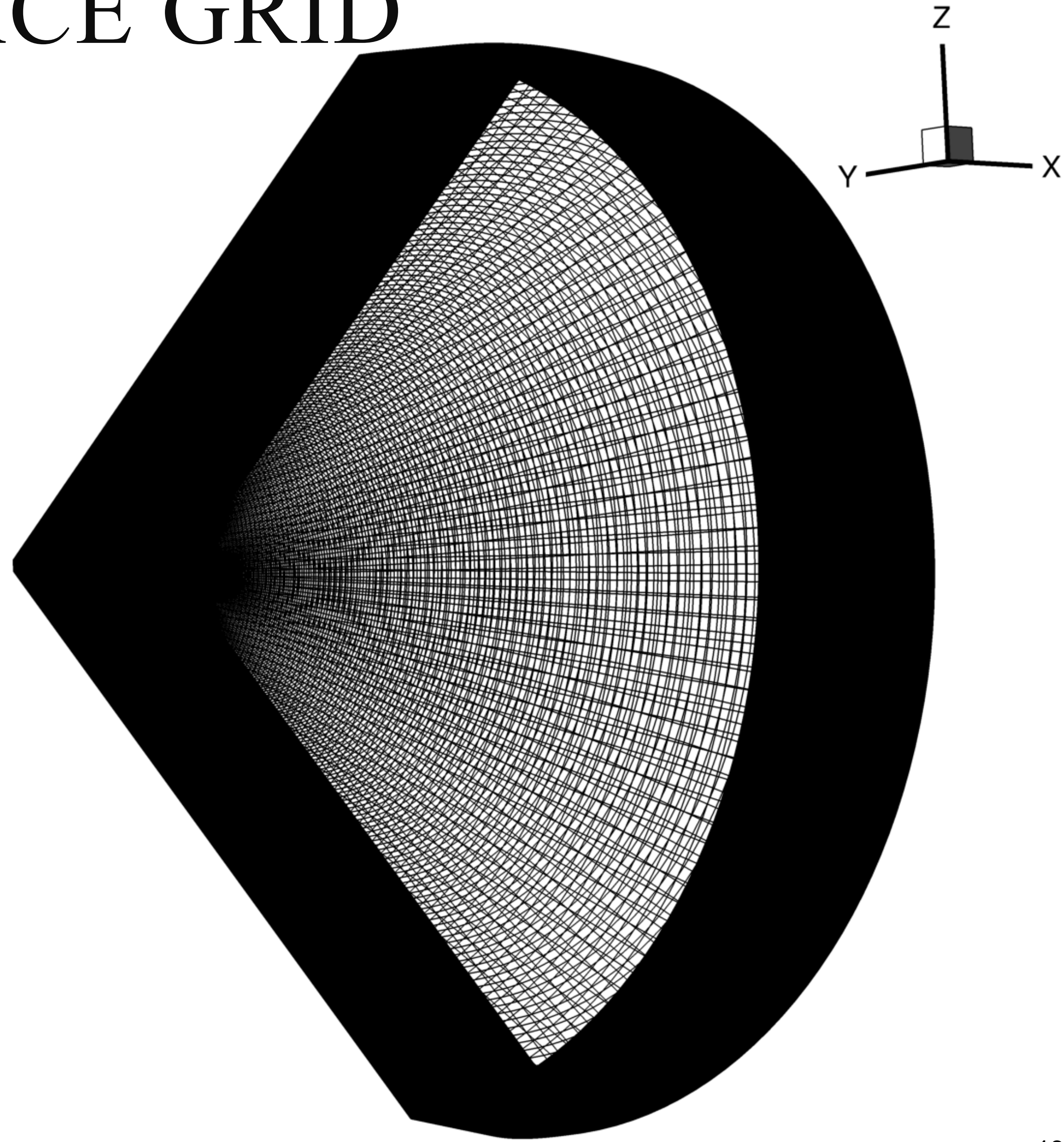
C608 SURFACE GRID

Grid 100
Mixed Element



C608 SURFACE GRID

Grid 100
Mixed Element

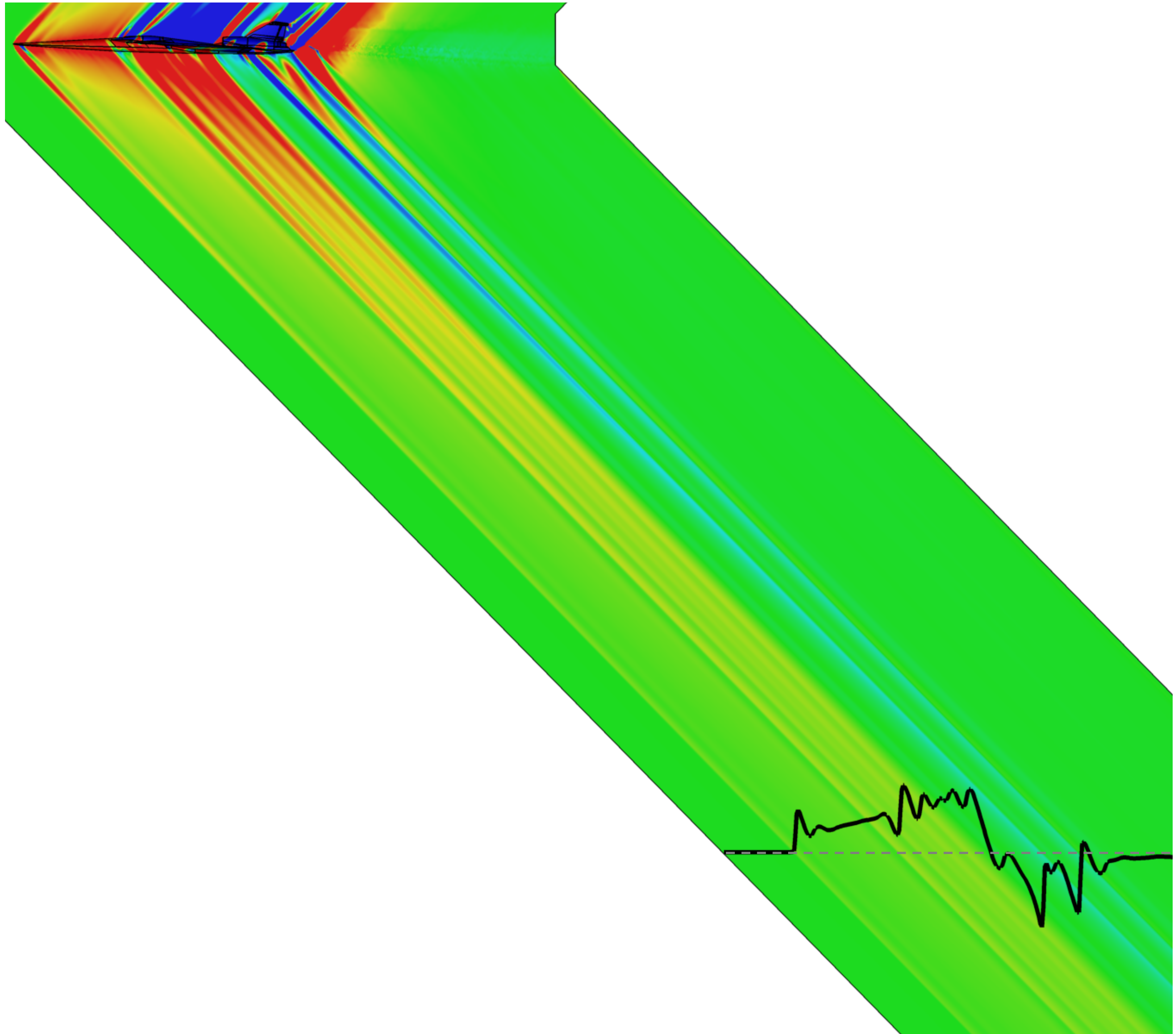


C608 dP/P_{INF}

Grid 100
Tetrahedral

FUN3D

dp/p_∞

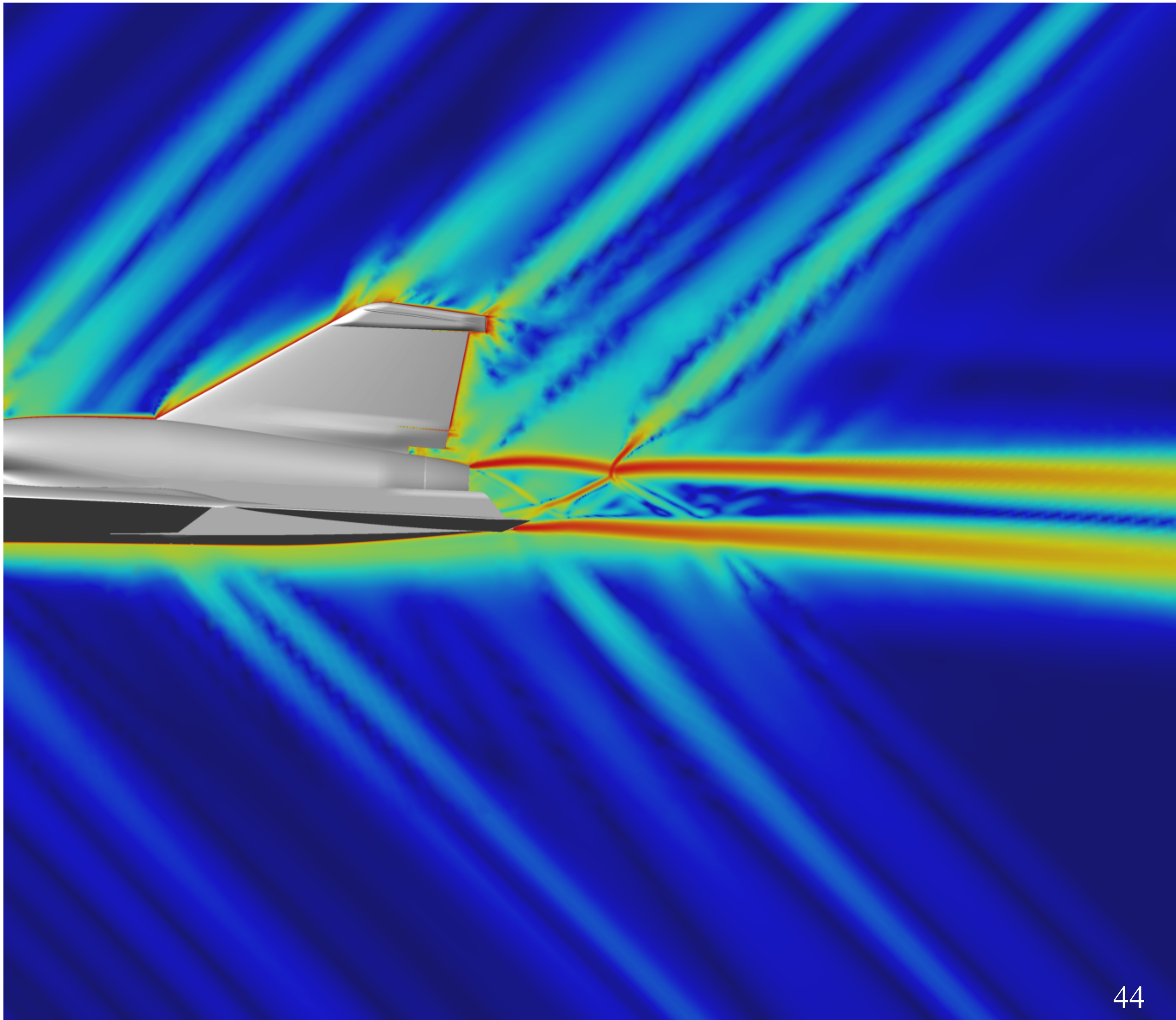


C608 DENSITY GRADIENT

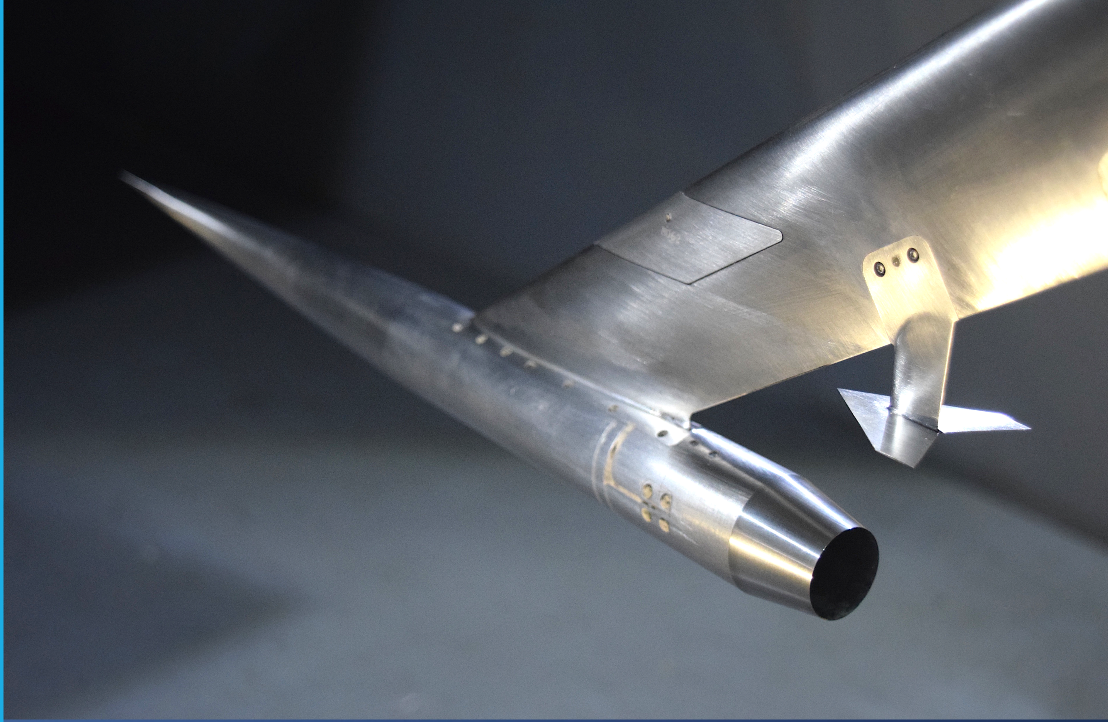
Grid 100
Tetrahedral

FUN3D

Density gradient (numerical schlieren)



SUBMISSIONS AND ANALYSIS

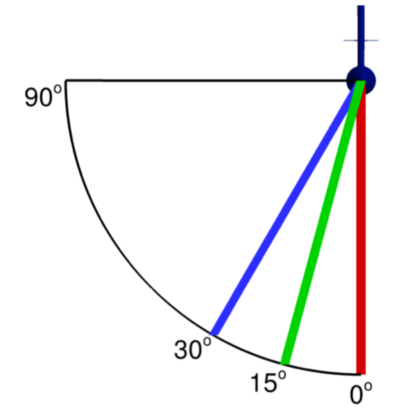


EXTRACT SIGNATURES FROM VOLUME

Tecplot macro was provided

Biconvex

- Data taken to match experiment
- 3 cuts, at roughly 15-inch radius at different off-track angles (Phi)
  - Z = -15.108 inches at Phi = 0.26°
  - Z = -14.496 inches at Phi = 15.12°
  - Z = -13.070 inches at Phi = 30.15°



C608

- 3 body lengths, L = 3,240 inches
- 0° – 180° in 2° increments to obtain off-track angles

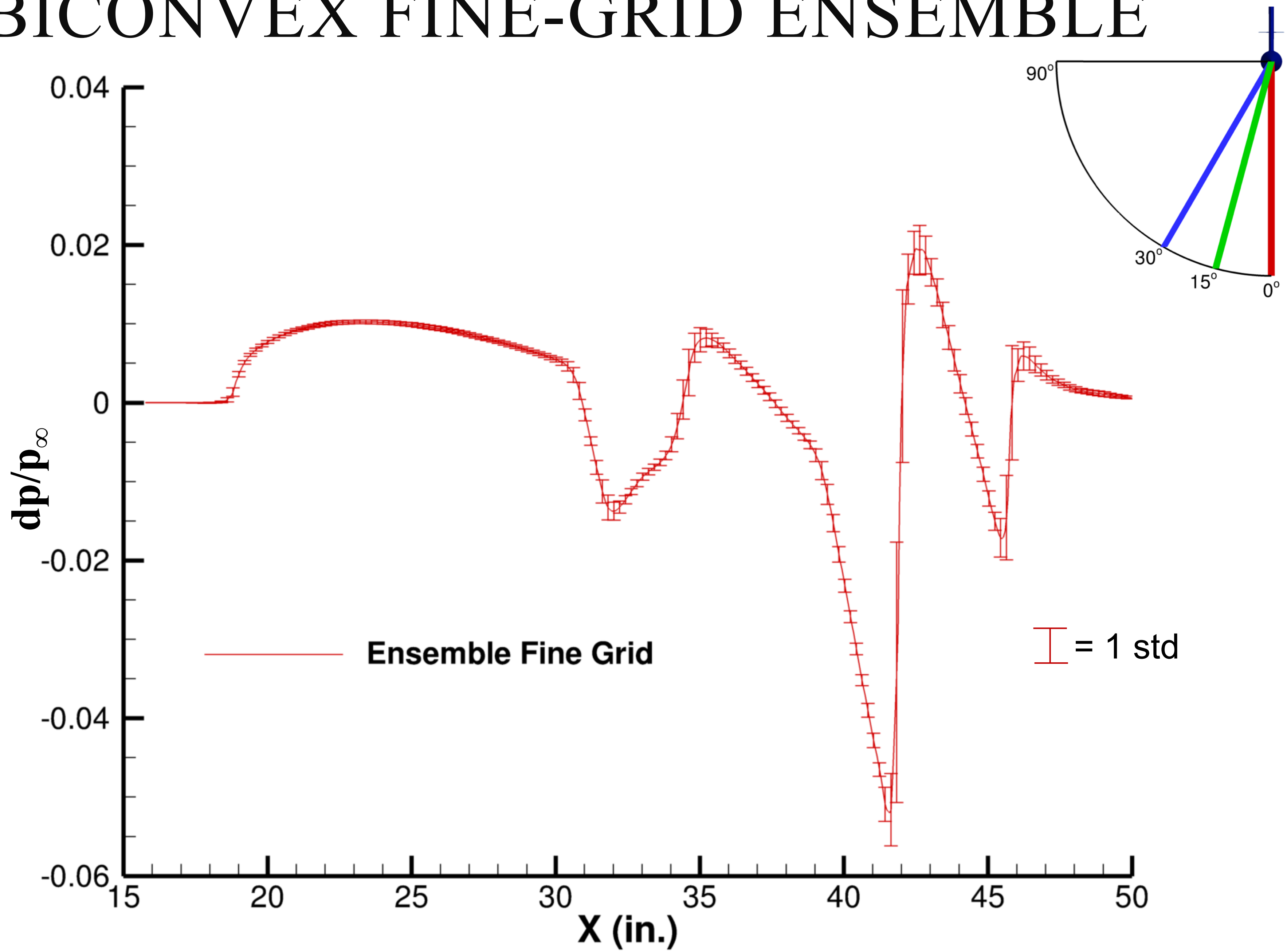
DATA PROCESSING

- Thank You! Consistency improved from second and first workshops
- Received signatures via SFTP or email
- Some were reformatted, zero padded, or sorted
- Data 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

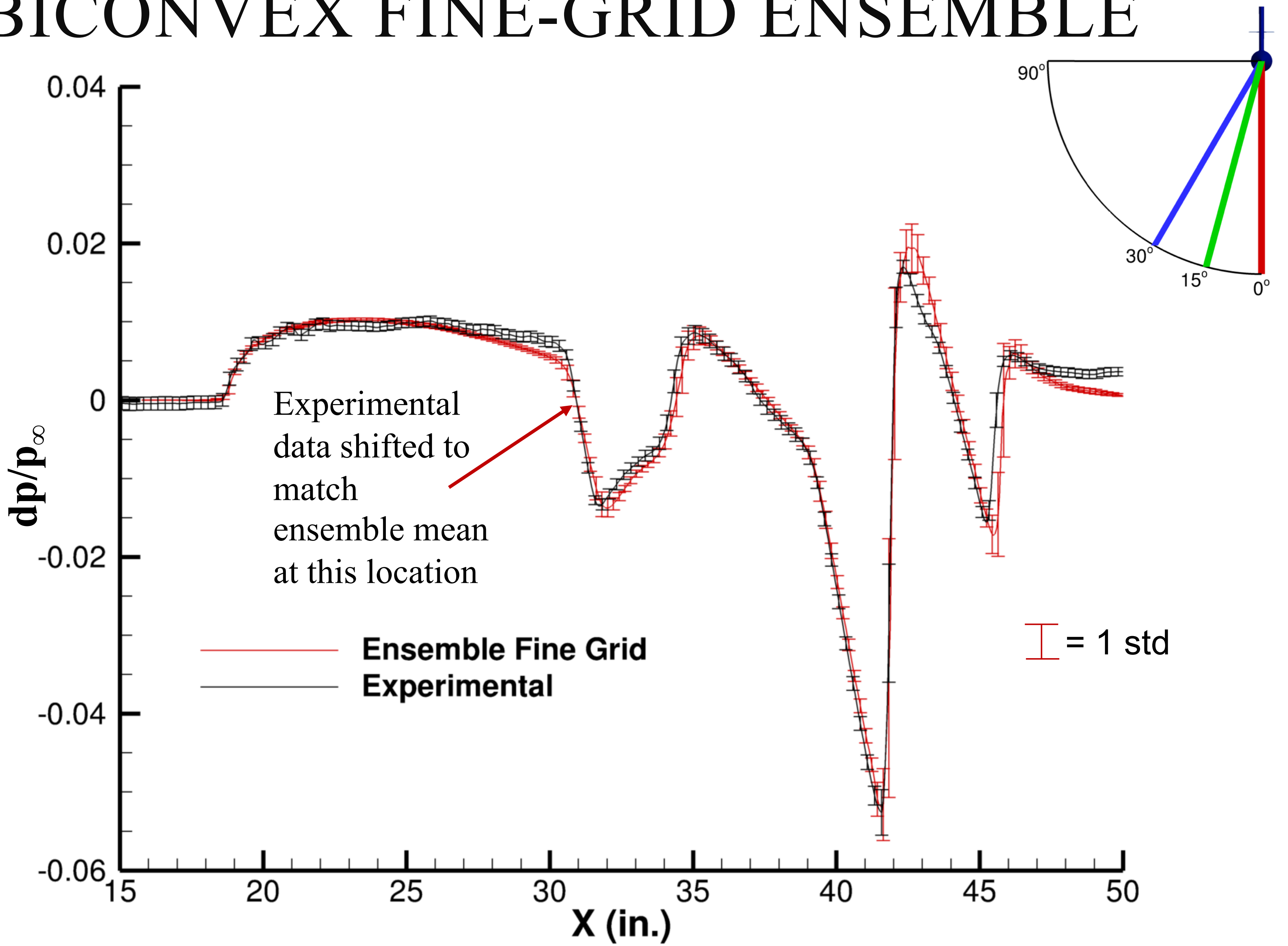
NEAR FIELD AND GROUND SIGNATURE STATISTICS

- Population mean and standard deviation of interpolated near field signature every 0.05 inch (Biconvex) or 0.5 inch (C608)
- Analogous to wind tunnel spatial averaging
- Indication of high variation areas to watch for in participant talks

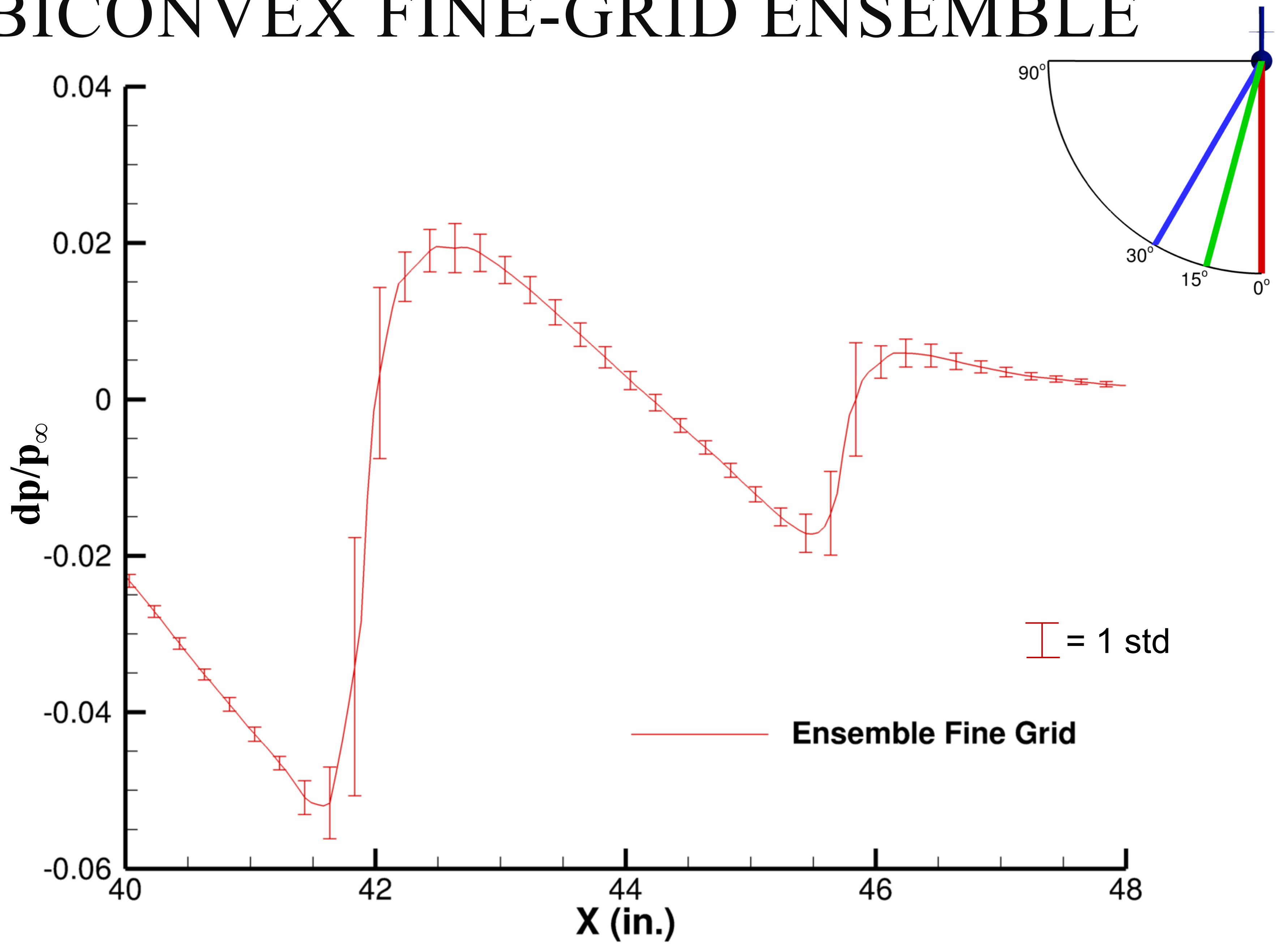
BICONVEX FINE-GRID ENSEMBLE



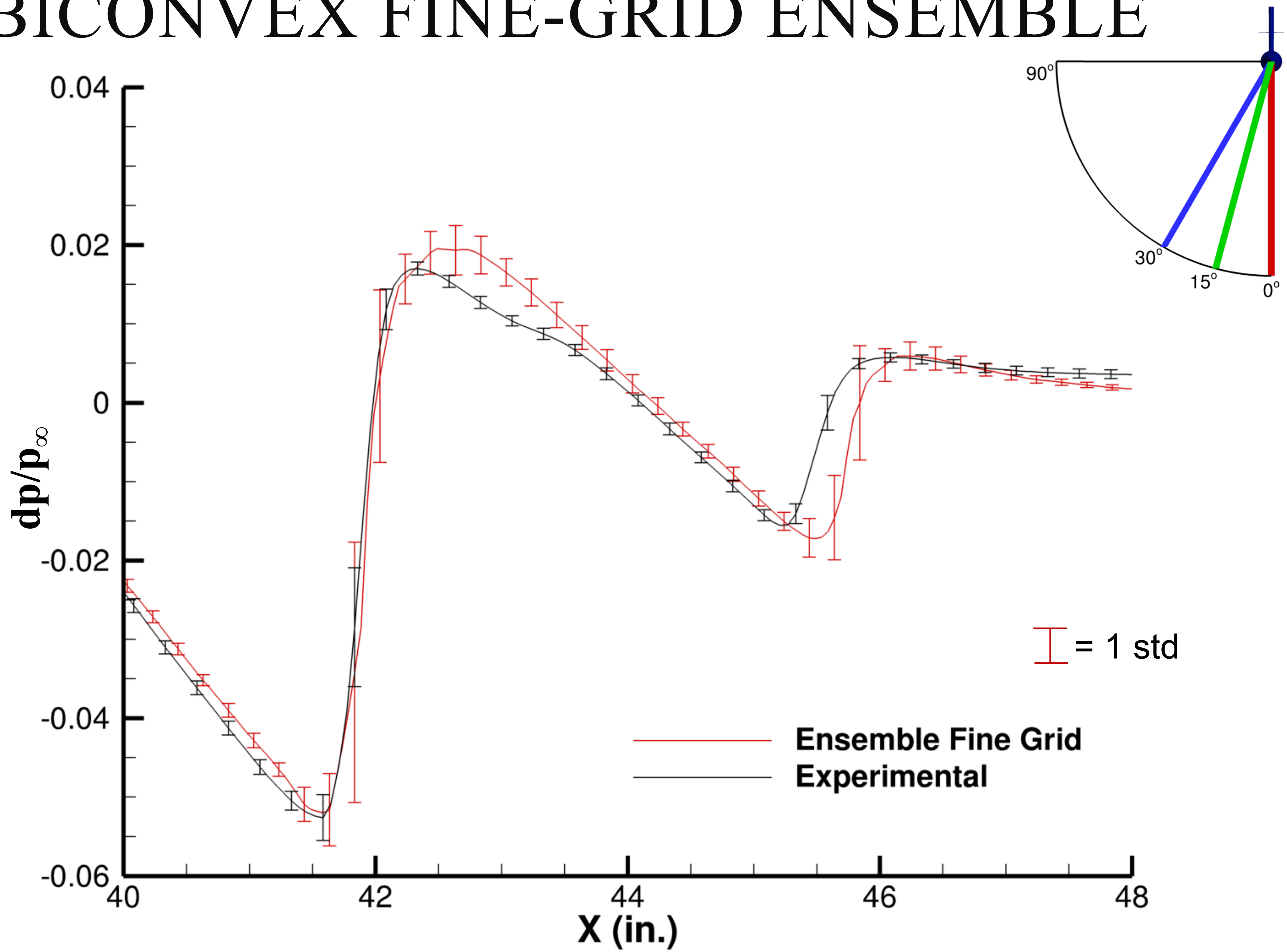
BICONVEX FINE-GRID ENSEMBLE



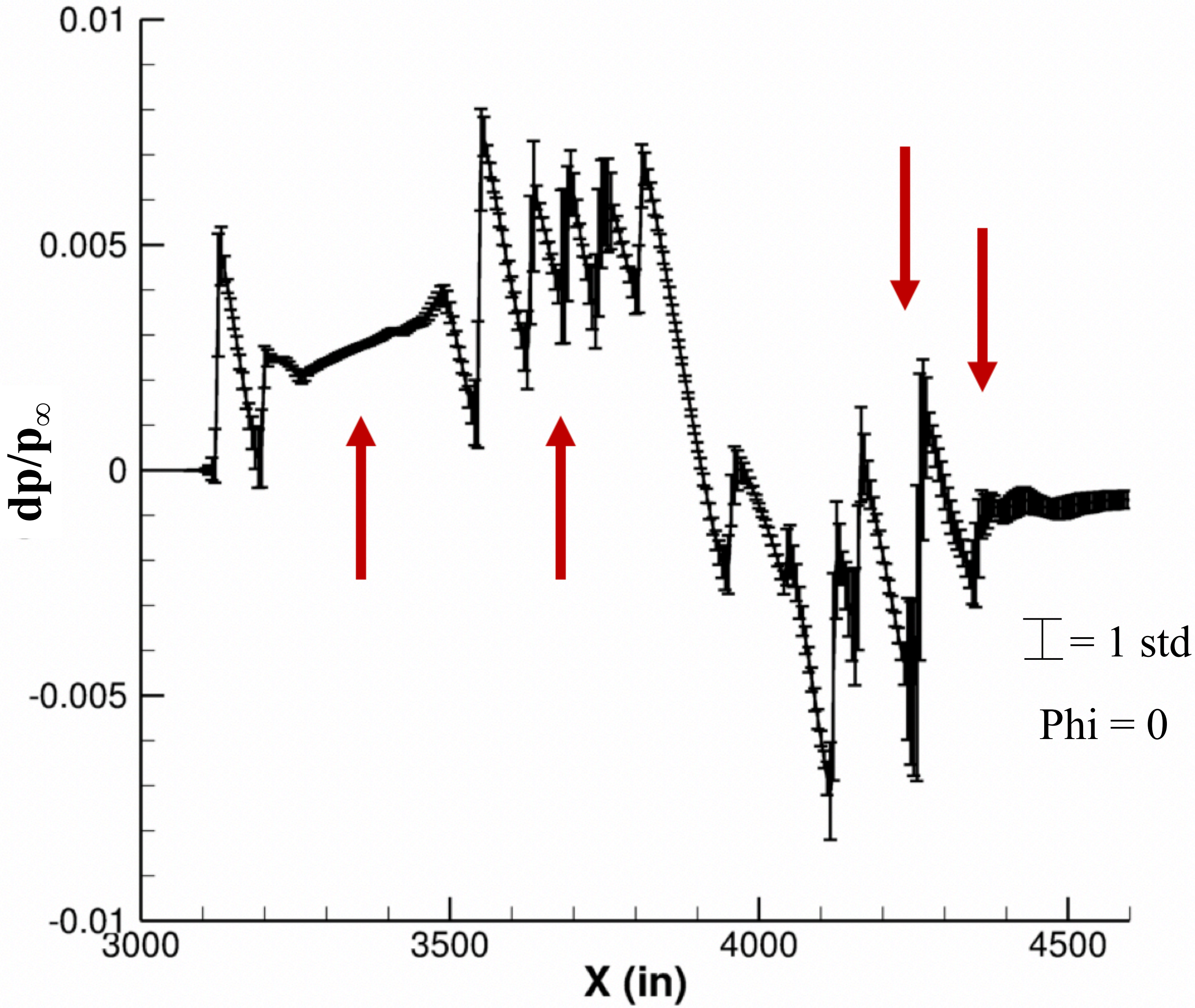
BICONVEX FINE-GRID ENSEMBLE



BICONVEX FINE-GRID ENSEMBLE



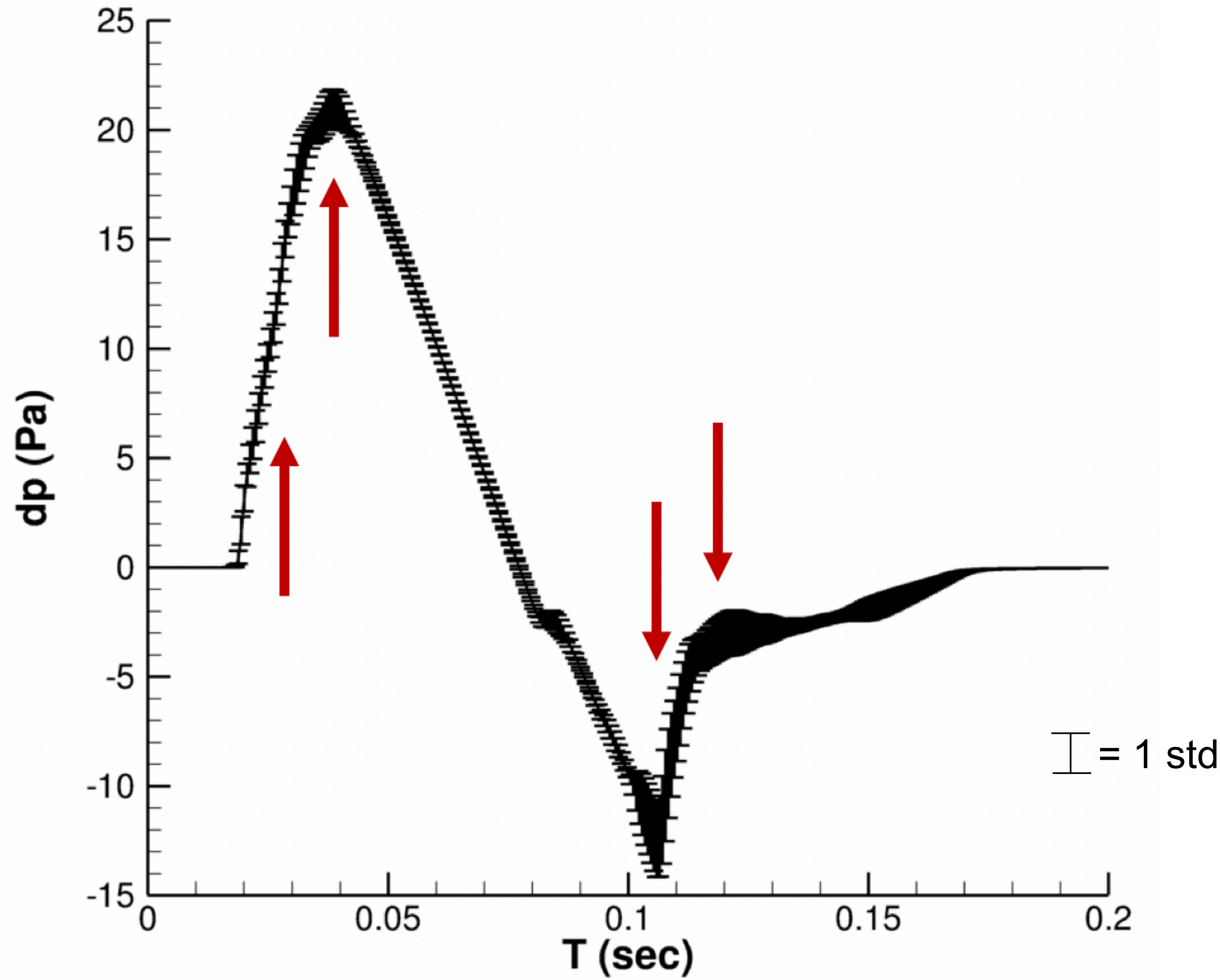
C608 FINE-GRID ENSEMBLE



GROUND PROPAGATION

- Geometry and grids provided in “full-scale”
- US Standard atmosphere and ANSI S1.26 Annex C relative humidity from 53200 ft. altitude
- sBOOM version 2.82 (Rallabhandi)
  - Burgers’ equation with molecular relaxation
- Submissions are windowed with fore and aft ramps

C608 FINE-GRID ENSEMBLE PROPAGATED TO GROUND



ACKNOWLEDGMENTS

- All participants
- Norma Farr, Scott Brynildsen, and Michael Wiese at Geolab for geometry preparation
- Alex Kleb for notice of intent assessment, C608 workshop grids, and C608 geometry assessment
- Jochen Kirz and Todd Michal for grid evaluation and feedback
- Joe Derlaga for statistical tools
- Mark Gammon and Nigel Taylor for geometry assessment
- NASA Commercial Supersonic Technology Project

SUMMARY

More to follow after the participant talks

- Examination of outliers
- Propagation
- Loudness measures