USM3D and OVERFLOW Simulations for 1st AIAA Sonic Boom Prediction Workshop

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National Harbor, Maryland
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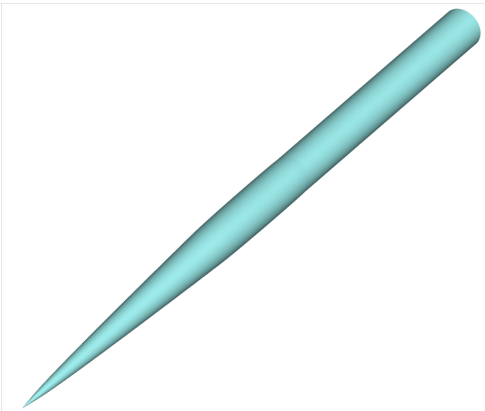
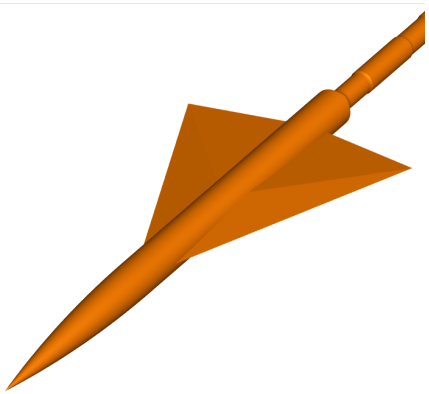
Outline

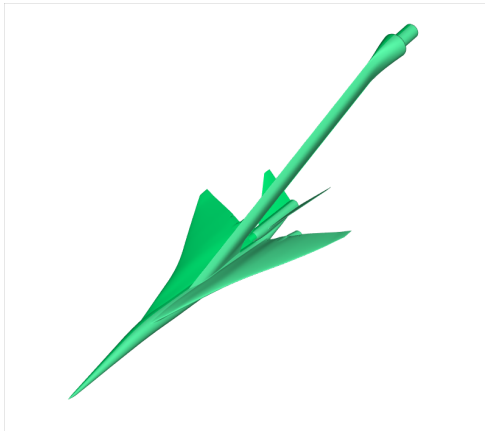
- Motivation
- Computational Models
  - USM3D
  - OVERFLOW
- Computational Grid Methodology
- Results



Seeb-ALR



69° Delta Wing-Body



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- Conclusions

Motivation

- Accurate sonic boom pressure signatures at several body lengths
- Robust stretching / shearing method for tetrahedral meshes
- Single mesh for on- and off-track pressure signatures
- Automated tool to construct mesh

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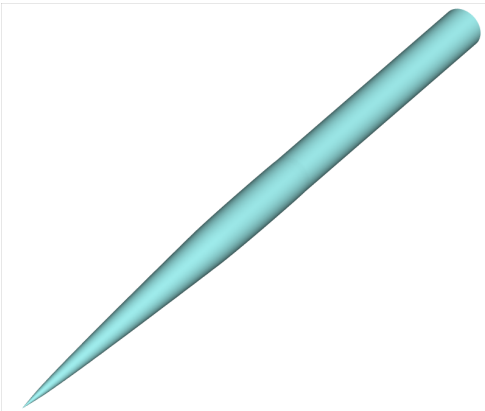

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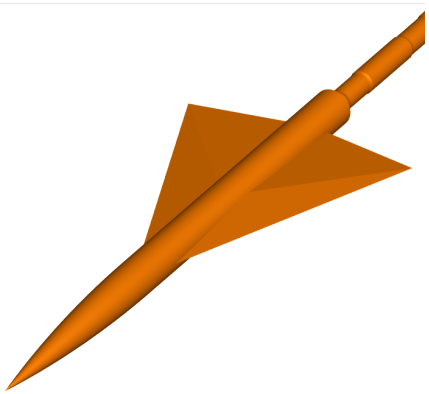

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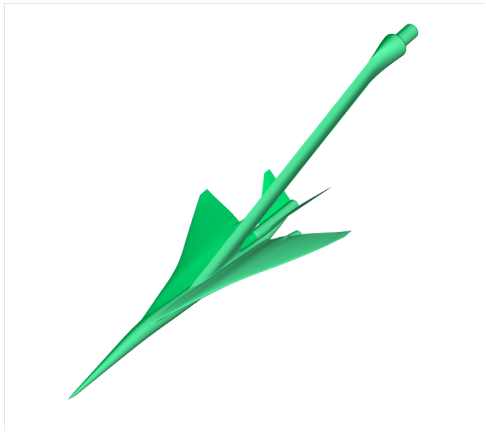

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- Conclusions

Computational Tools: NASA Codes

USM3D	OVERFLOW 2.2
• Unstructured tetrahedra, cell-centered, finite volume	• Structured overset, vertex based, finite difference
• Euler & Navier-Stokes	• Navier-Stokes
• Steady state simulations	• Steady state simulations
• Upwind spatial discretization	• Central & upwind spatial discretization
• Standard & characteristic based BC's	• Standard & characteristic based BC's
• Spalart-Allmaras turbulence model	• Spalart-Allmaras turbulence model

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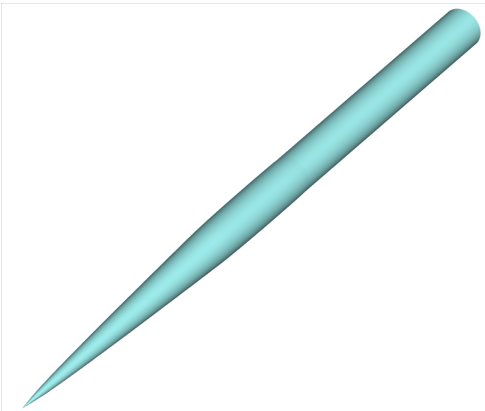

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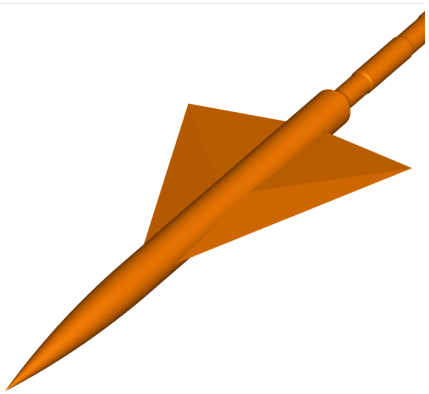

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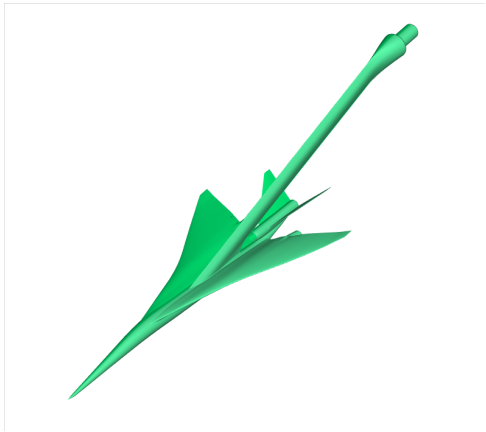

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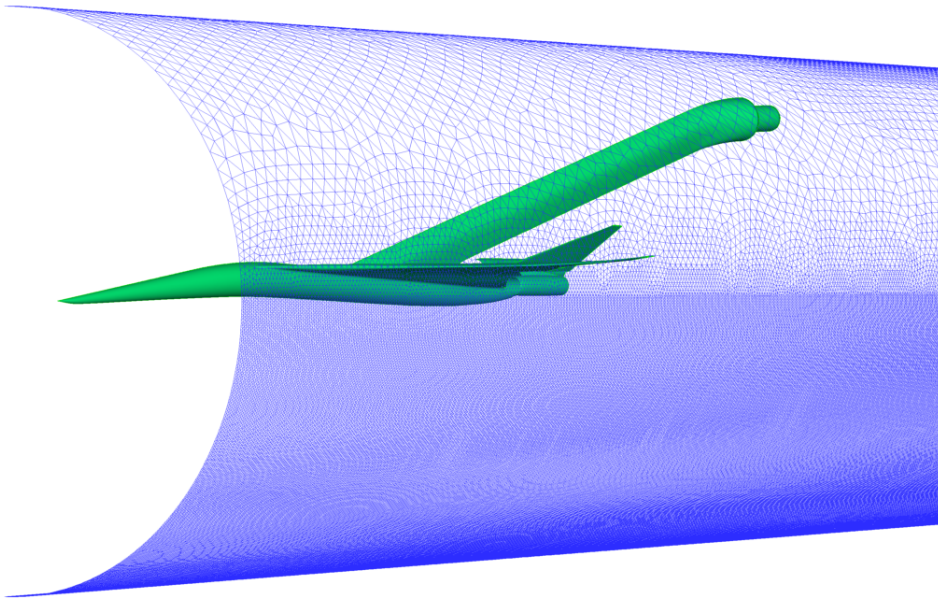
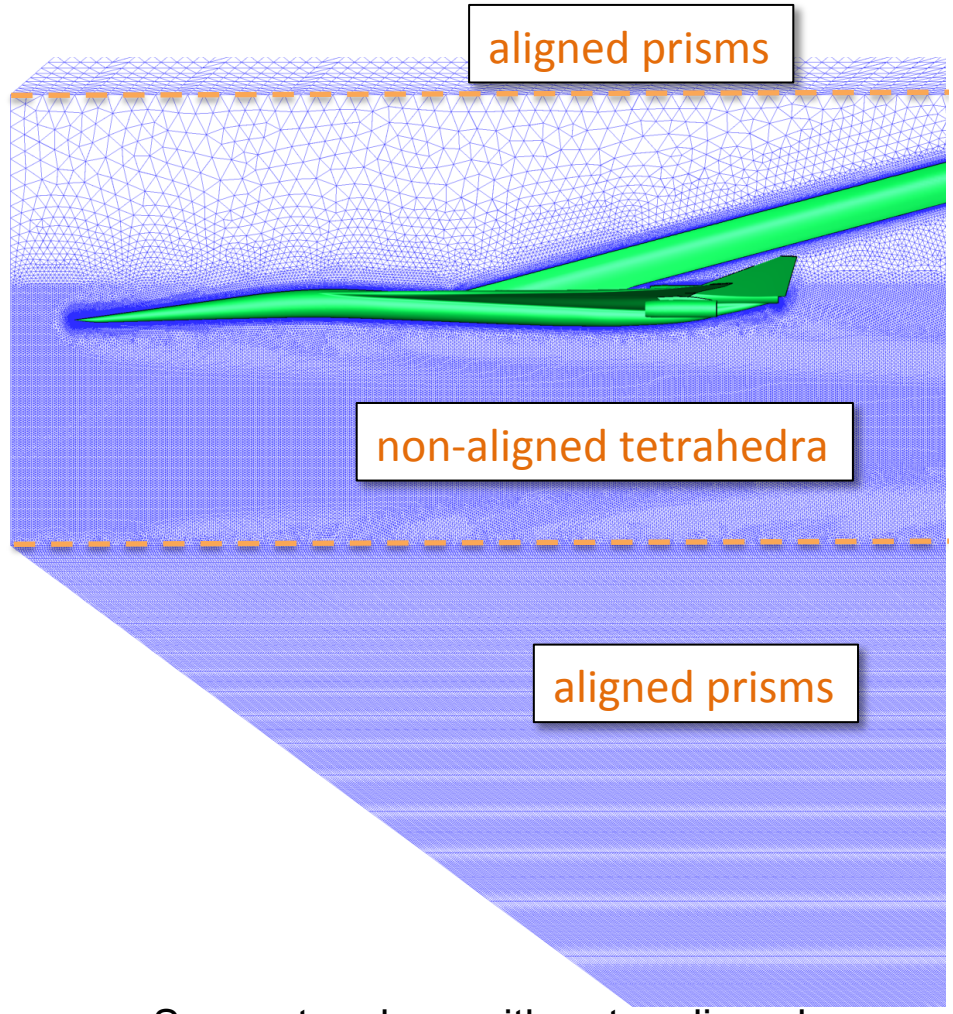
- Conclusions

Computational Tools: USM3D Meshes

Mach Cone Aligned Prism (MCAP) meshes for 1021 model



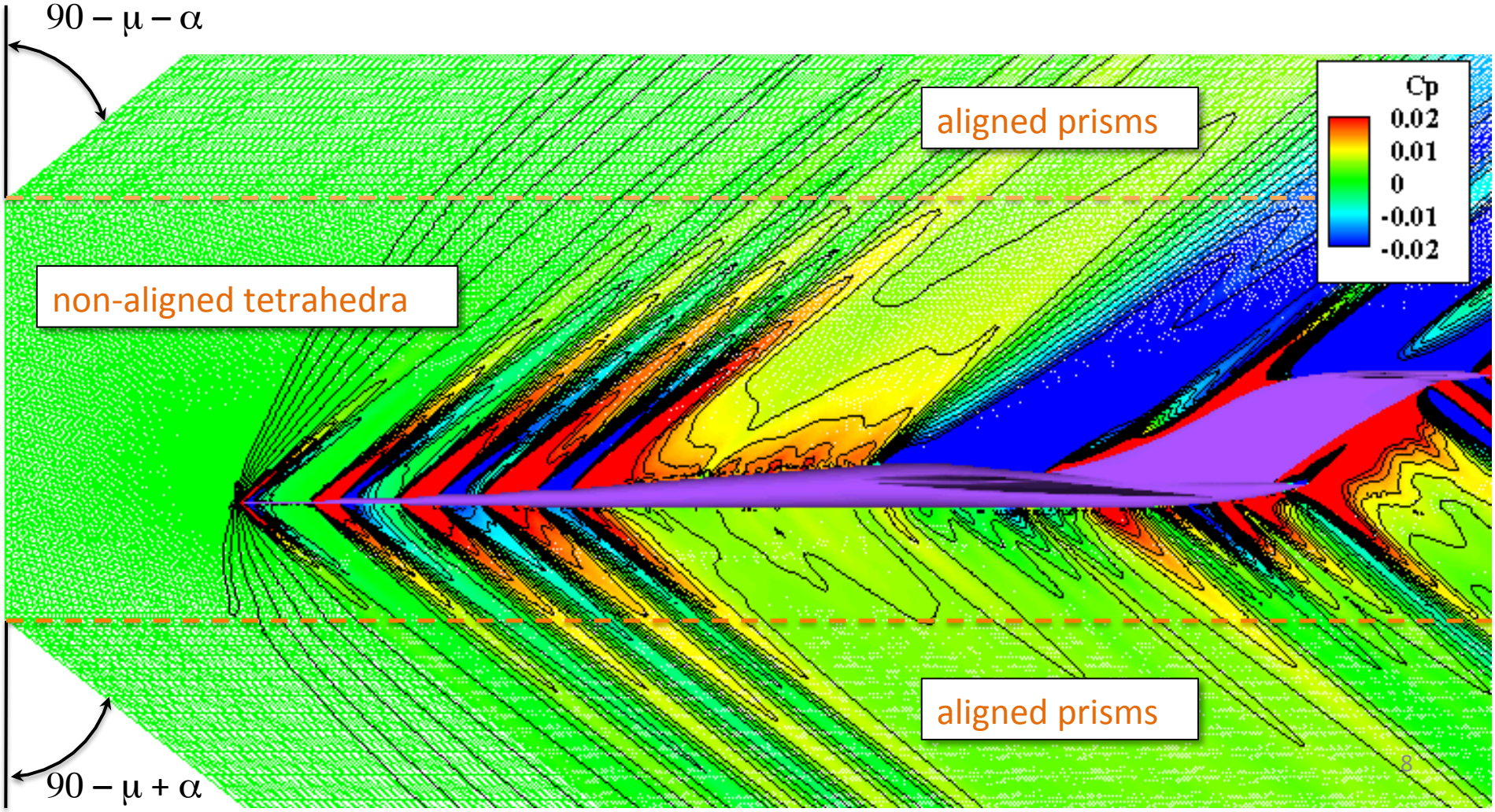
Cylindrical near-body mesh



Symmetry plane with outer aligned prism grid

Shearing/Mach Angle Alignment of the Prismatic Grid

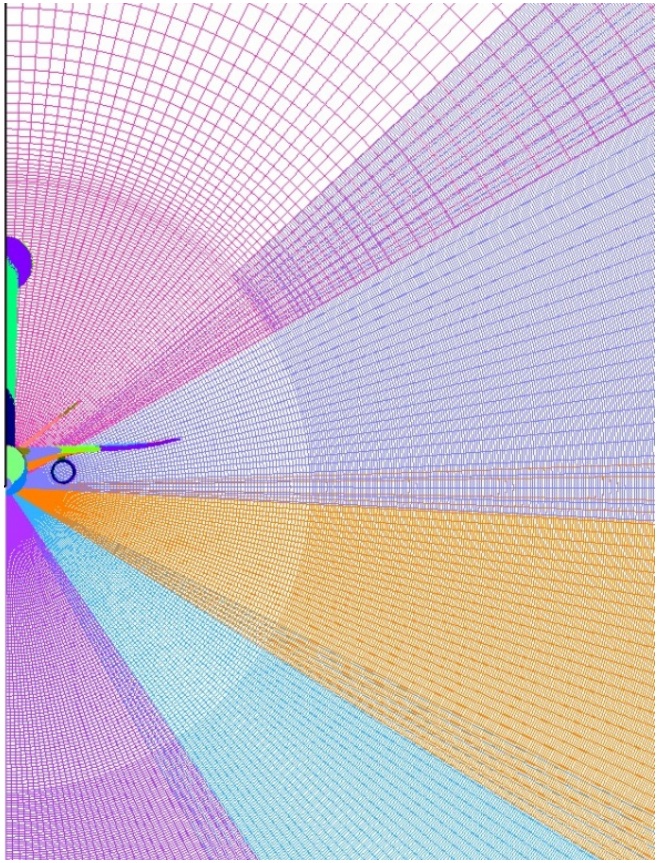
α= angle of attack
μ= $\sin^{-1}(1/M)$



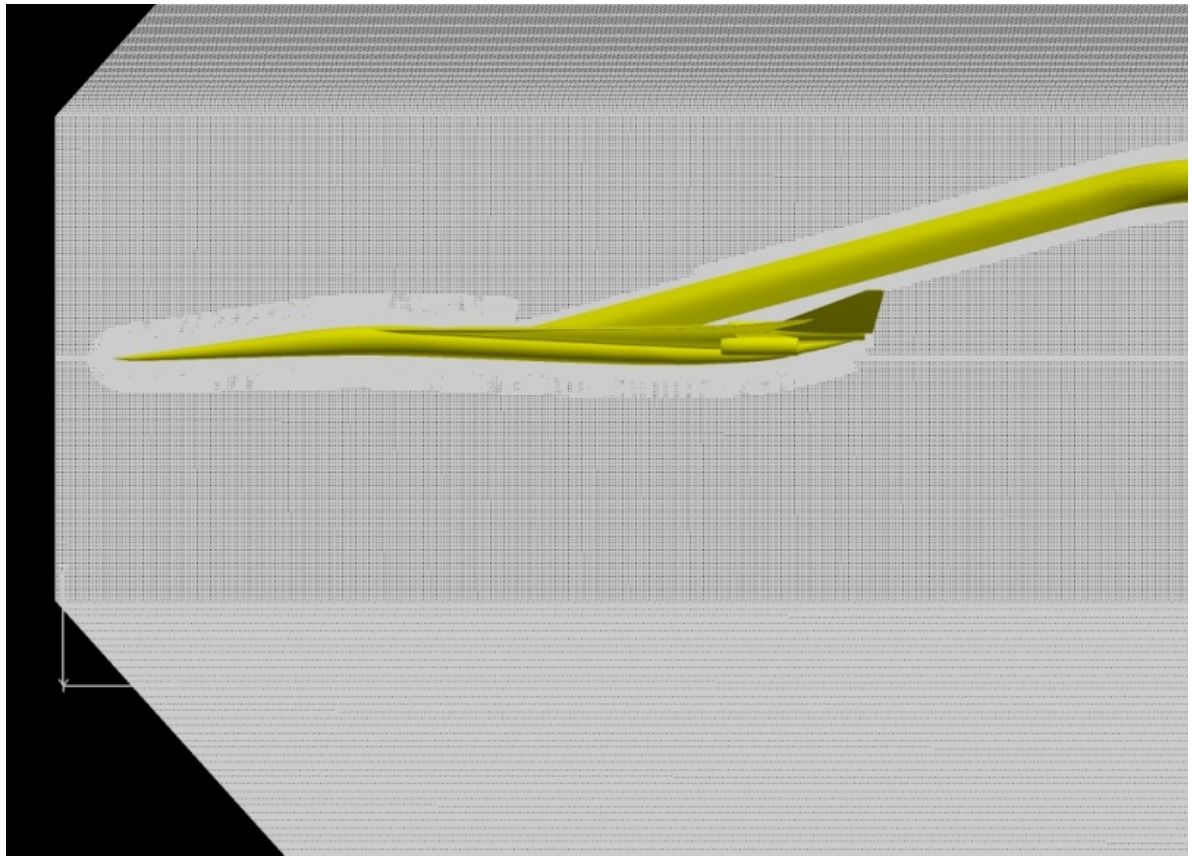
Computational Tools: Overset Meshes

OVERFLOW Overset Meshes for 1021 Model

Front View



Symmetry Plane View



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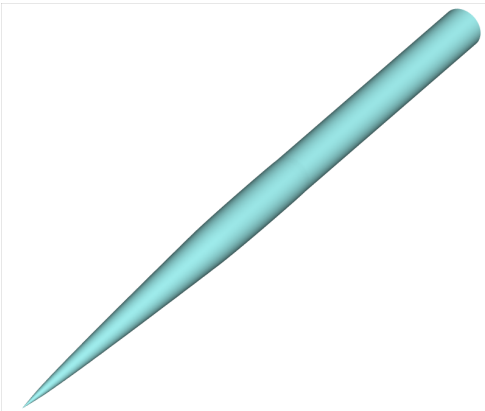
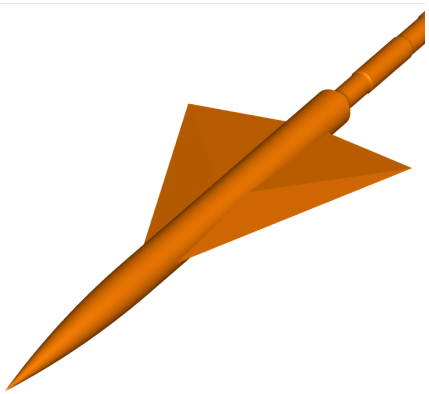
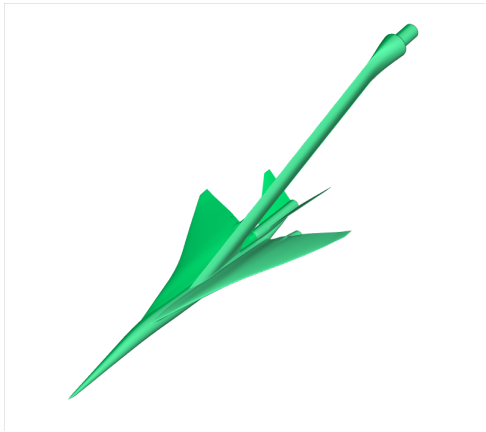
- **Results**



Seeb-ALR



69° Delta Wing-Body



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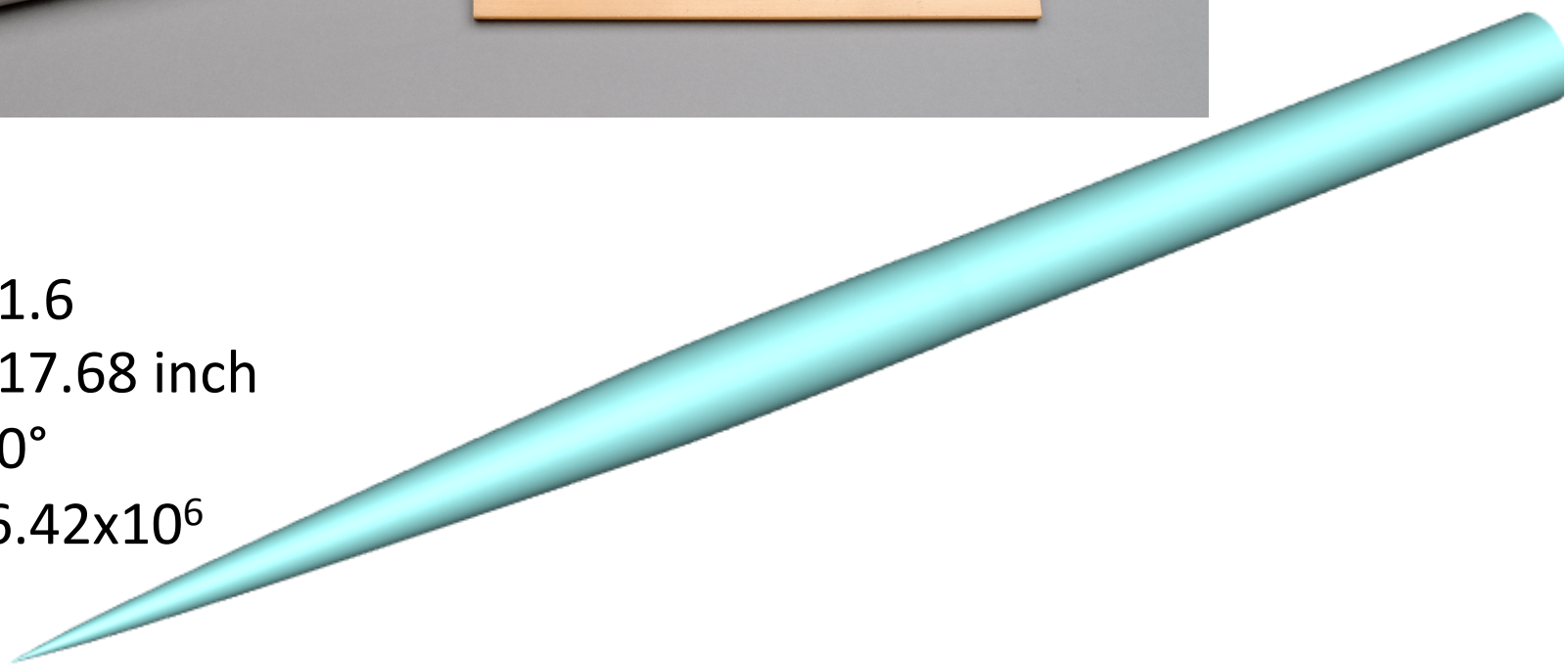
Conclusions

Lockheed Seeb-ALR



Mach = 1.6

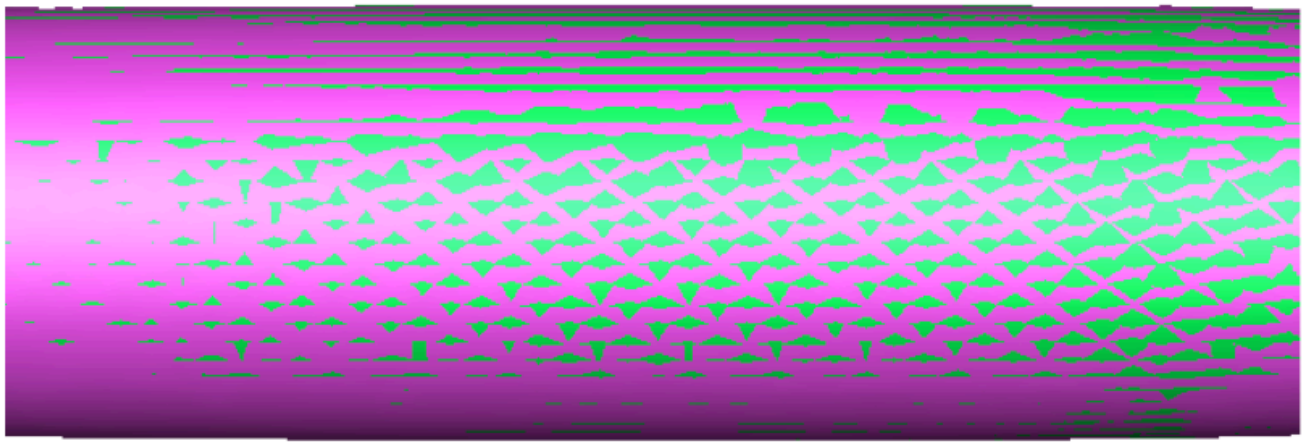
L_{Ref} = 17.68 inch

α = 0°

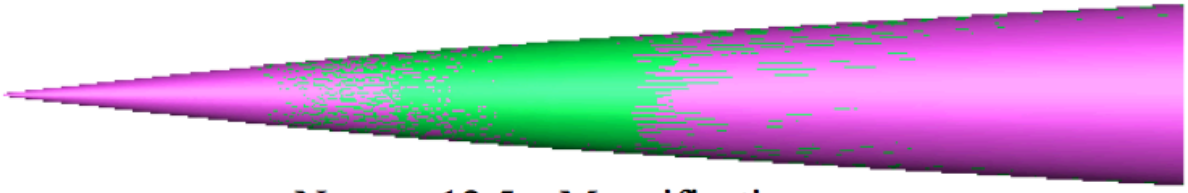
Rn =6.42x10^6

Variation in Surface Geometry

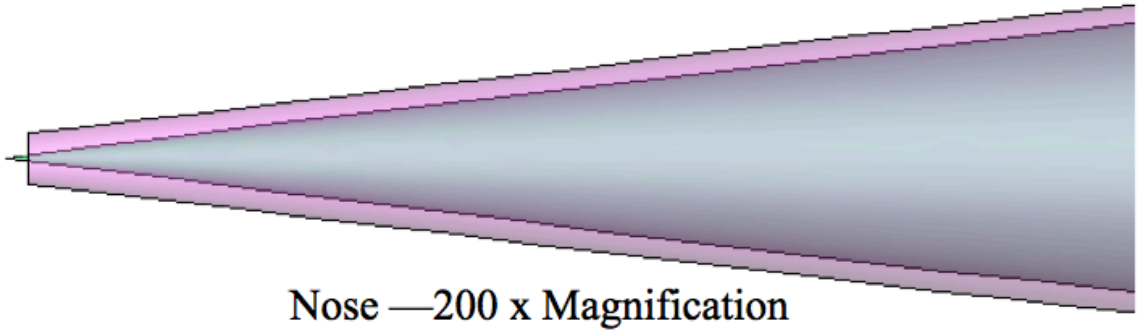
CAD definition (Green)-------Workshop Geometry (Magenta)



Maximum Thickness Point ----12.5 X Magnification

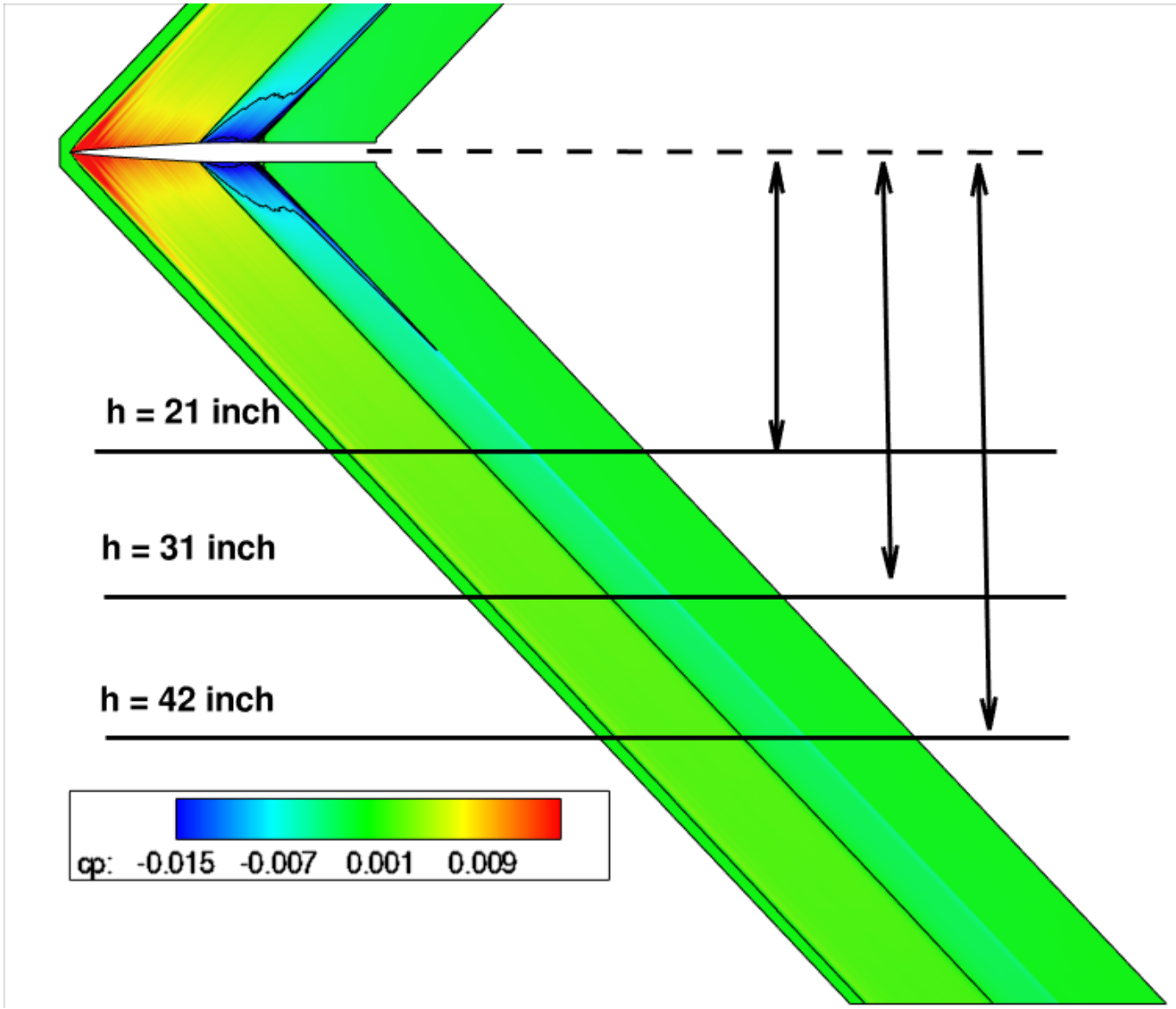


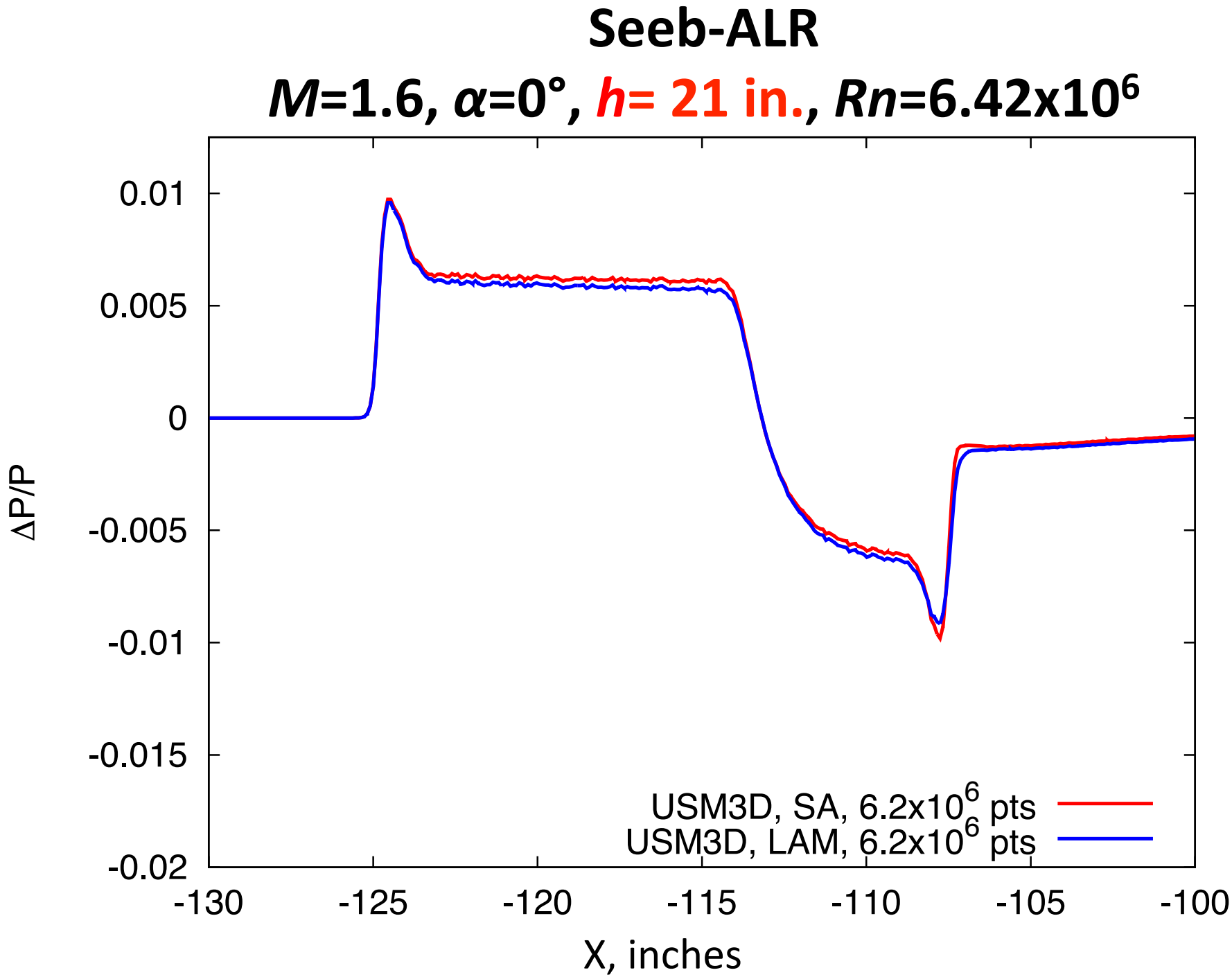
Nose —12.5 x Magnification

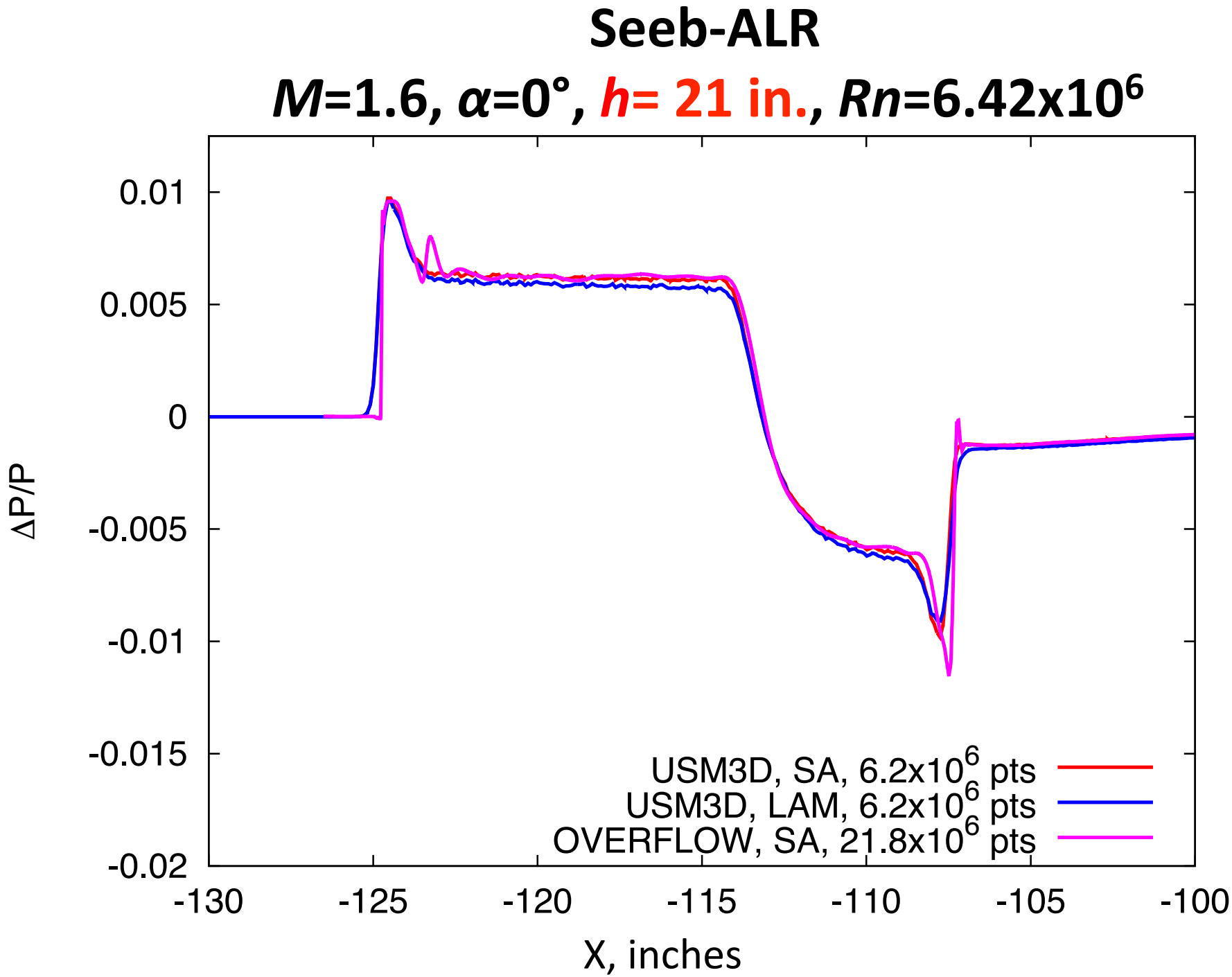


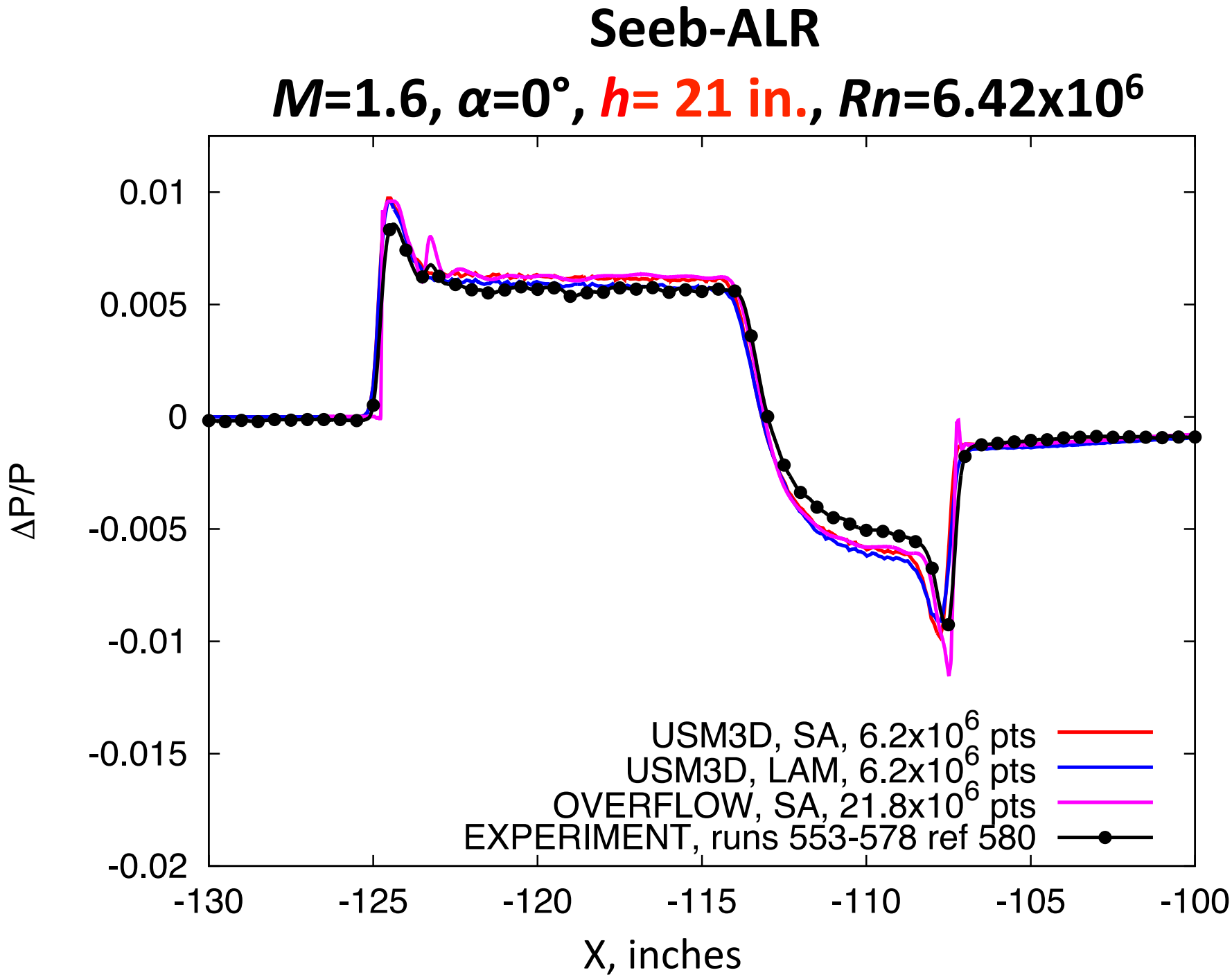
Nose —200 x Magnification

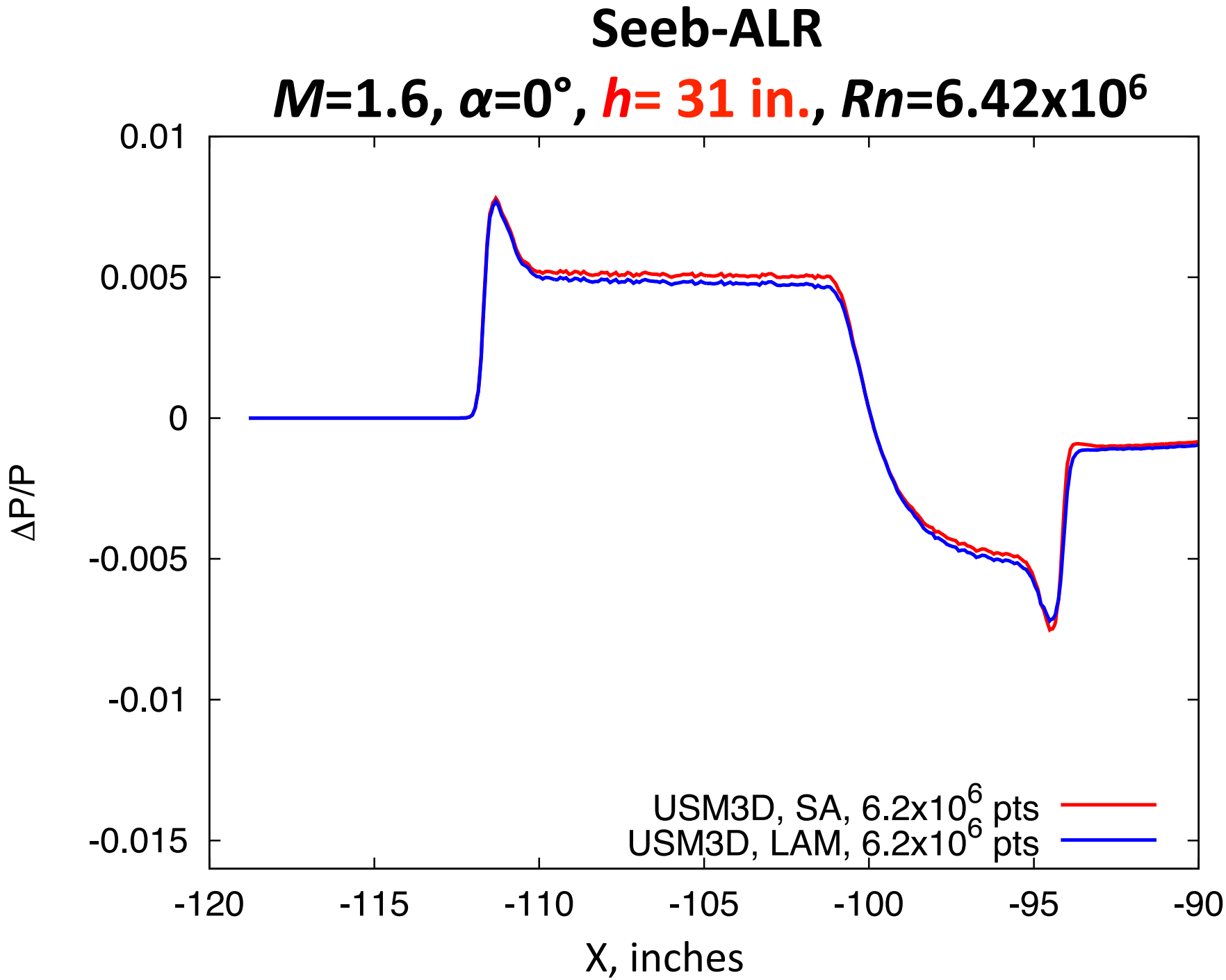
Mach Line Contours Superimposed on the Cp Contours M=1.6, α=0°, Rn=6.42x10^6

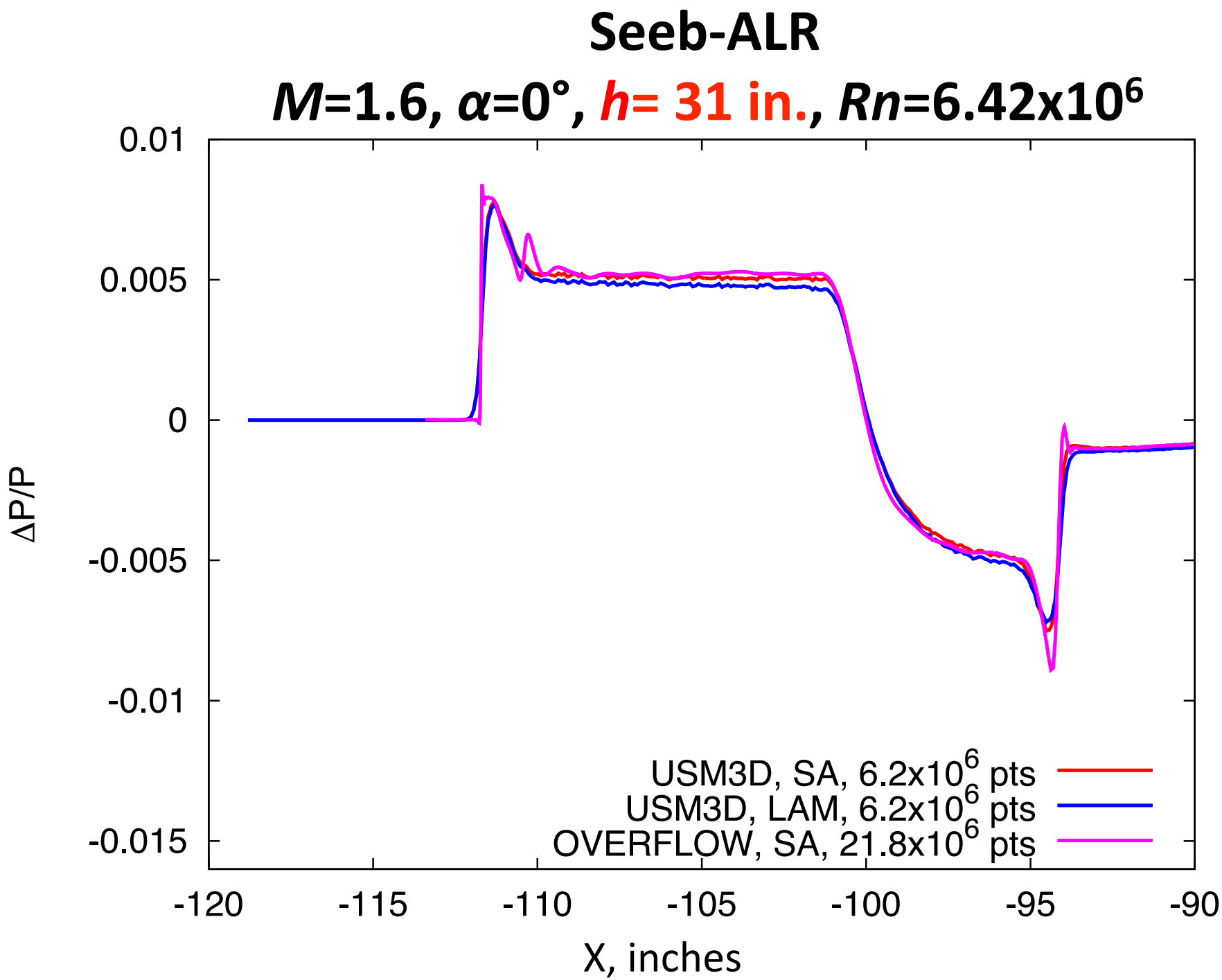


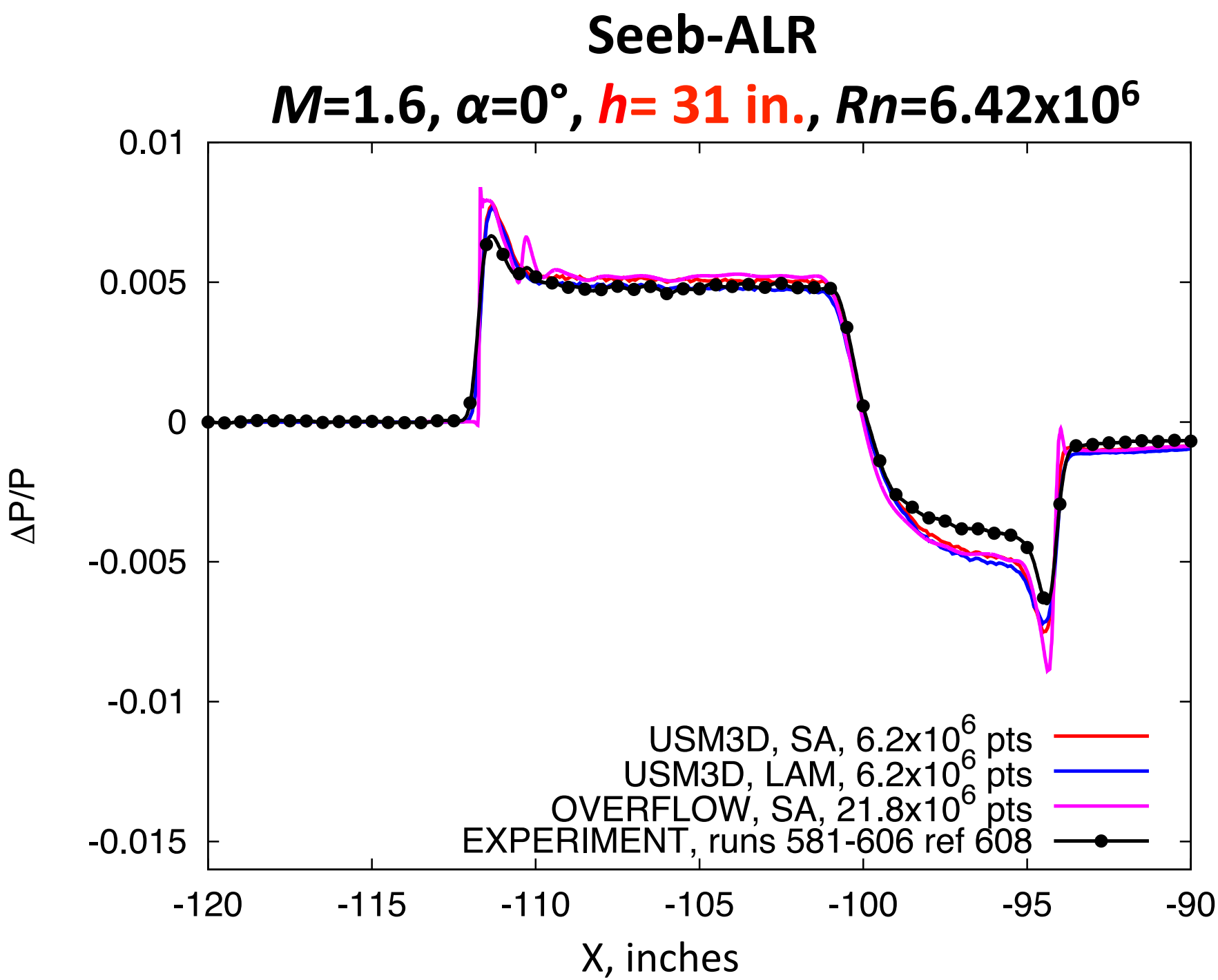

Seeb-ALR
M=1.6, α=0°, h= 21 in., Rn=6.42x10^6
0.01
0.005
0
-0.005
-0.01
-0.015
-0.02
ΔP/P
-130
-125
-120
-115
-110
-105
-100
X, inches
USM3D, SA, 6.2x10^6 pts
USM3D, LAM, 6.2x10^6 pts

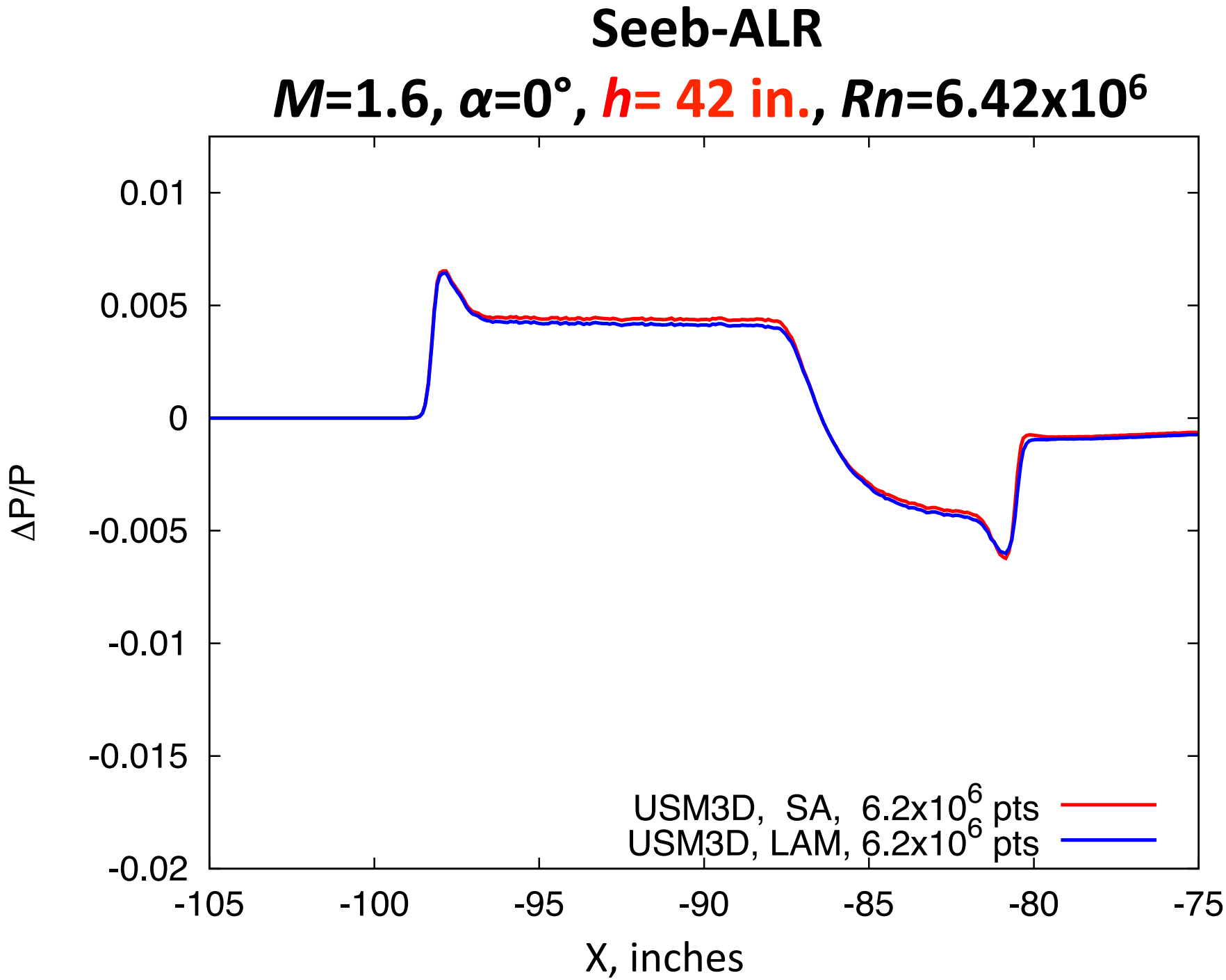

Seeb-ALR
M=1.6, α=0°, h= 21 in., Rn=6.42x10^6
0.01
0.005
0
-0.005
-0.01
-0.015
-0.02
ΔP/P
-130
-125
-120
-115
-110
-105
-100
X, inches
USM3D, SA, 6.2x10^6 pts
USM3D, LAM, 6.2x10^6 pts
OVERFLOW, SA, 21.8x10^6 pts

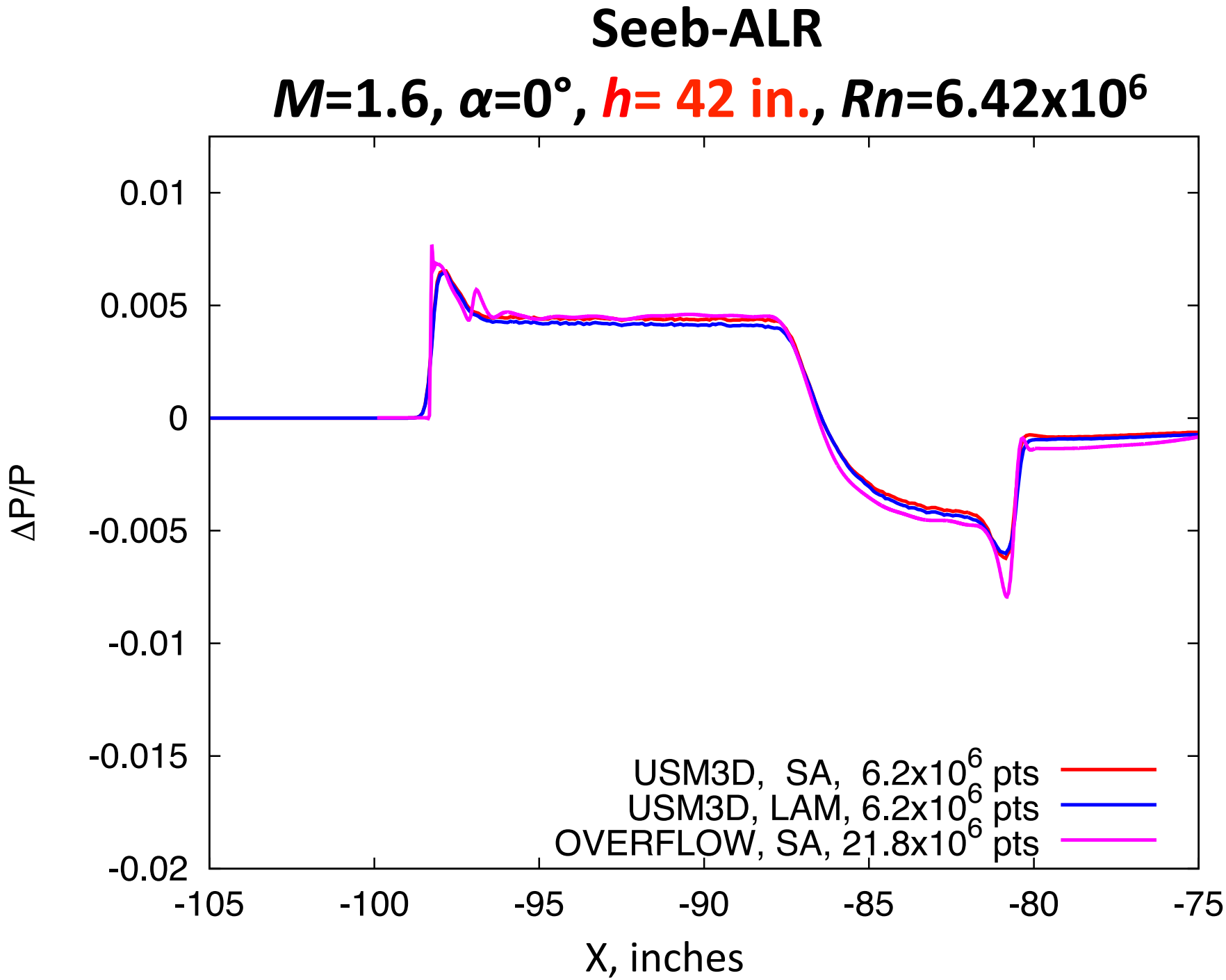

Seeb-ALR
M=1.6, α=0°, h= 21 in., Rn=6.42x10^6
0.01
0.005
0
-0.005
-0.01
-0.015
-0.02
ΔP/P
-130
-125
-120
-115
-110
-105
-100
X, inches
USM3D, SA, 6.2x10^6 pts
USM3D, LAM, 6.2x10^6 pts
OVERFLOW, SA, 21.8x10^6 pts
EXPERIMENT, runs 553-578 ref 580


Seeb-ALR
M=1.6, α=0°, h= 31 in., Rn=6.42x10^6
0.01
0.005
0
-0.005
-0.01
-0.015
ΔP/P
-120
-115
-110
-105
-100
-95
-90
X, inches
USM3D, SA, 6.2x10^6 pts
USM3D, LAM, 6.2x10^6 pts


Seeb-ALR
M=1.6, α=0°, h= 31 in., Rn=6.42x10^6
0.01
0.005
0
-0.005
-0.01
-0.015
ΔP/P
-120
-115
-110
-105
-100
-95
-90
X, inches
USM3D, SA, 6.2x10^6 pts
USM3D, LAM, 6.2x10^6 pts
OVERFLOW, SA, 21.8x10^6 pts


Seeb-ALR
M=1.6, α=0°, h= 31 in., Rn=6.42x10^6
0.01
0.005
0
-0.005
-0.01
-0.015
ΔP/P
-120
-115
-110
-105
-100
-95
-90
X, inches
USM3D, SA, 6.2x10^6 pts
USM3D, LAM, 6.2x10^6 pts
OVERFLOW, SA, 21.8x10^6 pts
EXPERIMENT, runs 581-606 ref 608


Seeb-ALR
M=1.6, α=0°, h= 42 in., Rn=6.42x10^6
0.01
0.005
0
-0.005
-0.01
-0.015
-0.02
ΔP/P
-105
-100
-95
-90
-85
-80
-75
X, inches
USM3D, SA, 6.2x10^6 pts
USM3D, LAM, 6.2x10^6 pts


Seeb-ALR
M=1.6, α=0°, h= 42 in., Rn=6.42x10^6
0.01
0.005
0
-0.005
-0.01
-0.015
-0.02
ΔP/P
-105
-100
-95
-90
-85
-80
-75
X, inches
USM3D, SA, 6.2x10^6 pts
USM3D, LAM, 6.2x10^6 pts
OVERFLOW, SA, 21.8x10^6 pts

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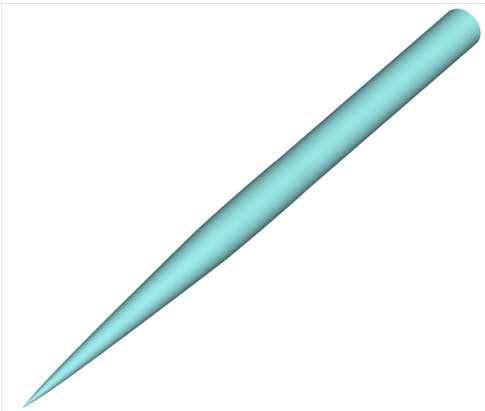
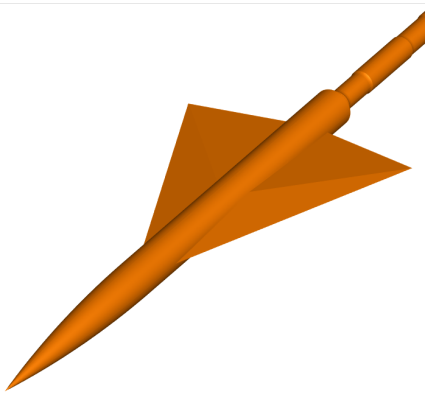
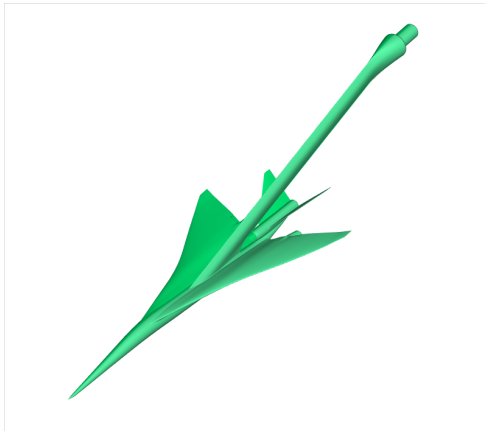


Seeb-ALR



69° Delta Wing-Body



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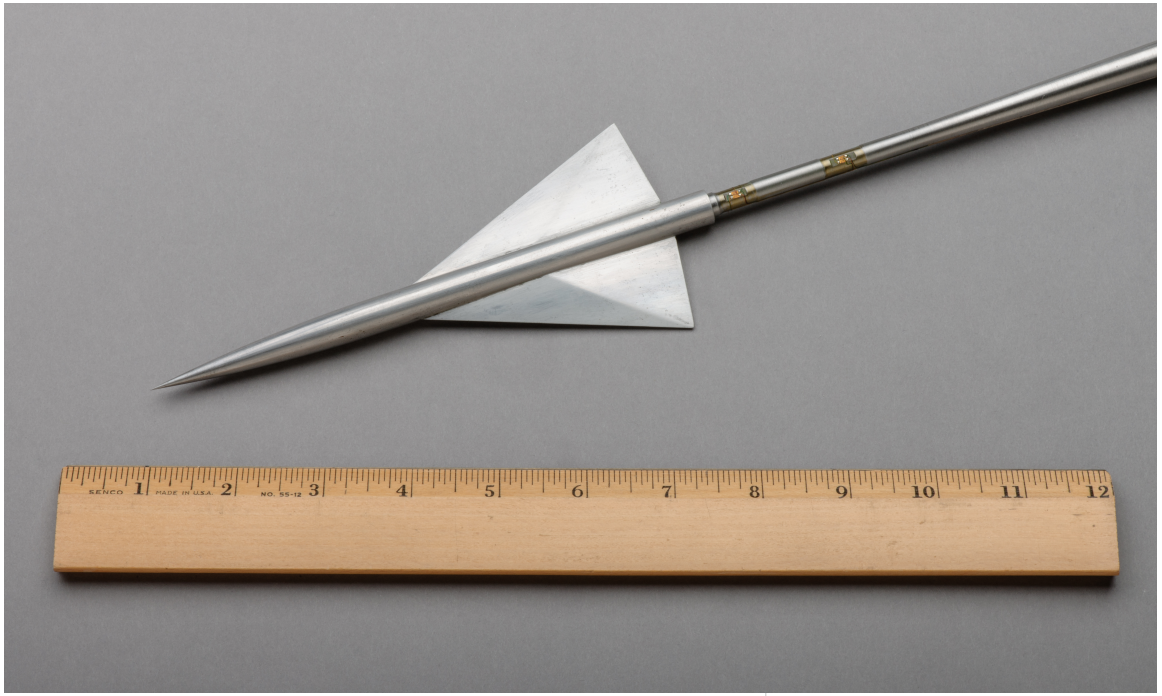
Conclusions

69° Delta Wing-Body

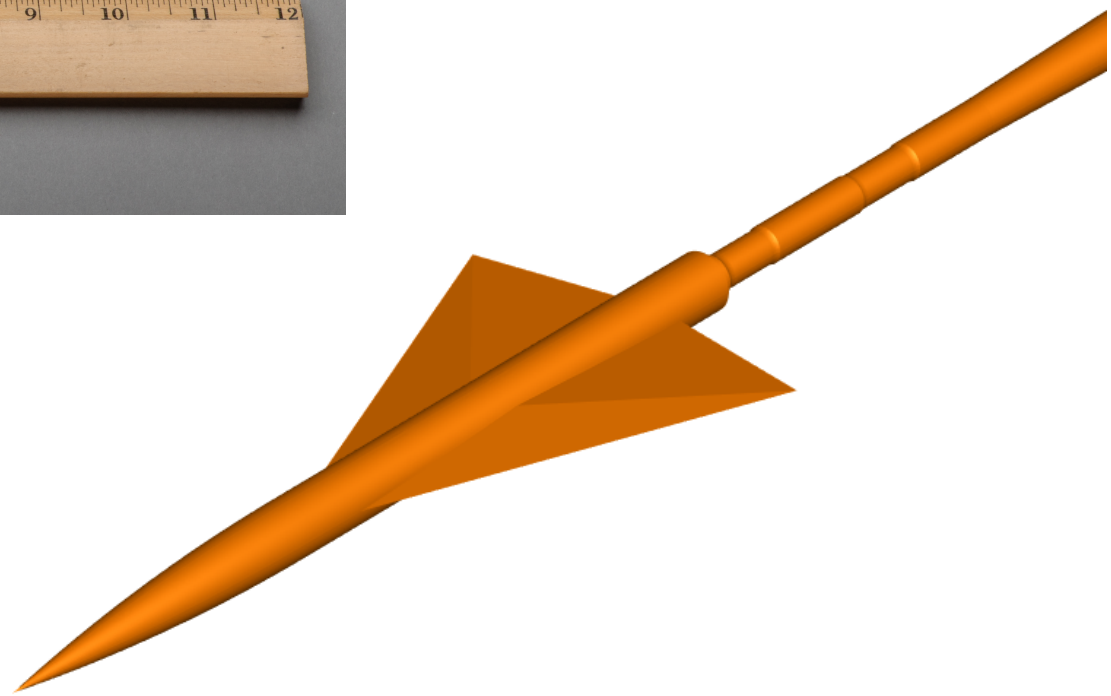


Mach = 1.7

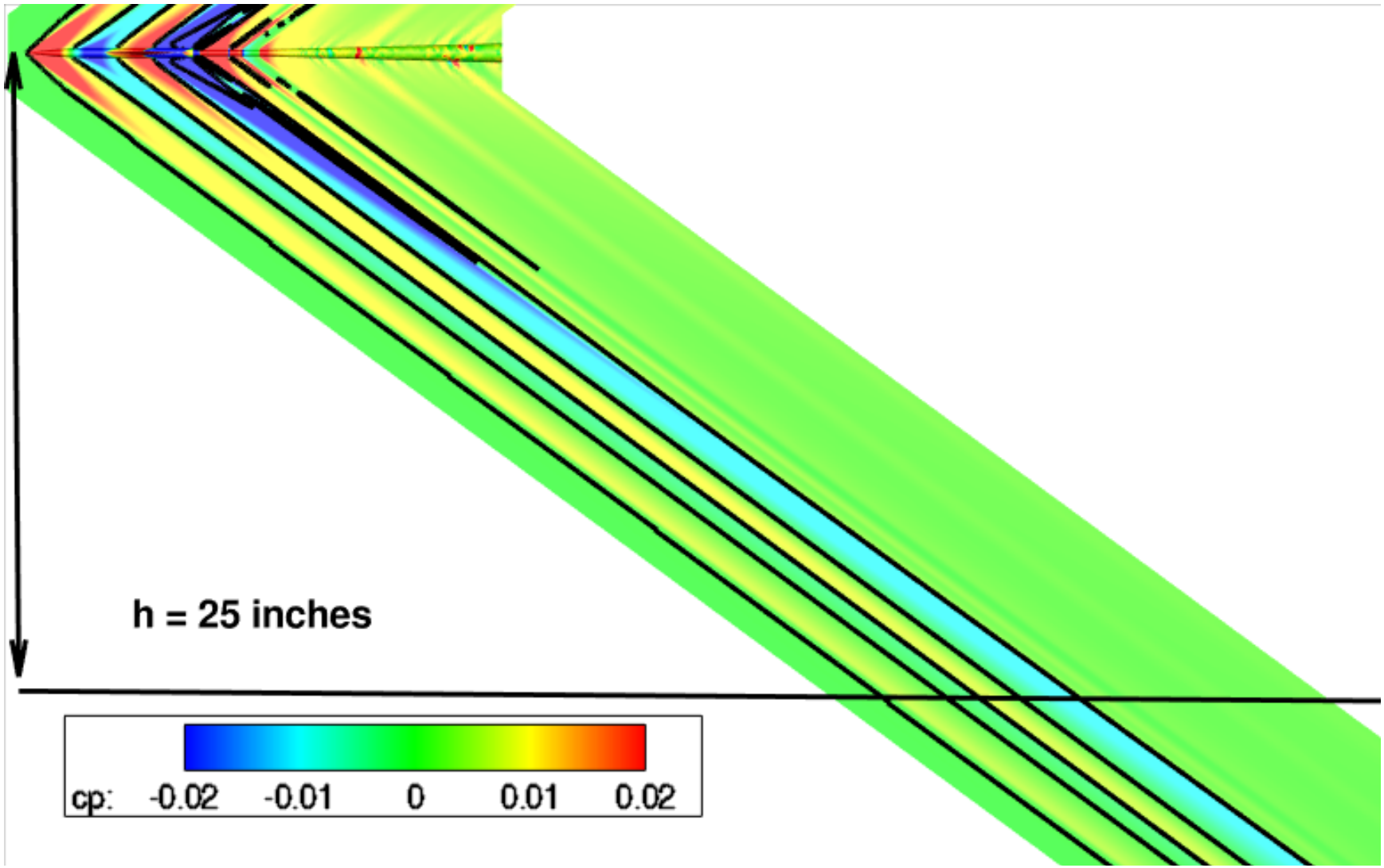
L_{Ref} = 6.898 inch

$\boldsymbol{\alpha}$ = 0°

Rn =2.43x10^6

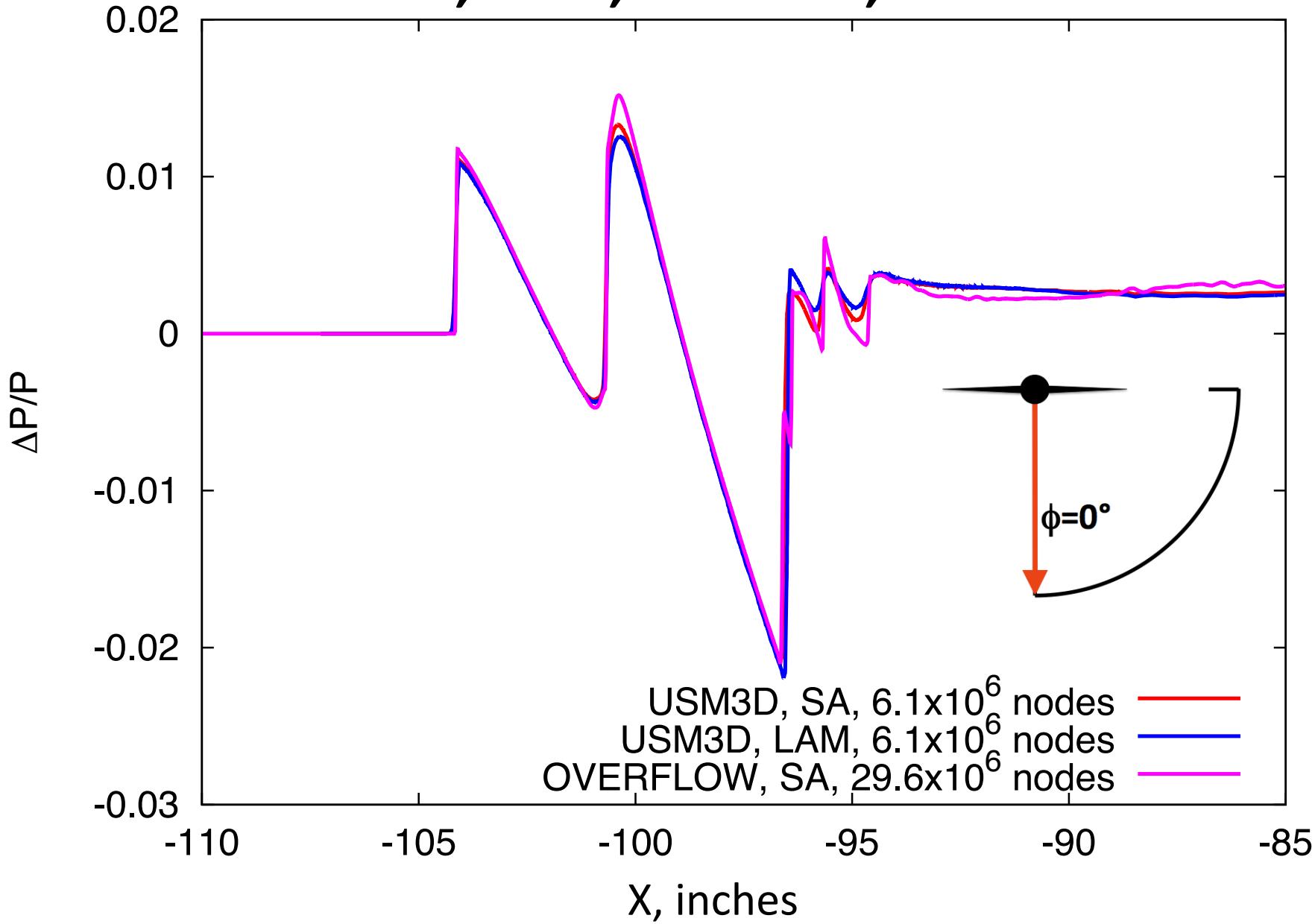


Mach Line Contours Superimposed on the Cp Contours M=1.7, α=0°, Rn=2.43x10^6



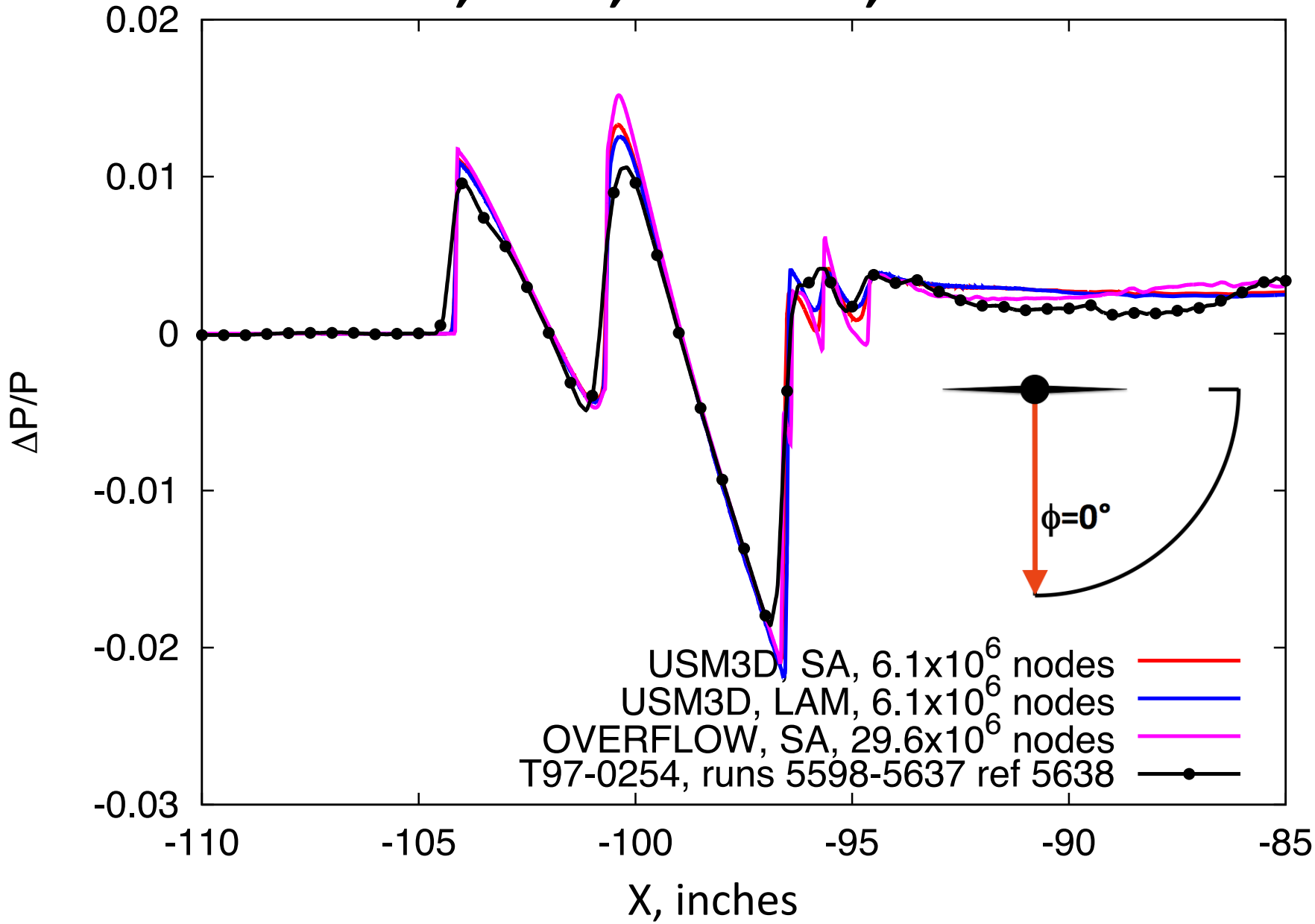
69° Delta Wing-Body

M=1.7, *α*=0°, *h*= 25 in., *Rn*=2.43x10^6



69° Delta Wing-Body

M=1.7, *α*=0°, *h*= 25 in., *Rn*=2.43x10^6



69° Delta Wing-Body

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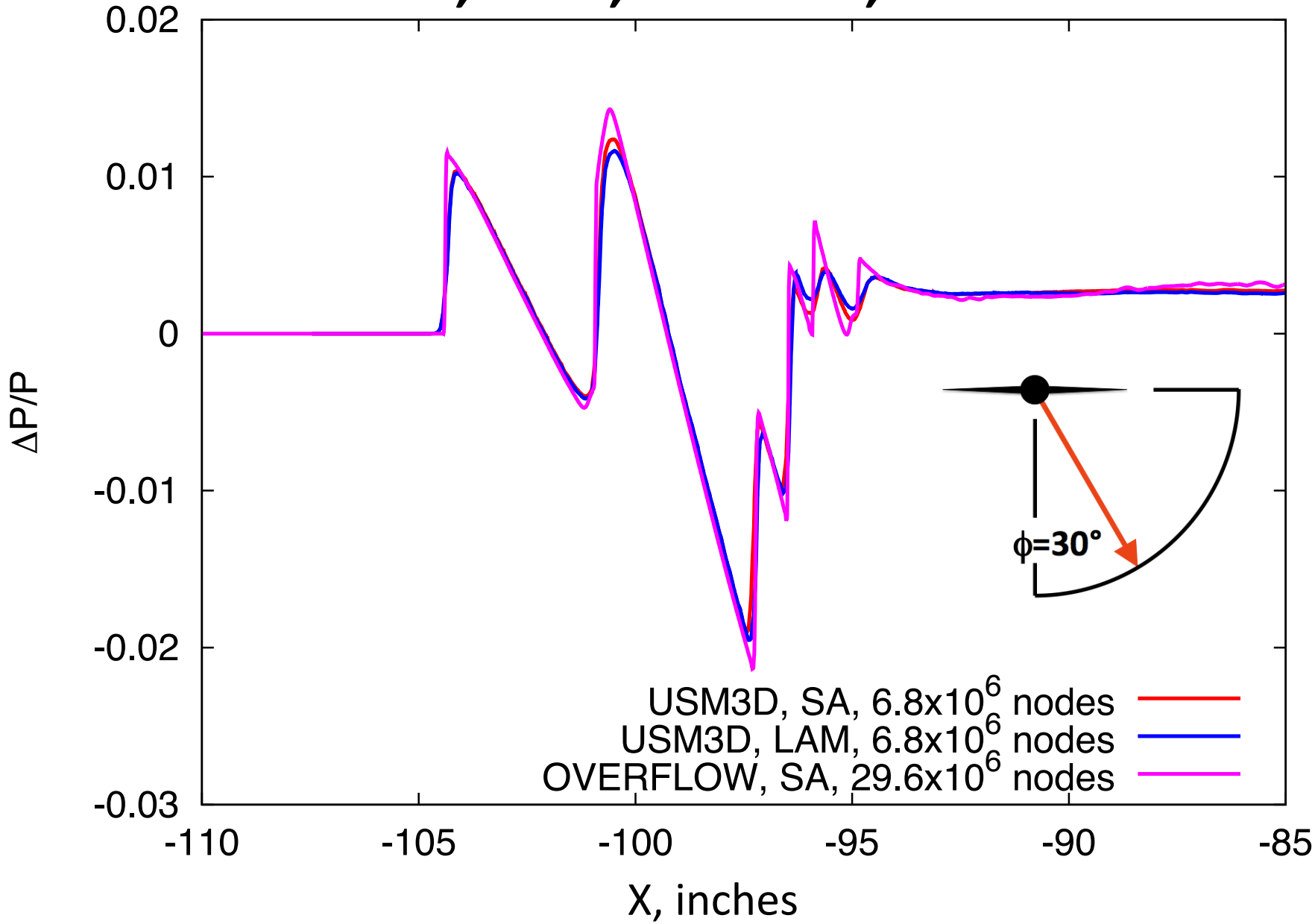

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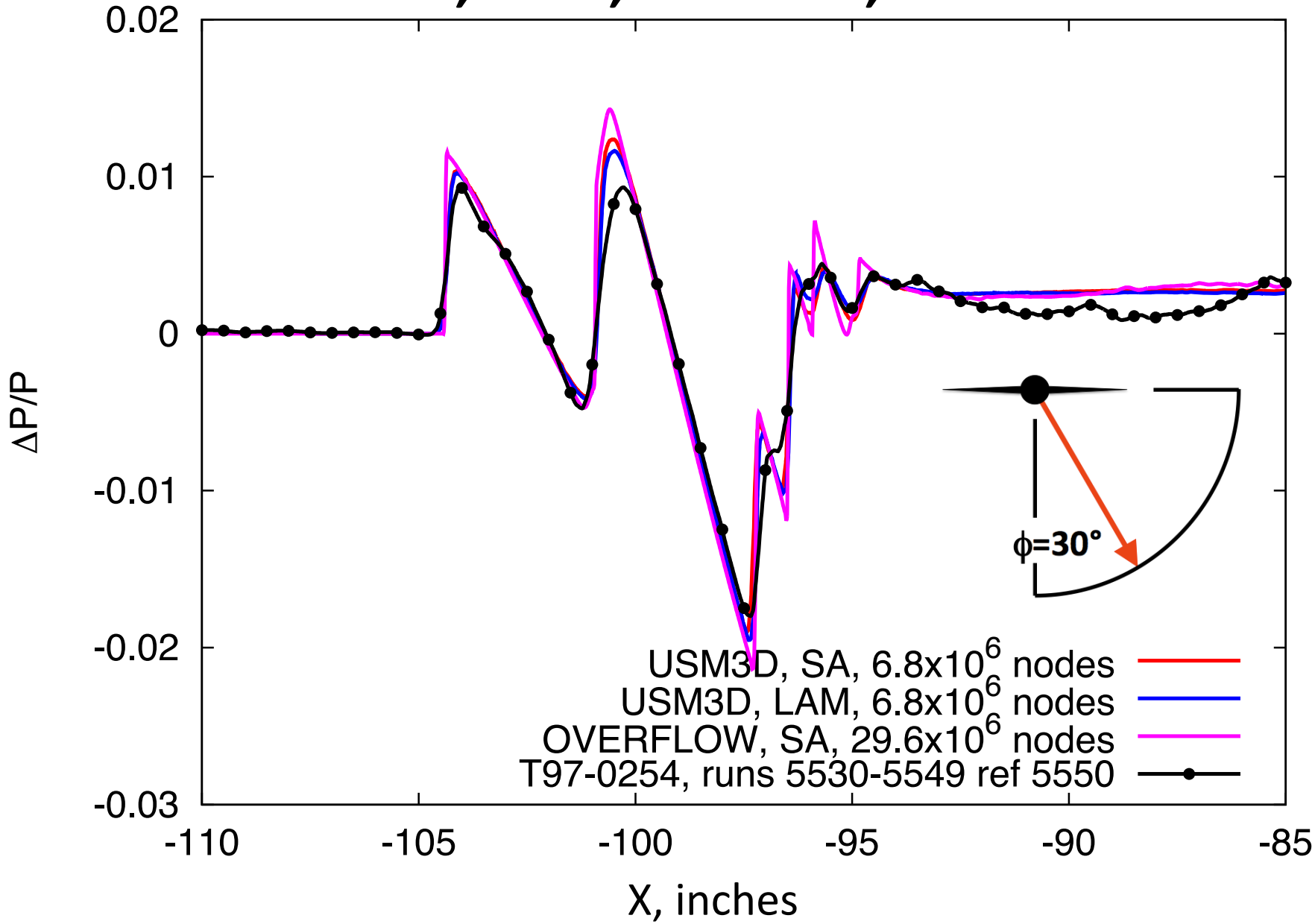

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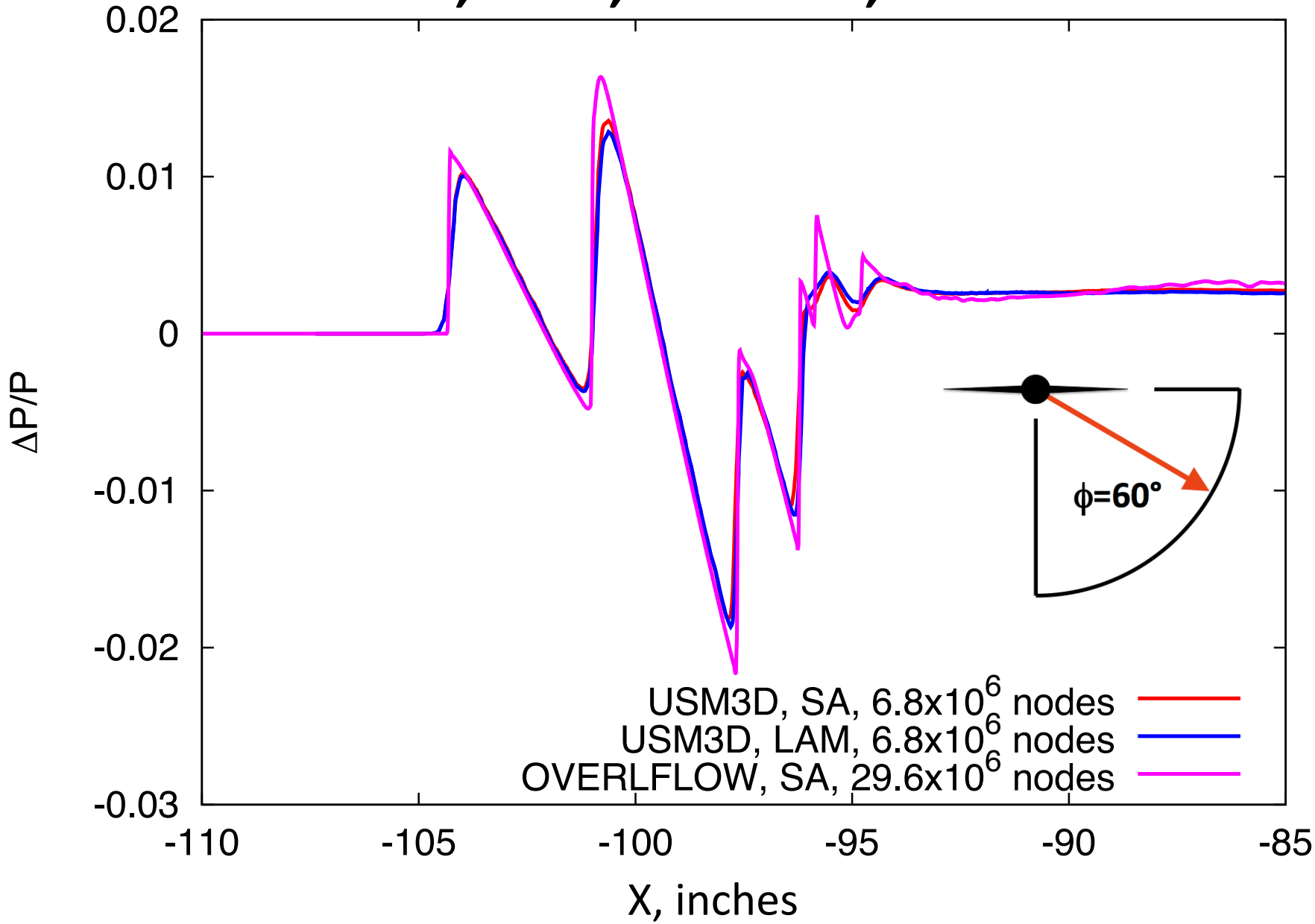
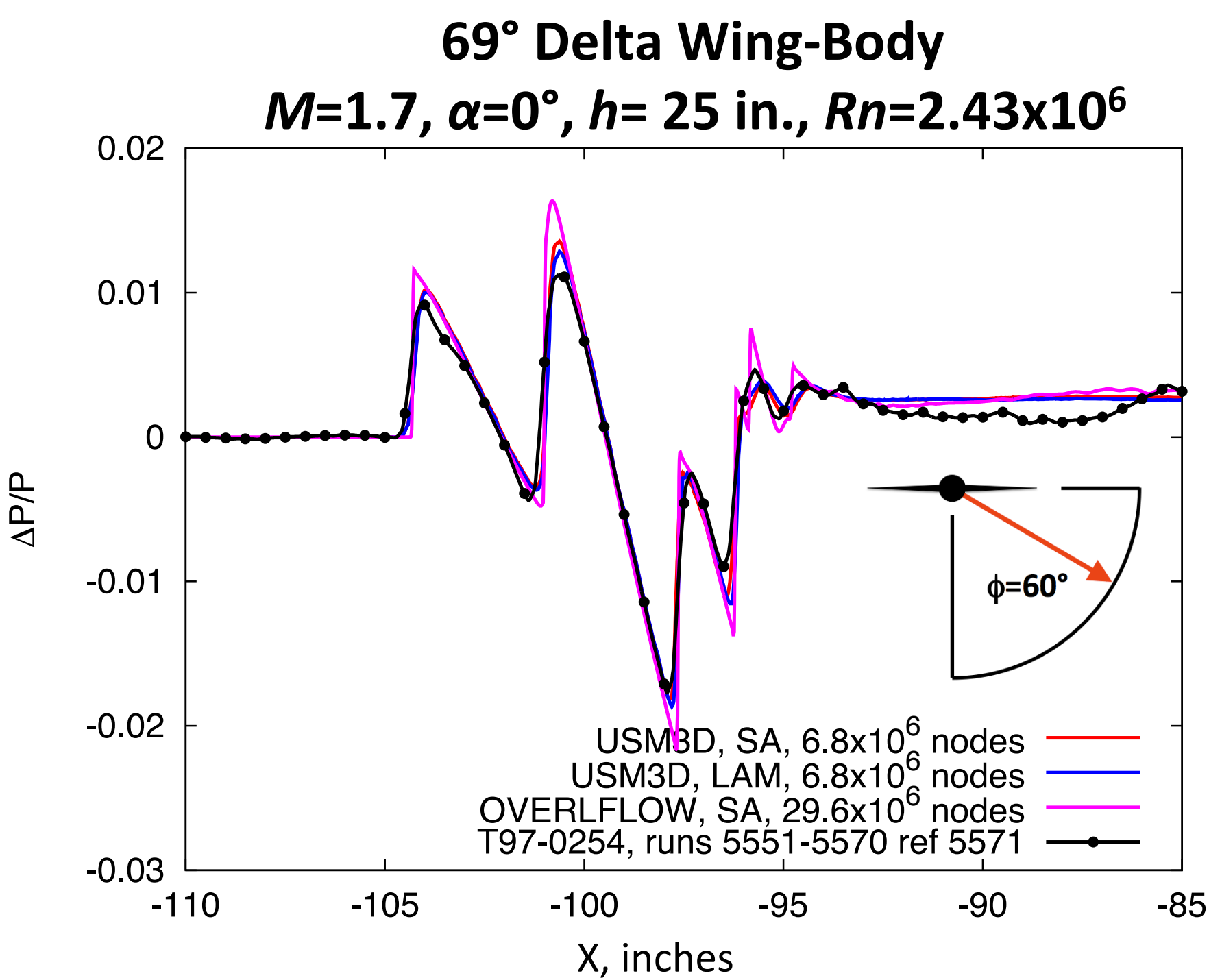
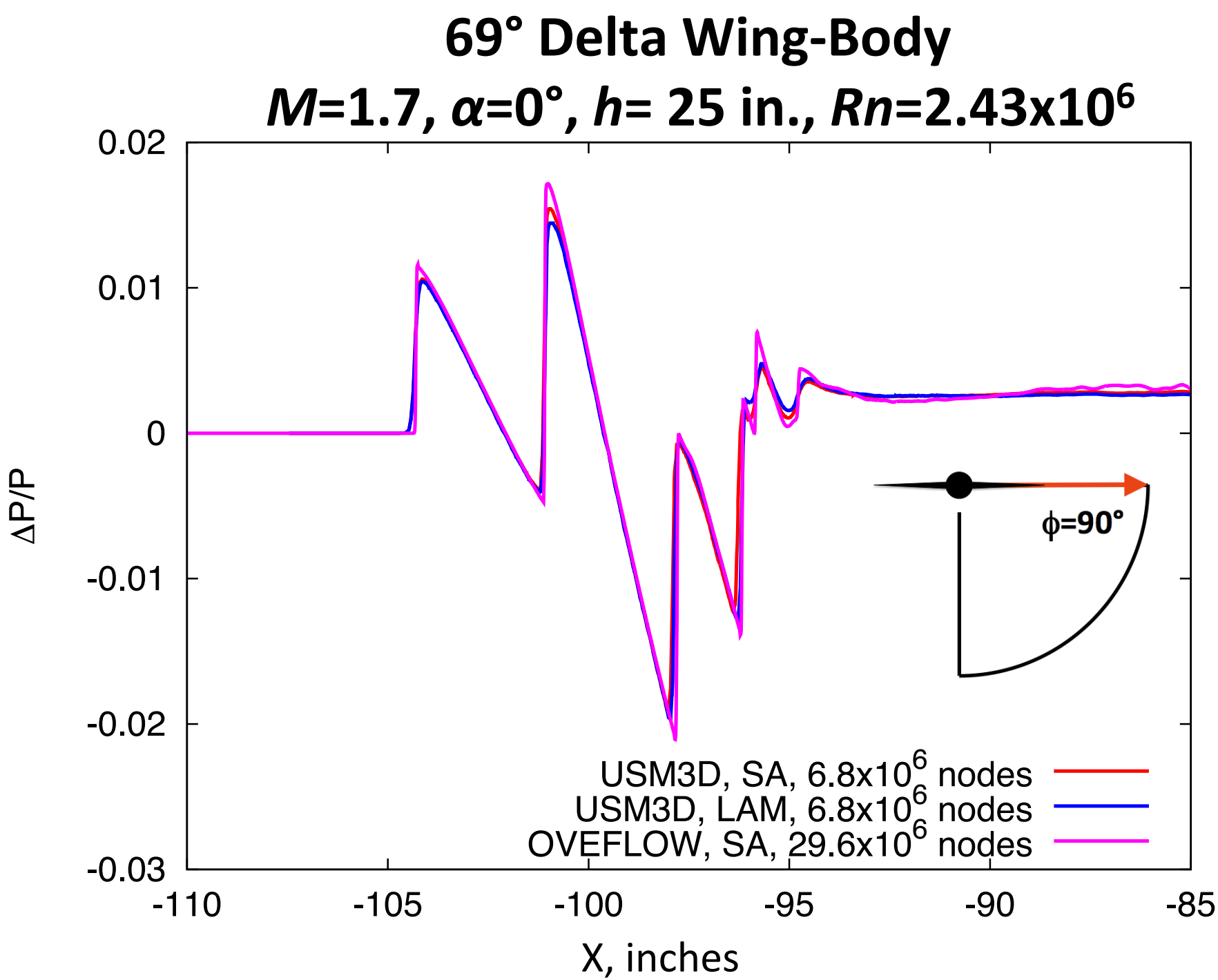
M=1.7, *α*=0°, *h*= 25 in., *Rn*=2.43x10^6

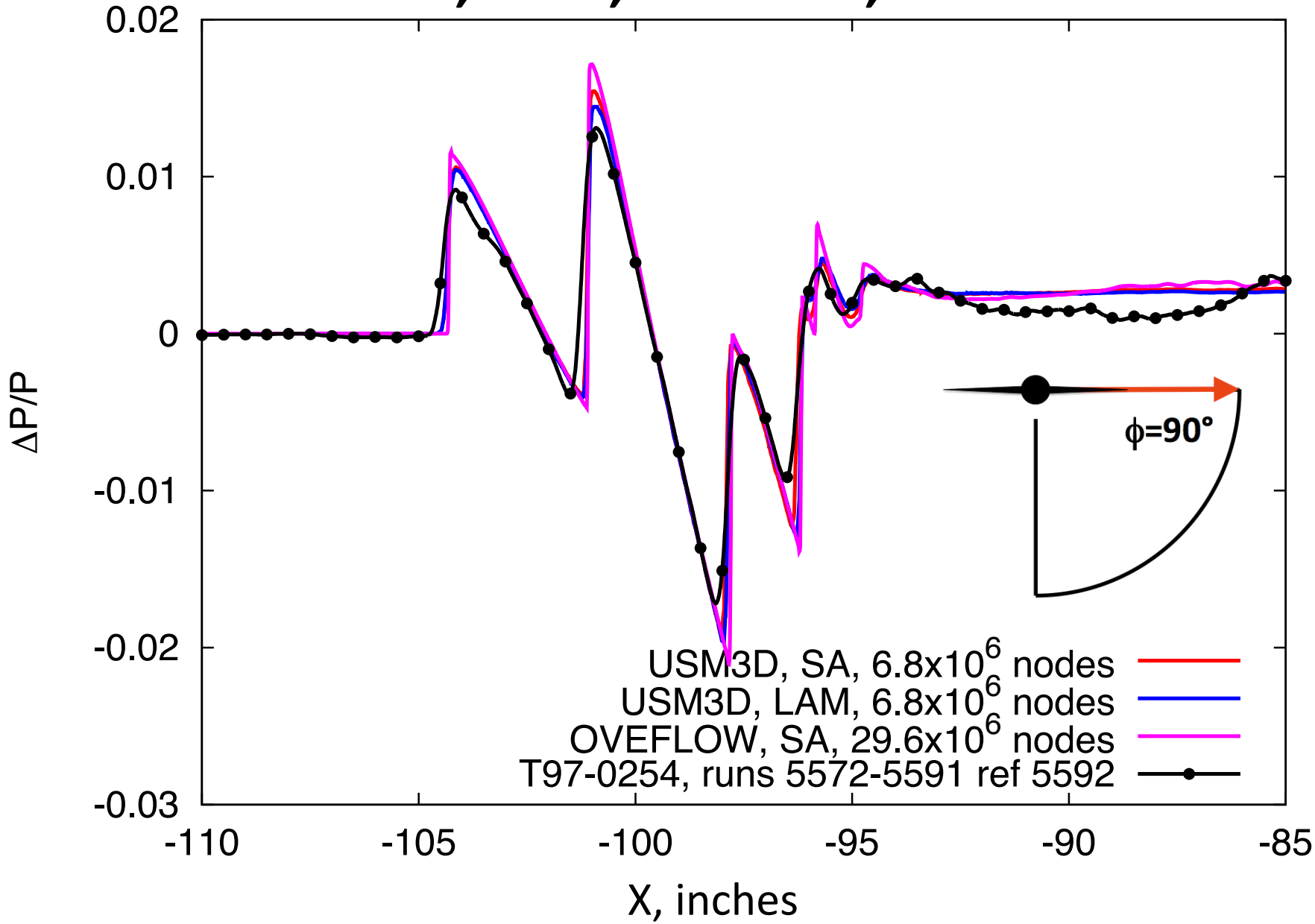



69° Delta Wing-Body
M=1.7, α=0°, h= 25 in., Rn=2.43x10^6
0.02
0.01
0
-0.01
-0.02
-0.03
ΔP/P
-110
-105
-100
-95
-90
-85
X, inches
ϕ=60°
USM3D, SA, 6.8x10^6 nodes
USM3D, LAM, 6.8x10^6 nodes
OVERLFLOW, SA, 29.6x10^6 nodes
T97-0254, runs 5551-5570 ref 5571


69° Delta Wing-Body
M=1.7, α=0°, h= 25 in., Rn=2.43x10^6
0.02
0.01
0
-0.01
-0.02
-0.03
ΔP/P
-110
-105
-100
-95
-90
-85
X, inches
ϕ=90°
USM3D, SA, 6.8x10^6 nodes
USM3D, LAM, 6.8x10^6 nodes
OVEFLOW, SA, 29.6x10^6 nodes

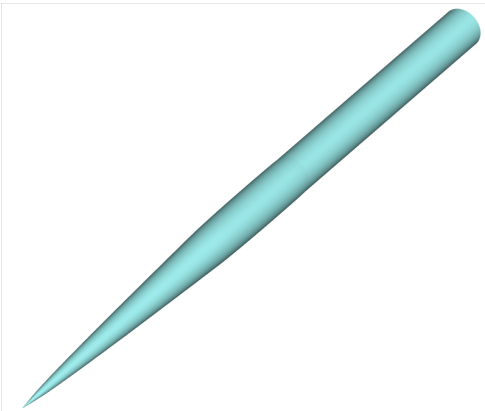
69° Delta Wing-Body

M=1.7, *α*=0°, *h*= 25 in., *Rn*=2.43x10^6

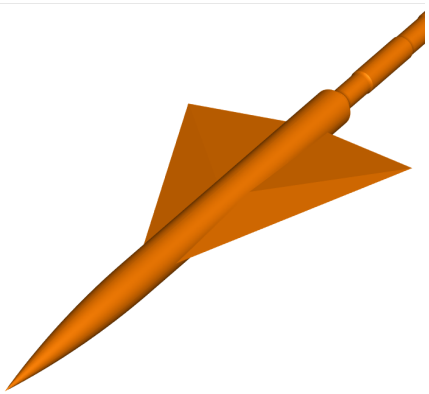


Outline

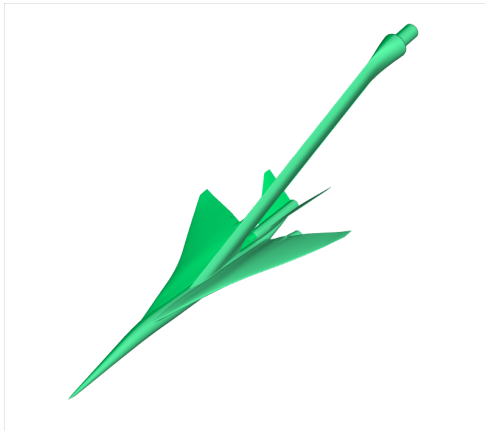
- Motivation
- Computational Models
  - USM3D
  - OVERFLOW
- Computational Grid Methodology
- **Results**



Seeb-ALR



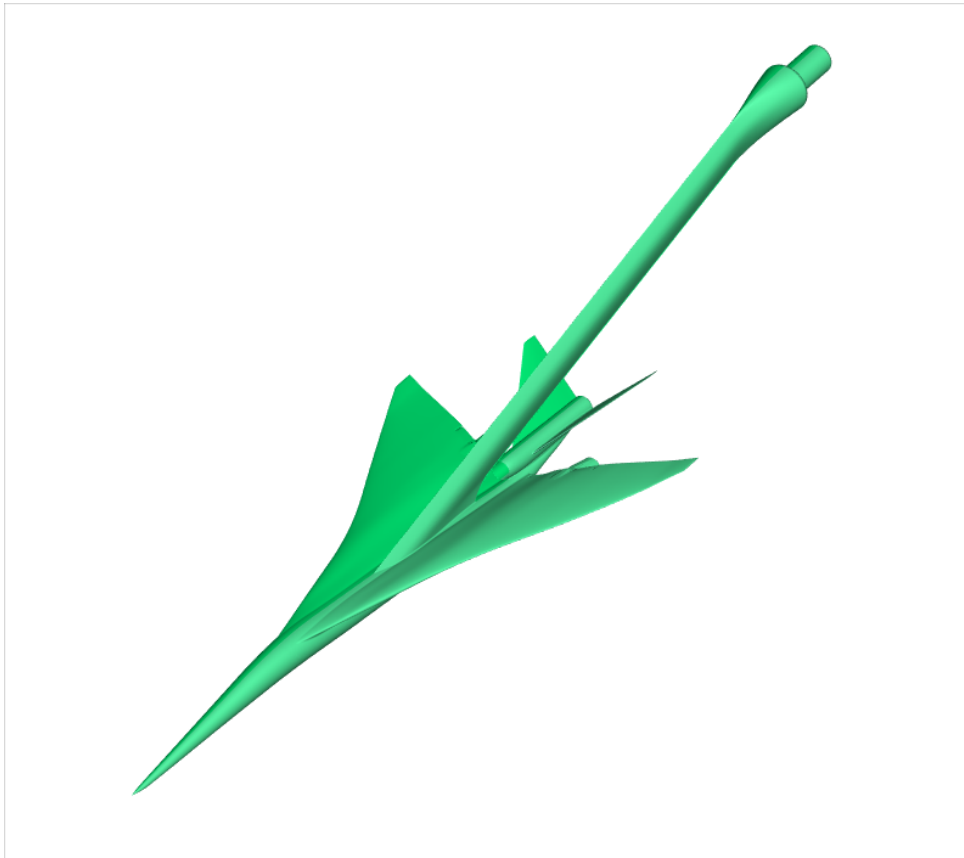
69° Delta Wing-Body



LM 1021

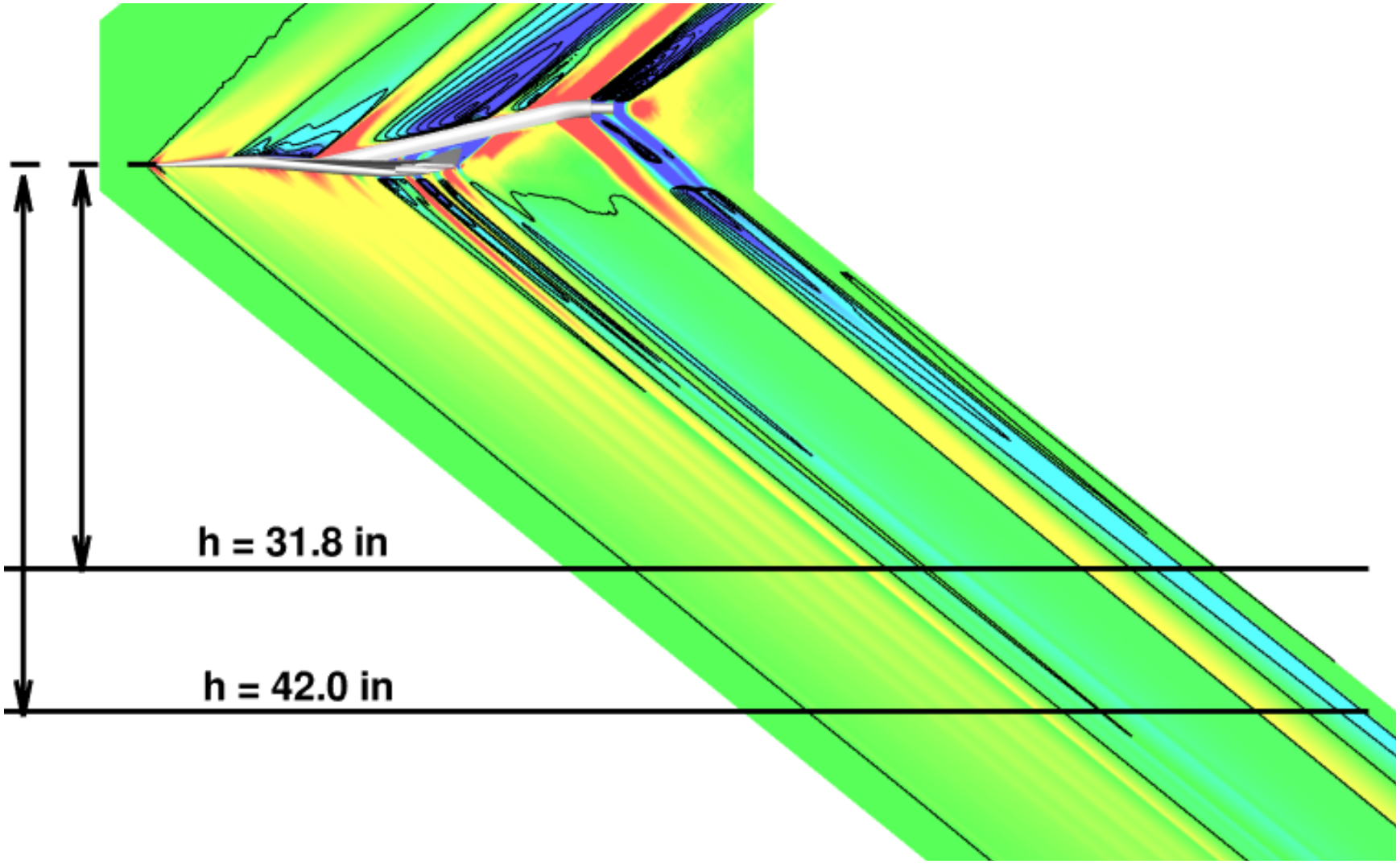
Conclusions

Lockheed Martin 1021 Model

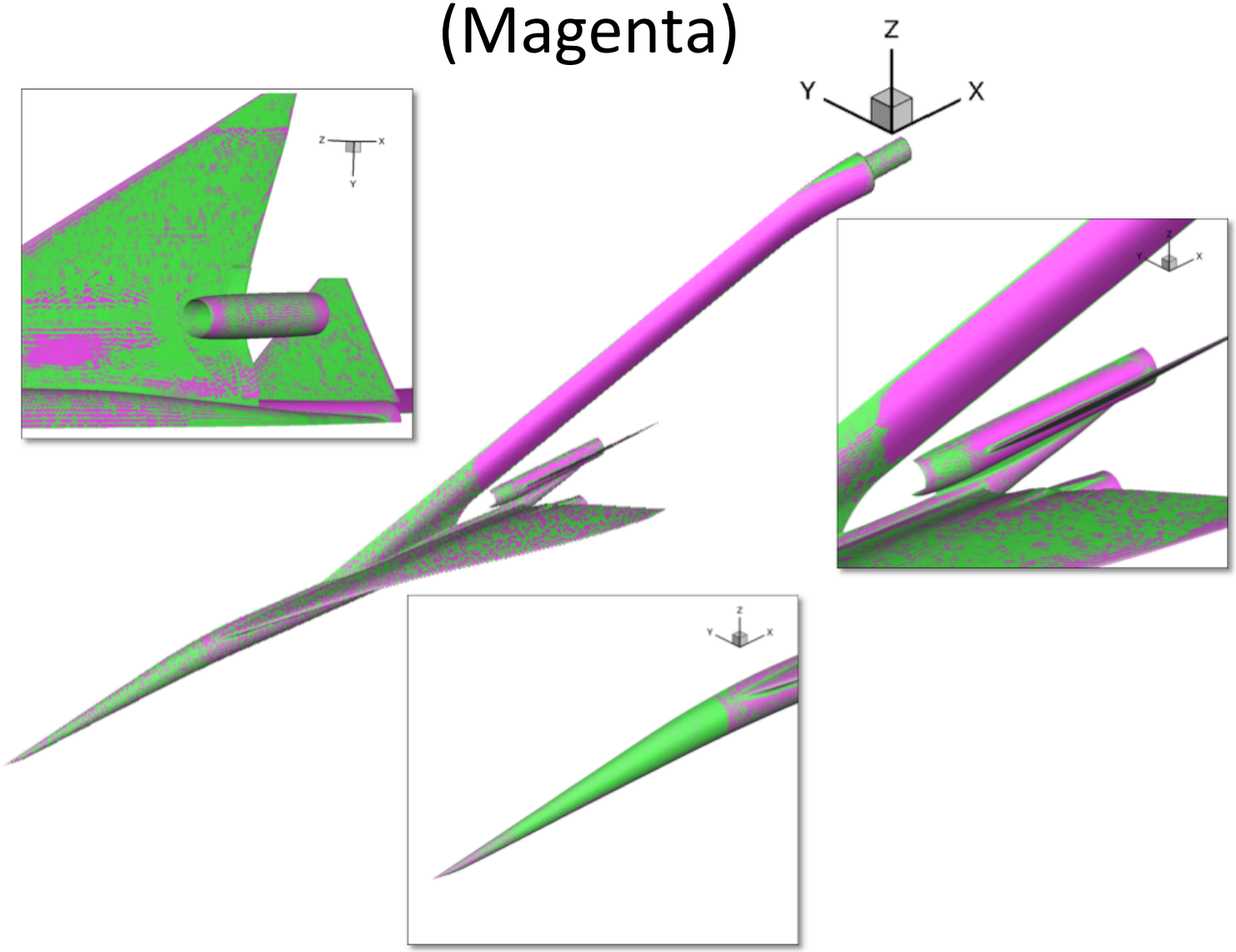


M=1.6, α=2.1°, L_{Ref} = 22.365 in., Rn=8.10x10^6

Mach Line Contours Superimposed on the Cp Contours M=1.6, α=2.1°, Rn=0.395x10^6

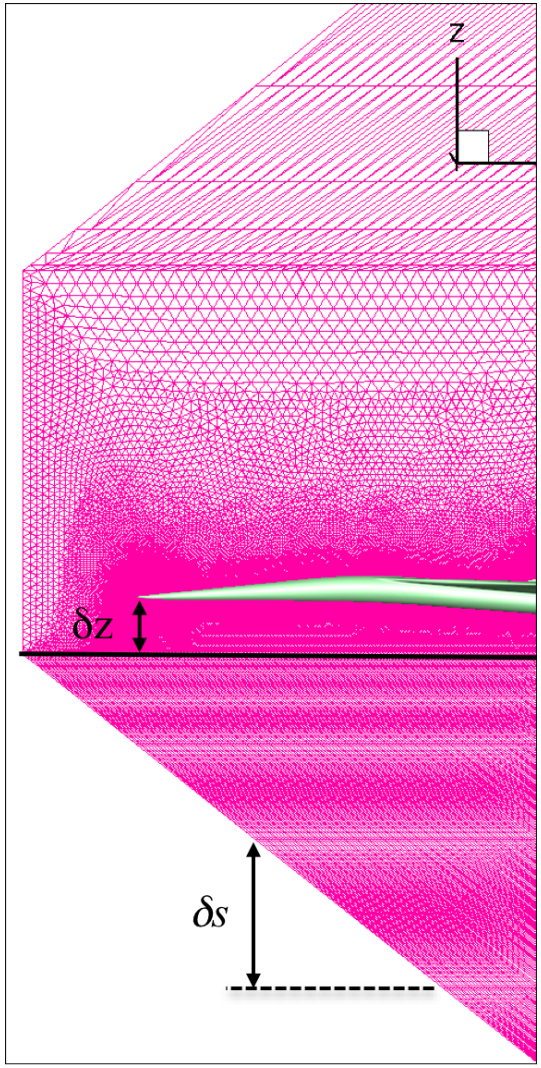


Geometric Differences Between 1021 As-built Geometry (Green), and Workshop Geometry (Magenta)

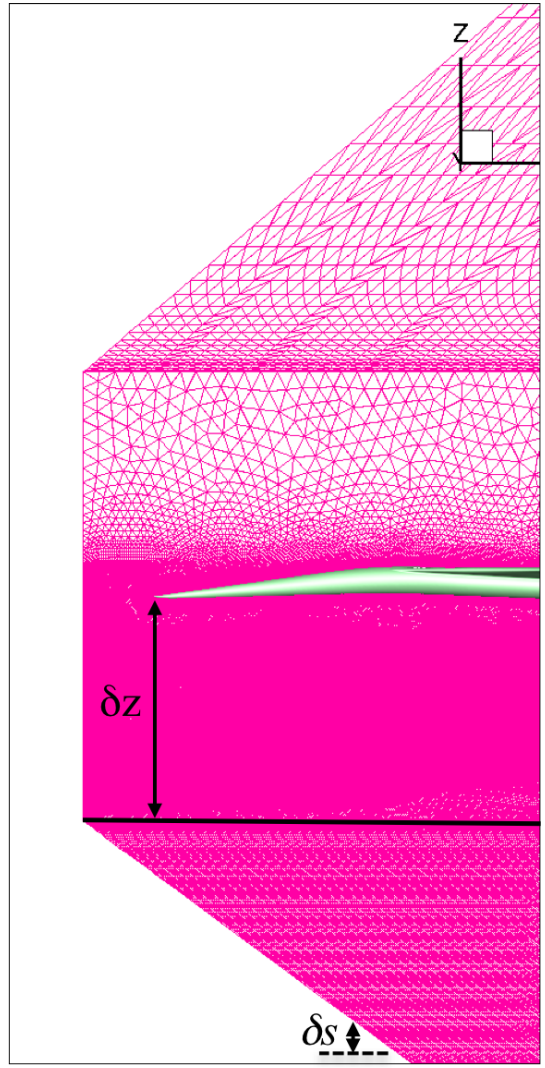


Lockheed Martin 1021 Model

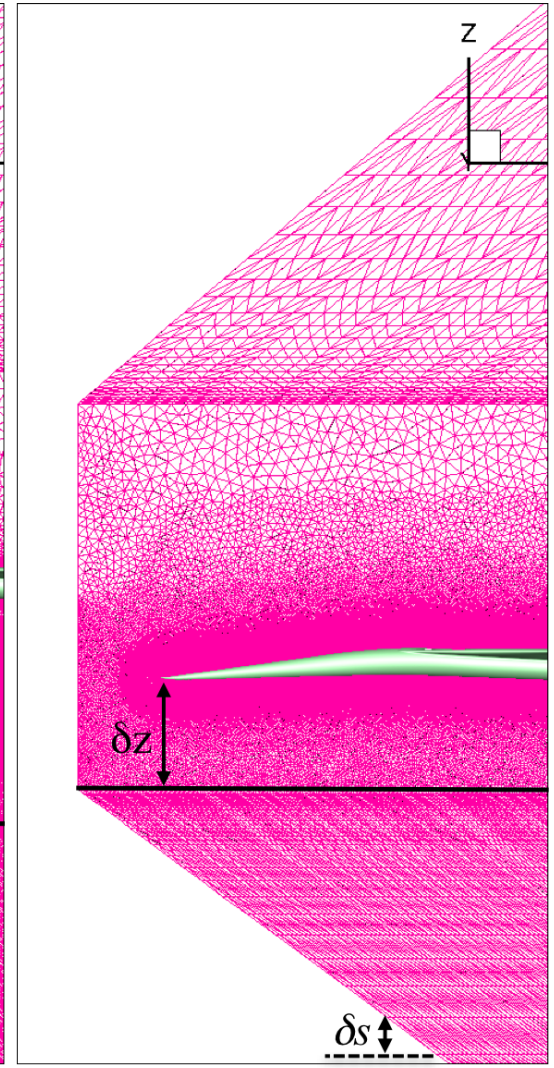
AFLR3 and BG



V-Grid and MCAP

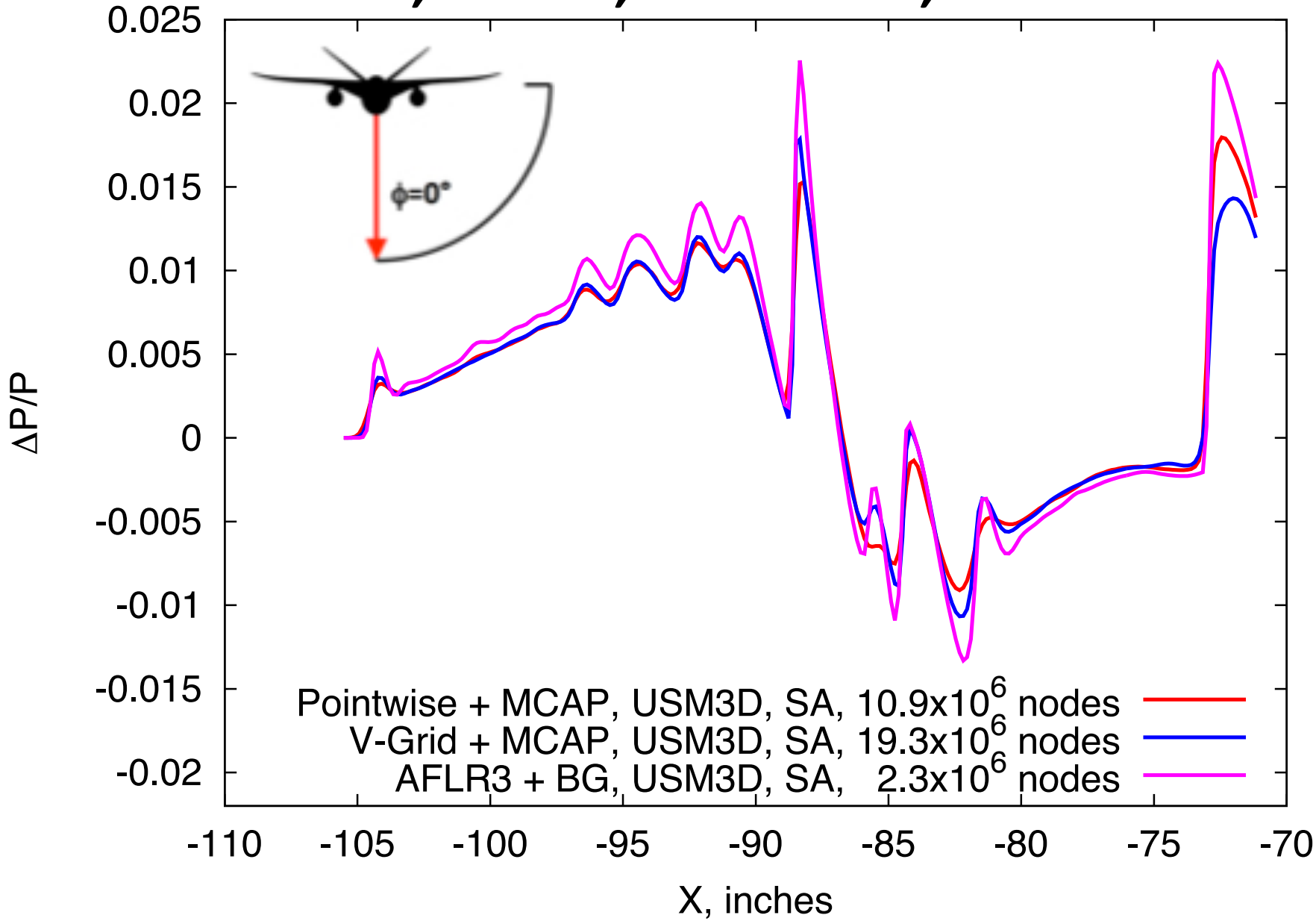


Pointwise and MCAP



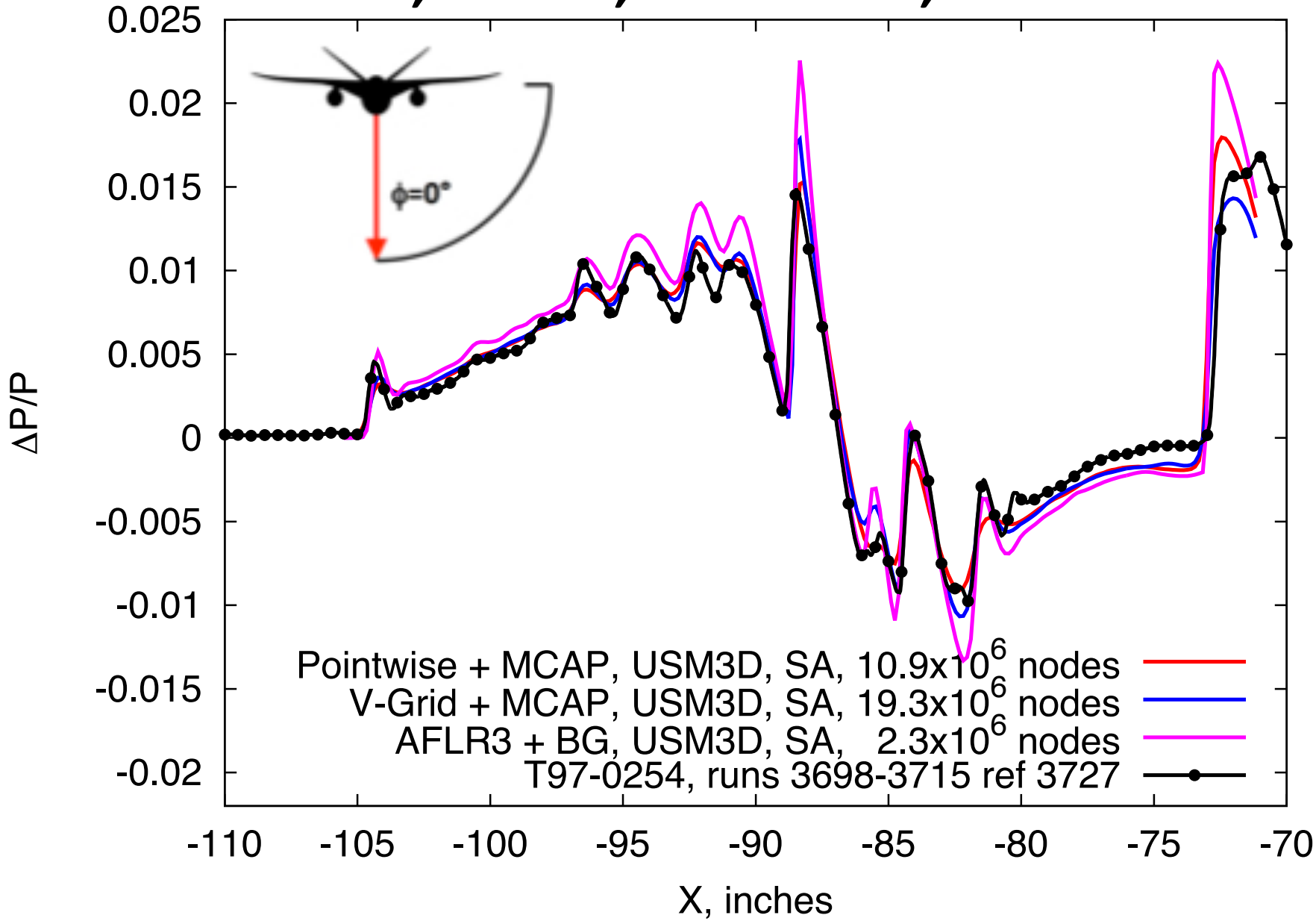
Mesh Effects for 1021 Model

M=1.6, α=2.1°, h= 31.8 in., Rn=8.10x10^6



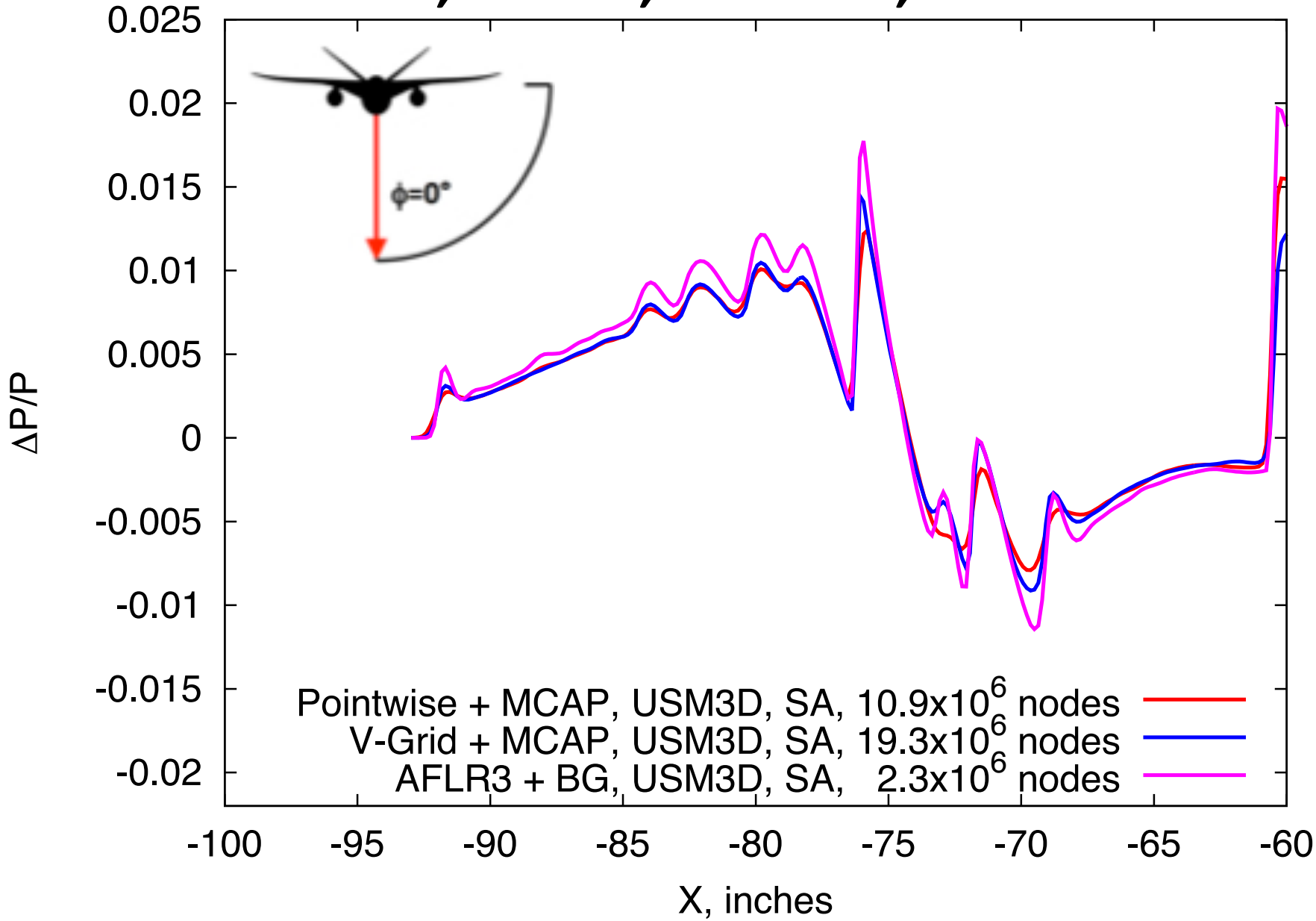
Mesh Effects for 1021 Model

M=1.6, α=2.1°, h= 31.8 in., Rn=8.10x10^6



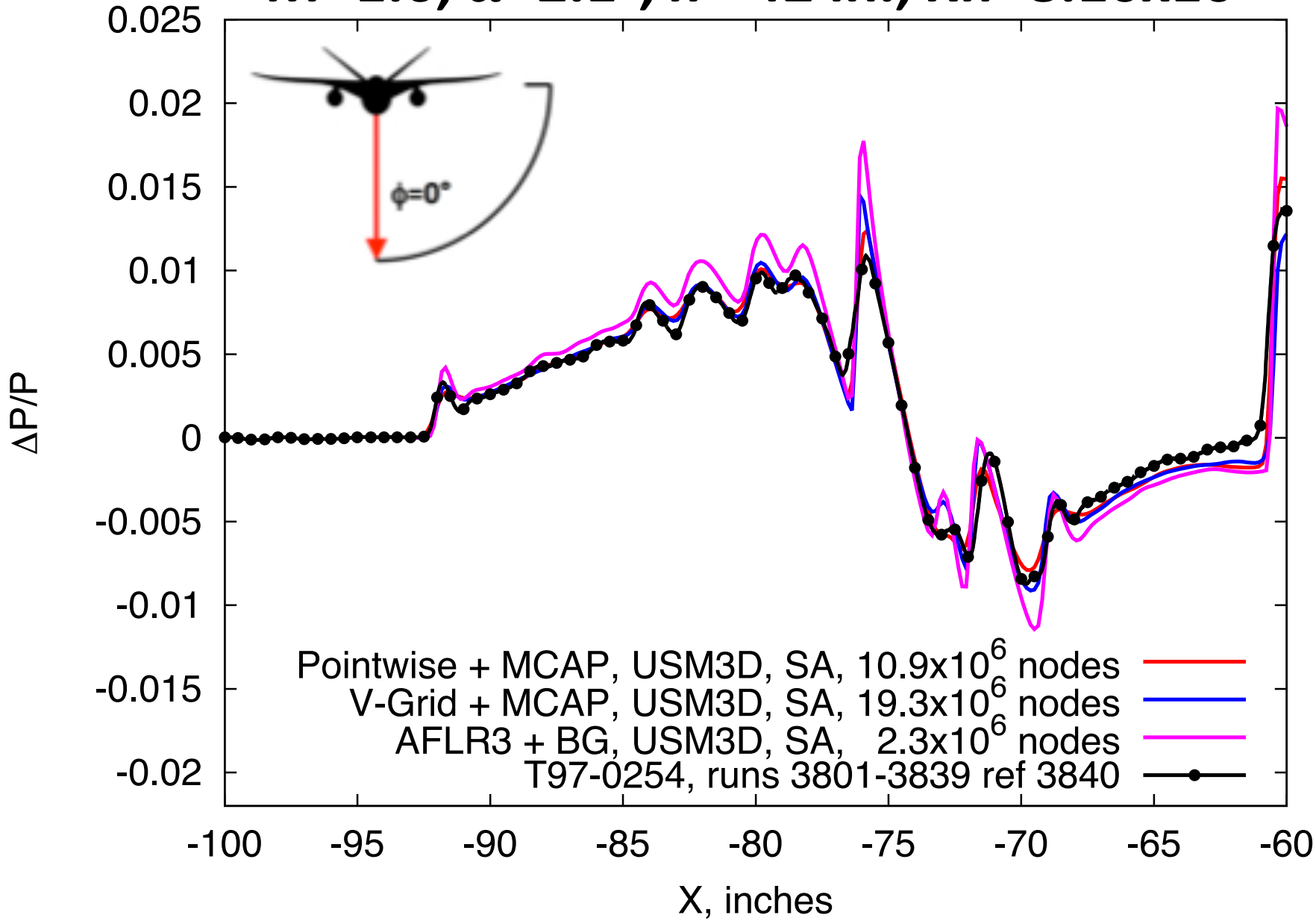
Mesh Effects for 1021 Model

M=1.6, *α*=2.1°, *h*= 42 in., *Rn*=8.10x10^6



Mesh Effects for 1021 Model

M=1.6, α=2.1°, h= 42 in., Rn=8.10x10^6



Summary

- Numerical simulations using USM3D and OVERFLOW were performed for all three geometries of the 1st AIAA Sonic Boom Prediction Workshop.

- The success is largely attributed to aligning cells with the Mach cone and stretching along Mach rays for accurate sonic boom computations.

- Solutions using the Workshop "Inflate" grid methodology provided sharper shockwaves than the MCAP.

- MCAP method produced results that more closely matched experiment.

AIAA-2014-0560

Session: APA-17, Applied CFD

Title: Computational and Experimental Assessment of Models for the First AIAA Sonic Boom Prediction Workshop

Authors: S. Cliff, D. Durston, A. Elmiligui, J. Jensen, W. Chan

Date: Tuesday, January 14th, National Harbor Conference Room 5

Time: 4:30 PM – 5:00 PM.

Questions ?