Wake Flow CFD Validation

STMD-ECF / ESM Hypersonic Transition & Turbulence Modeling Workshop

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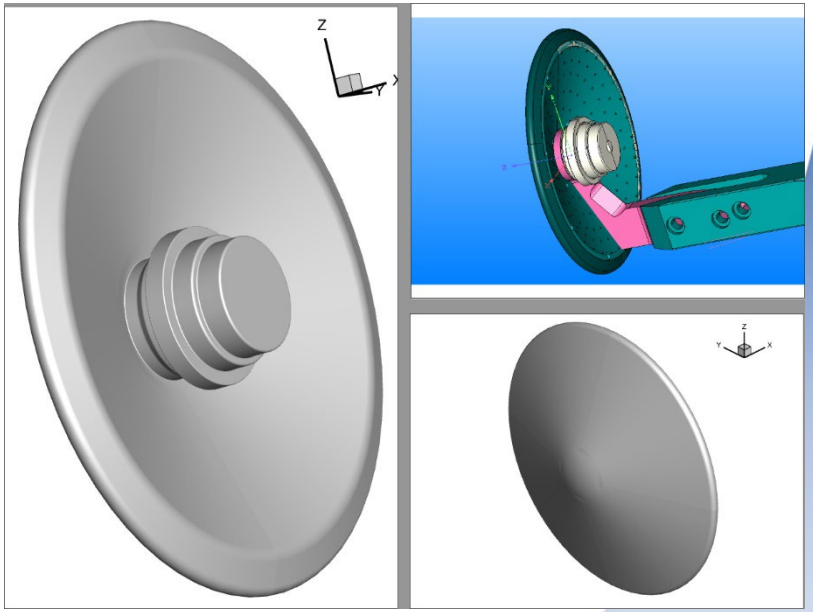
ESM Wake Flow

- **In FY 23 testing was conducted in Langley's 31-Inch Mach 10 wind tunnel to provide velocity data in the freestream and wake of a blunt body. Velocities measured using planar laser-induced fluorescence (PLIF) and femtosecond laser electronic excitation tagging (FLEET)**
  - Validation data for CFD simulations
- **Comparisons of wake flow velocity data with numerical simulation data (LAURA).**
  - Conditions: Re = **0.5**, 1.0, and 1.8 x 10^6/ft @ AoA = 0
  - PLIF data documented @ Jan 24 SciTech Forum in AIAA 2024-2323 (Re=0.5 x 10^6)

Aerothermodynamics Branch

ESM Wake Flow

- **Geometry and Grid**
  - Model – 5” diameter 70-degree sphere-cone (representative of hypersonic inflatable aerodynamic (HIAD) decelerator type vehicle)
  - Surface and volume grids created using Pointwise.
  - Volume grid ~ 23 million cells total w/ 16.3 million in wake (no plane of symmetry)
    - 71,500 surface cells
  - 97 blocks decomposed into 635 blocks.
  - No sting in CFD
  - Attempt to align grid with shear layer



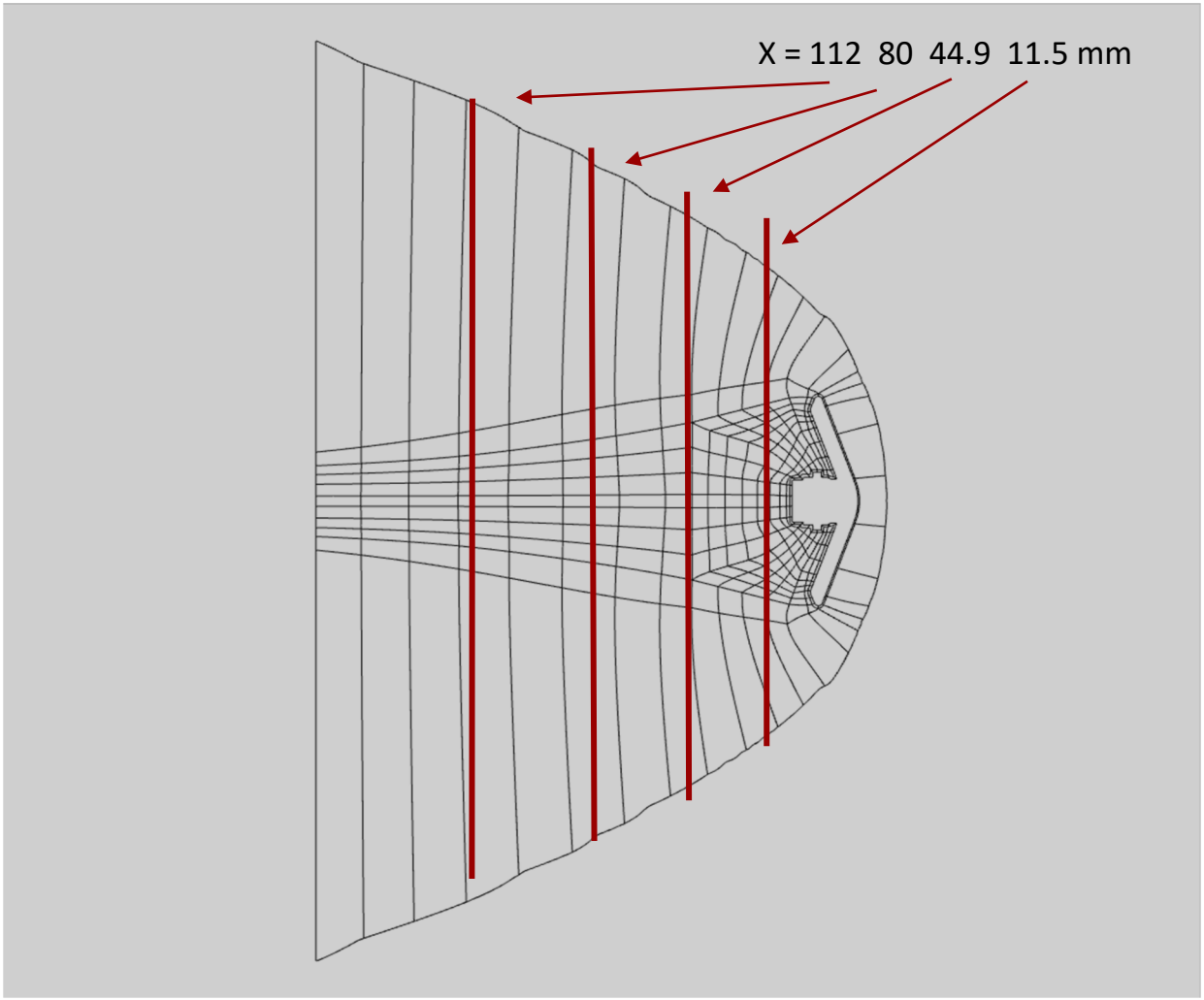
Aerothermodynamics Branch

ESM Wake Flow

- **Langley Aerothermodynamic Upwind Relaxation Algorithm (LAURA)**
  - While developed for hypersonic blunt body flows, validated for slender as well.
  - Perfect gas and reacting gas flows in thermal and chemical non-equilibrium
  - 3D, axisymmetric, 2D flows
  - Steady state and 1^{st}/ 2^{nd} order in time
  - Laminar and turbulent flow – algebraic, 1 and 2 equation models
  - Grid alignment routine – outer domain follows shock/ $Cell_{Re}$=3 near wall region
  - Structured grid systems
  - Simulation data - **3D perfect gas, steady state and 1^{st} order time, laminar**
    - **Conditions – 31-Inch Mach 10 freestream at 0.5 x 10^6/ft, T_w = 300K**

Aerothermodynamics Branch

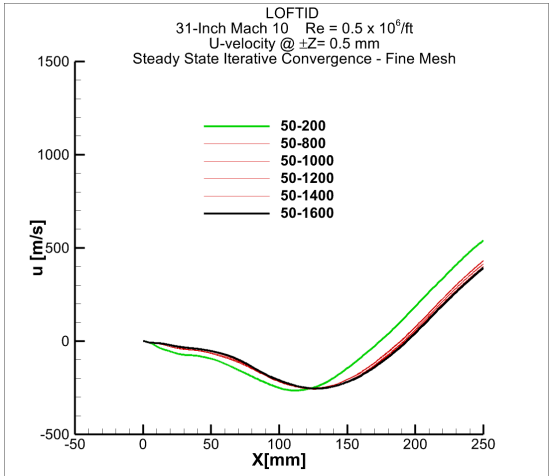
ESM Wake Flow

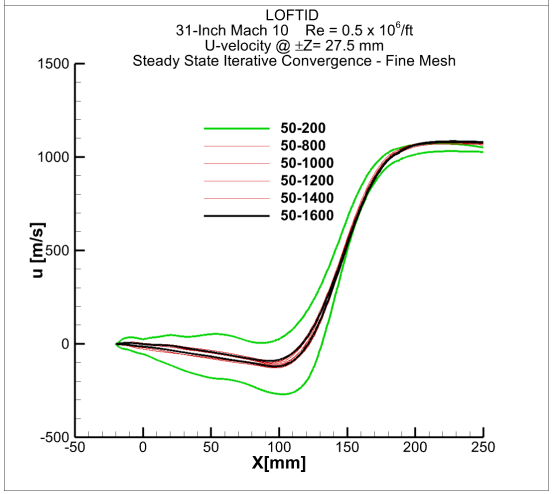


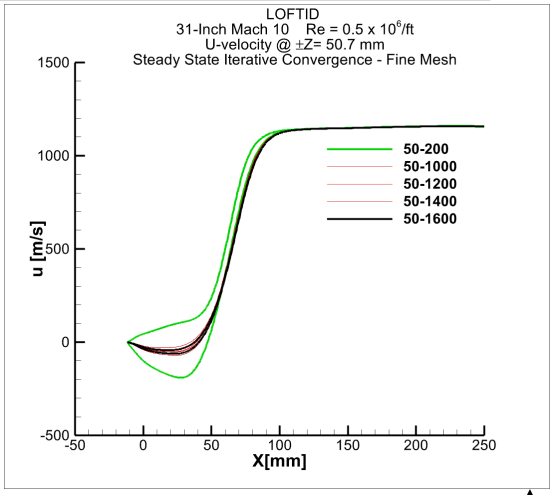
Aerothermodynamics Branch

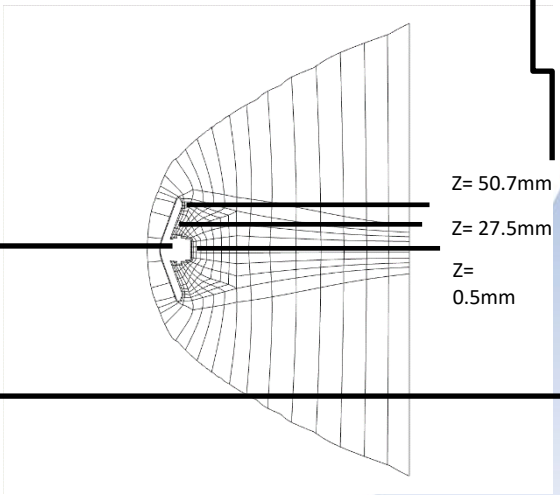
ESM Wake Flow

Iterative Convergence









ESM Wake Flow

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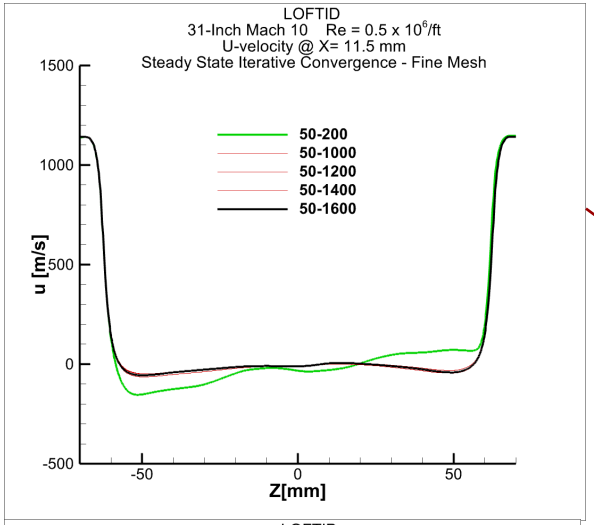
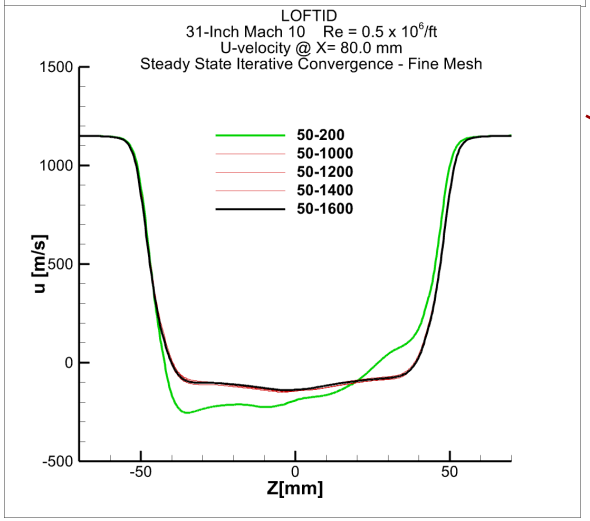
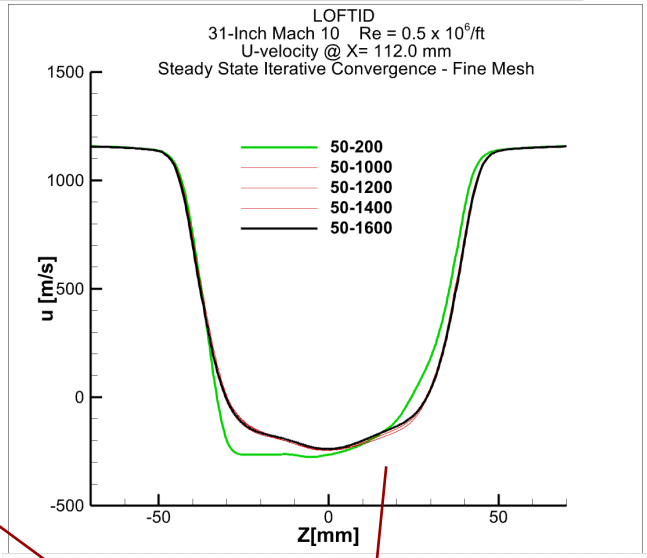
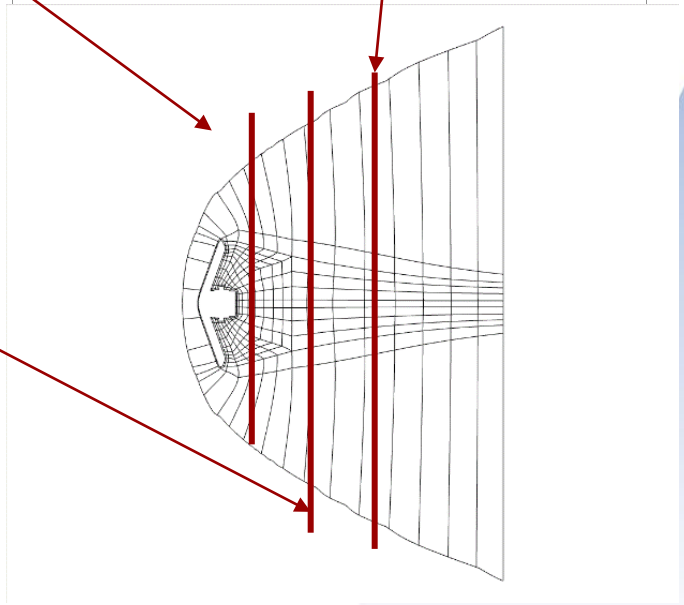


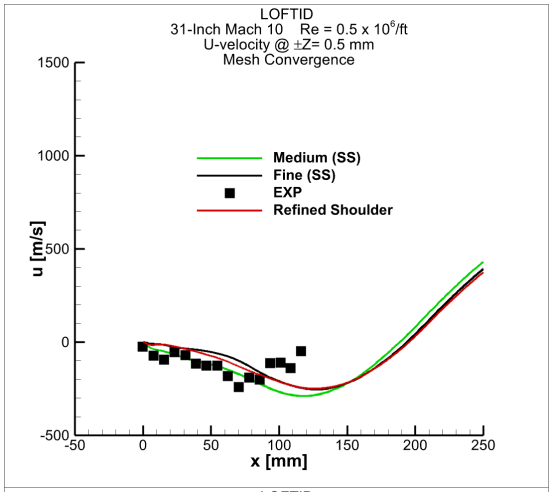


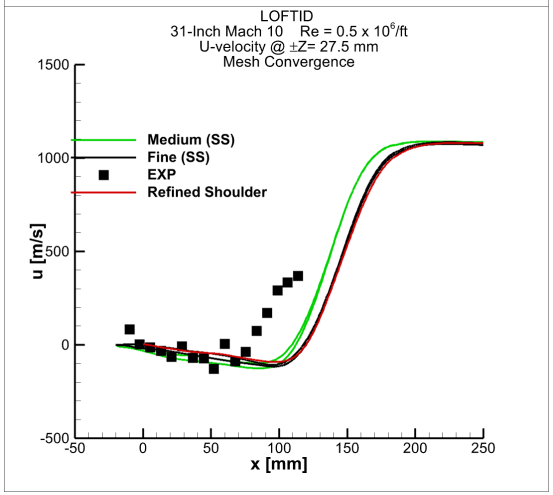


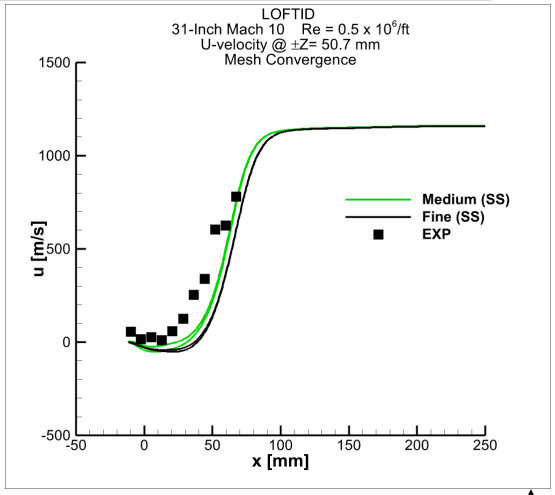


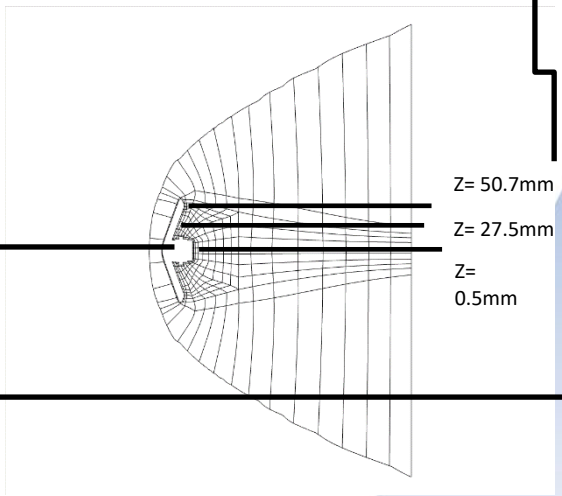
ESM Wake Flow

Mesh Convergence









ESM Wake Flow

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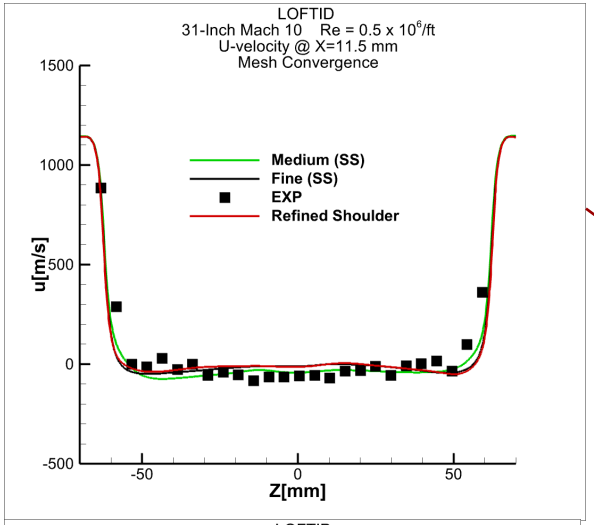
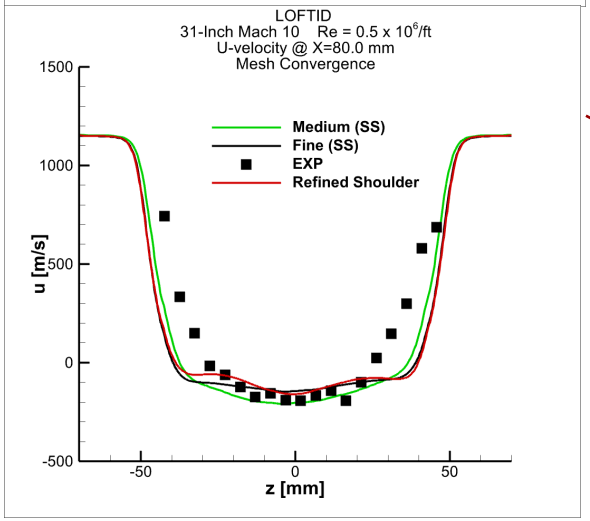
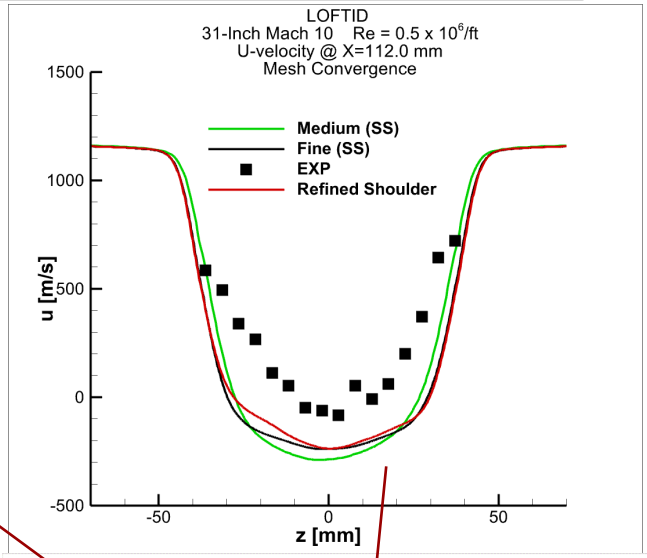
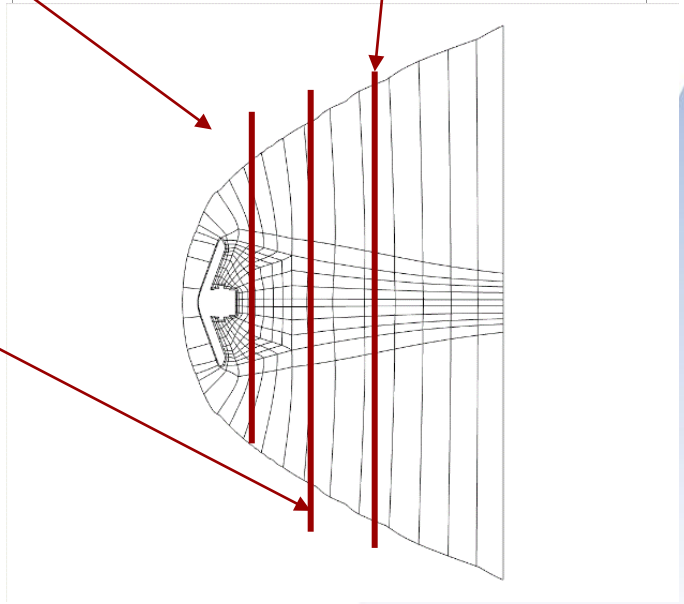
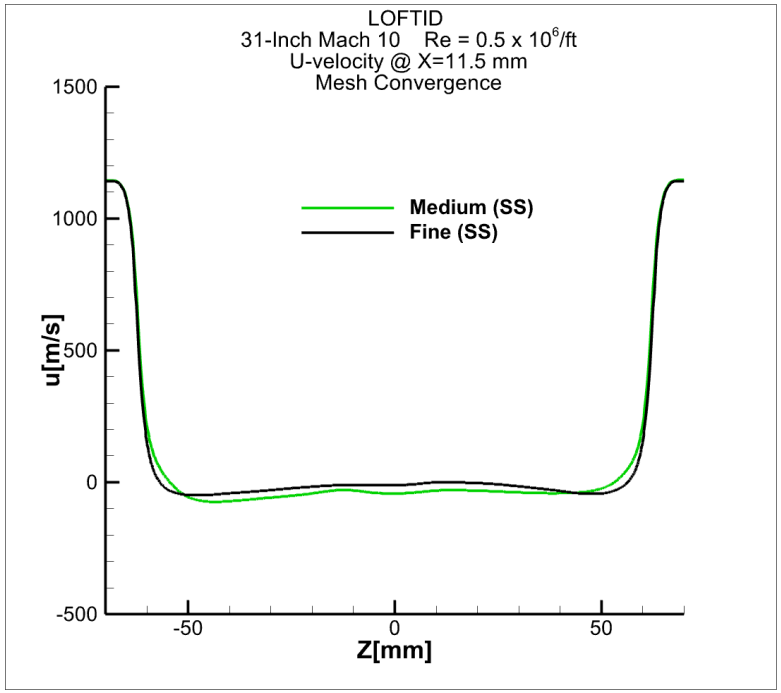


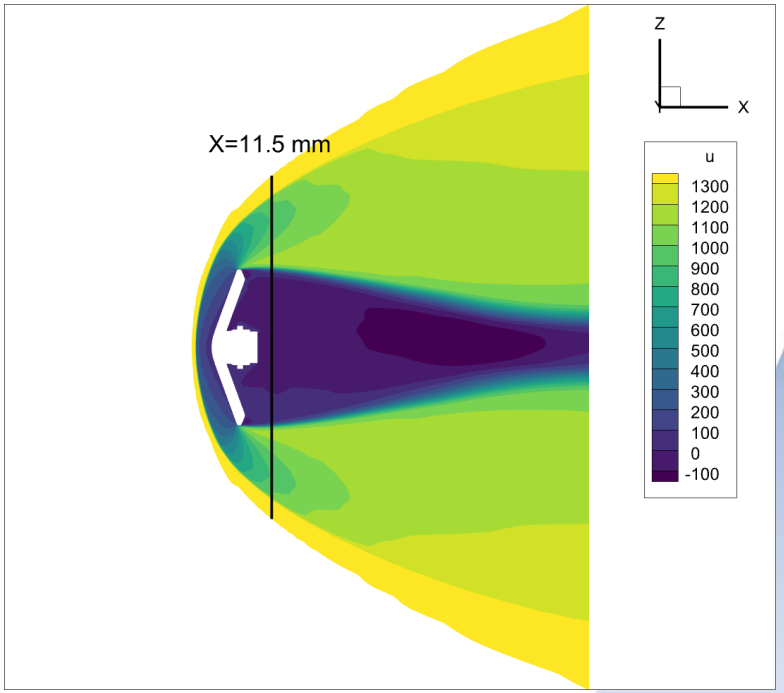






ESM Wake Flow





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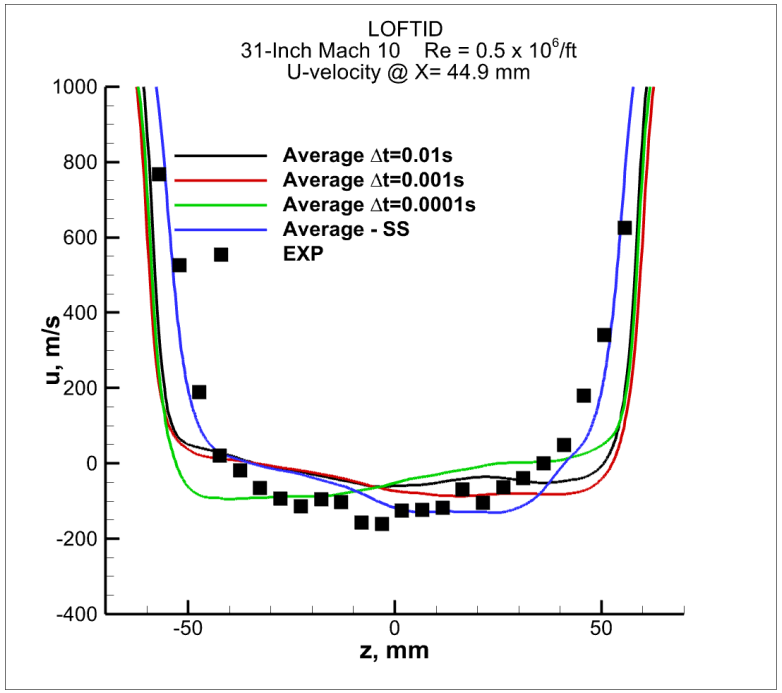
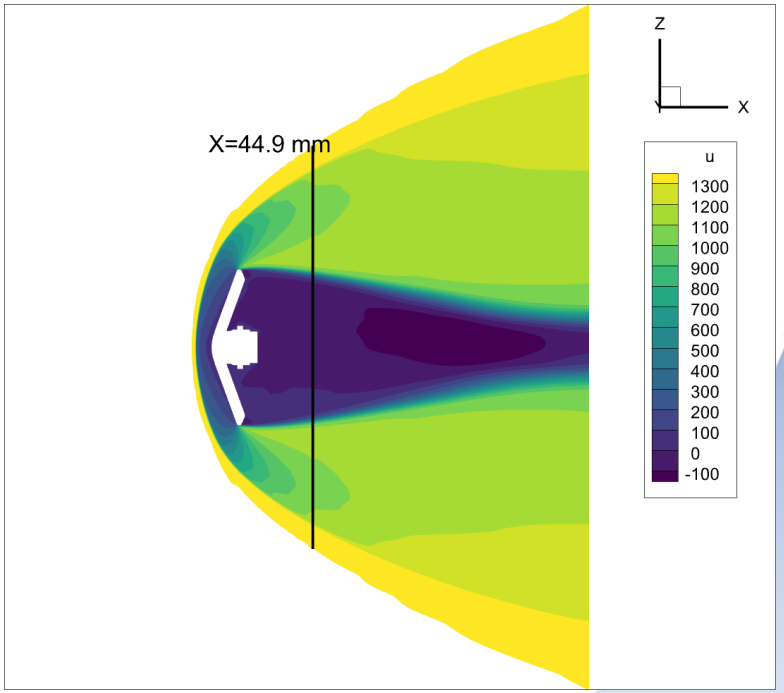
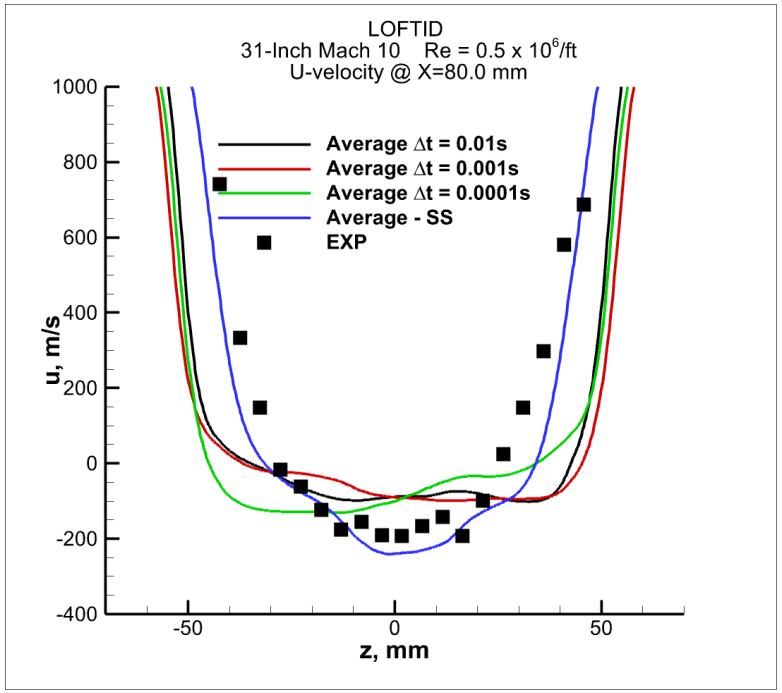
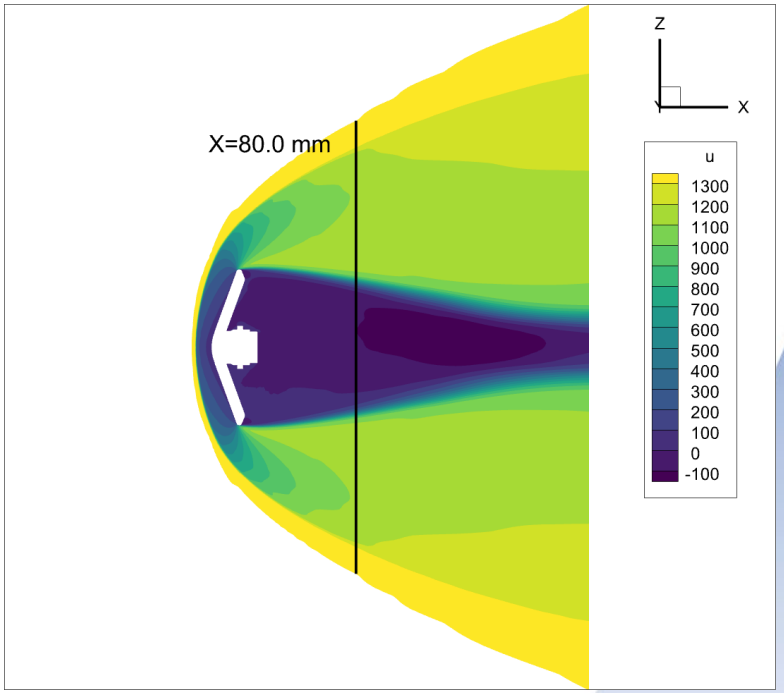




ESM Wake Flow





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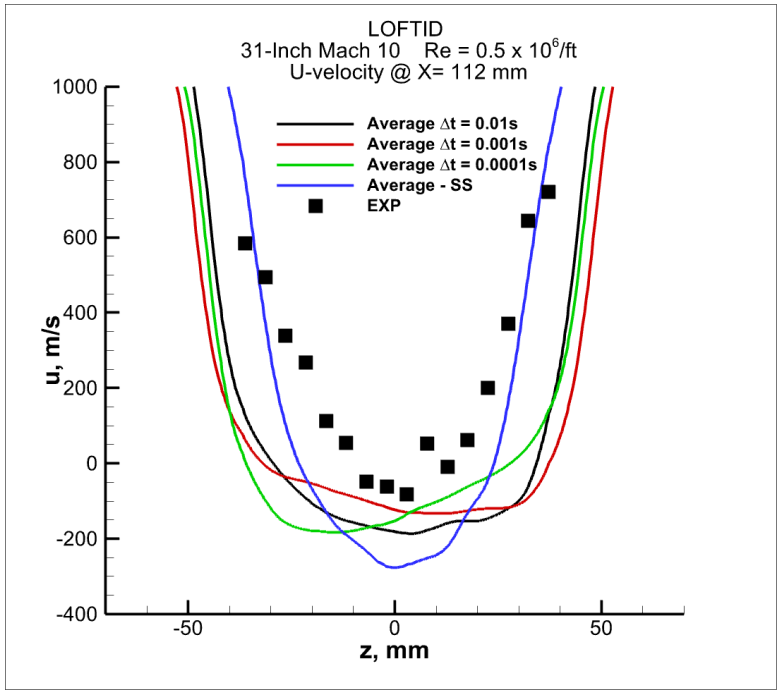

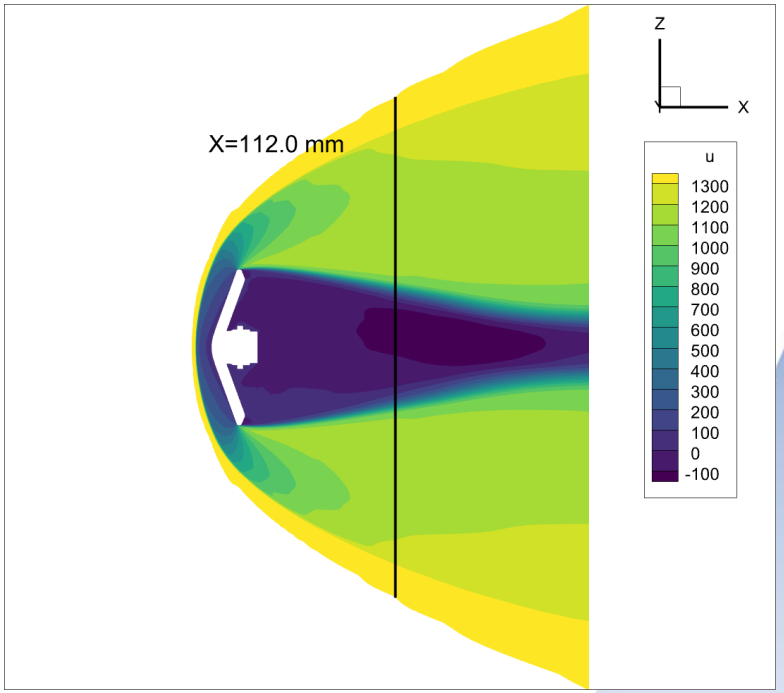

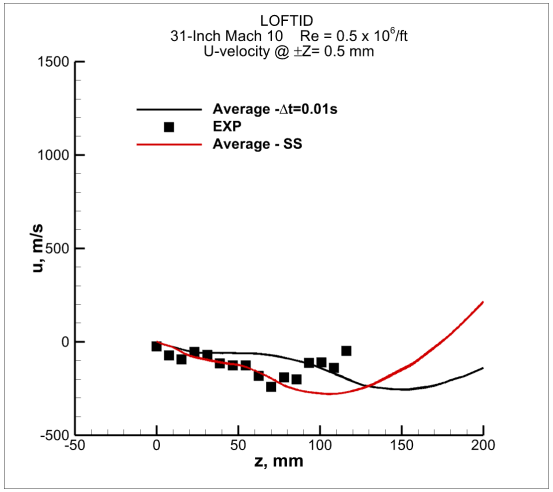
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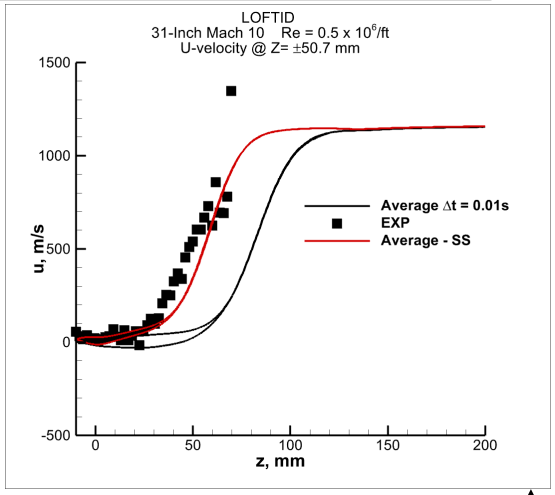
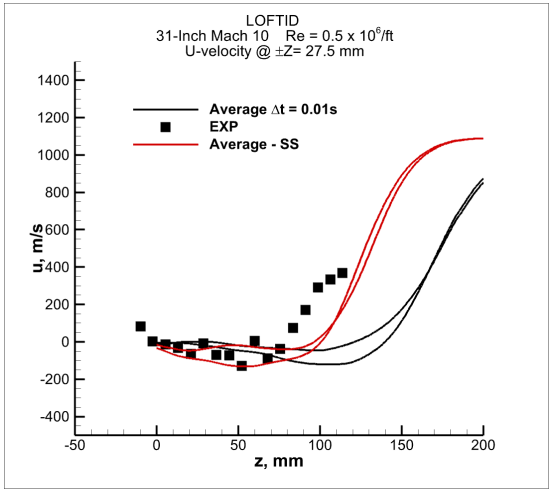
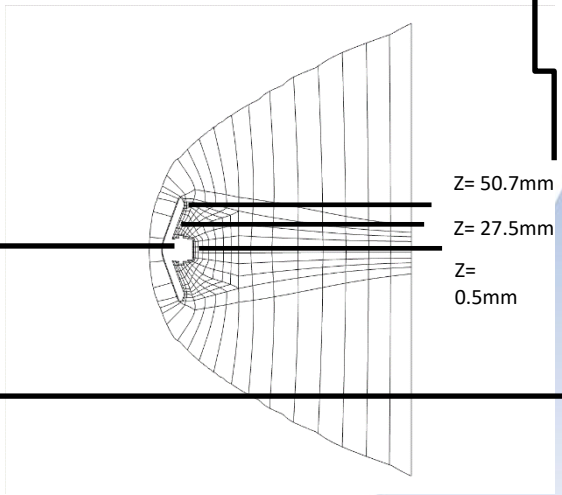
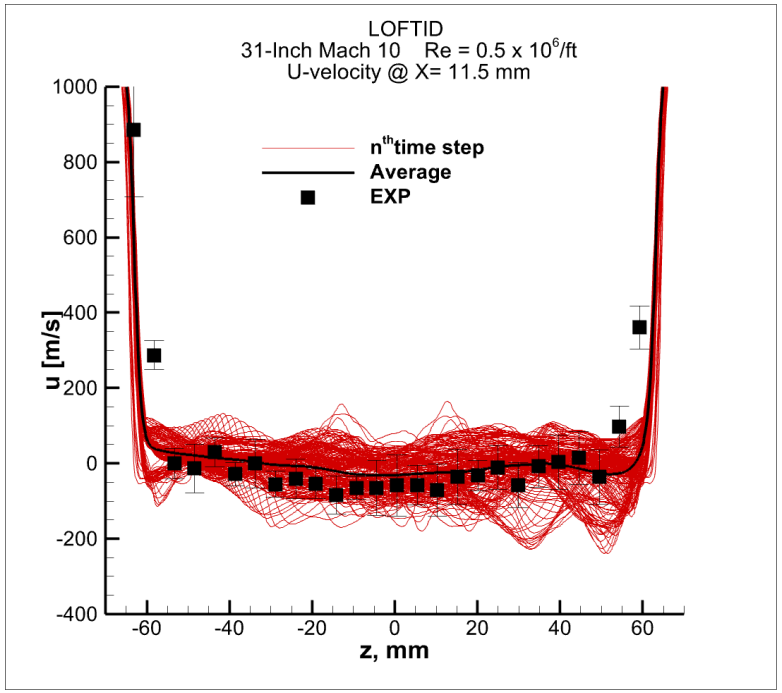
31-Inch Mach 10 Re = 0.5 x 10^6/ft
U-velocity @ ±Z= 0.5 mm
Average -Δt=0.01s
EXP
Average - SS
u, m/s
z, mm

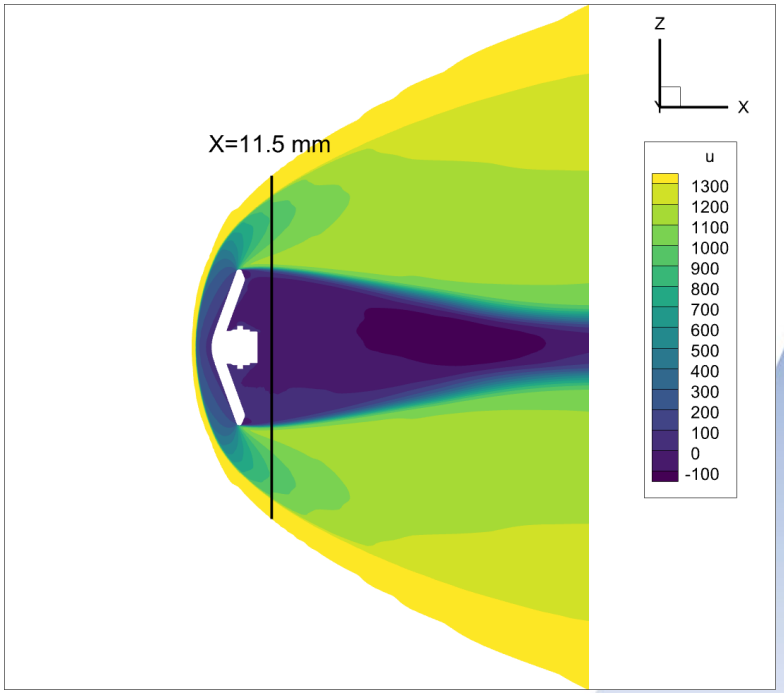

LOFTID
31-Inch Mach 10 Re = 0.5 x 10^6/ft
U-velocity @ Z= ±50.7 mm
Average Δt = 0.01s
EXP
Average - SS
u, m/s
z, mm


LOFTID
31-Inch Mach 10 Re = 0.5 x 10^6/ft
U-velocity @ ±Z= 27.5 mm
Average Δt = 0.01s
EXP
Average - SS
u, m/s
z, mm


Z= 50.7mm
Z= 27.5mm
Z= 0.5mm

ESM Wake Flow





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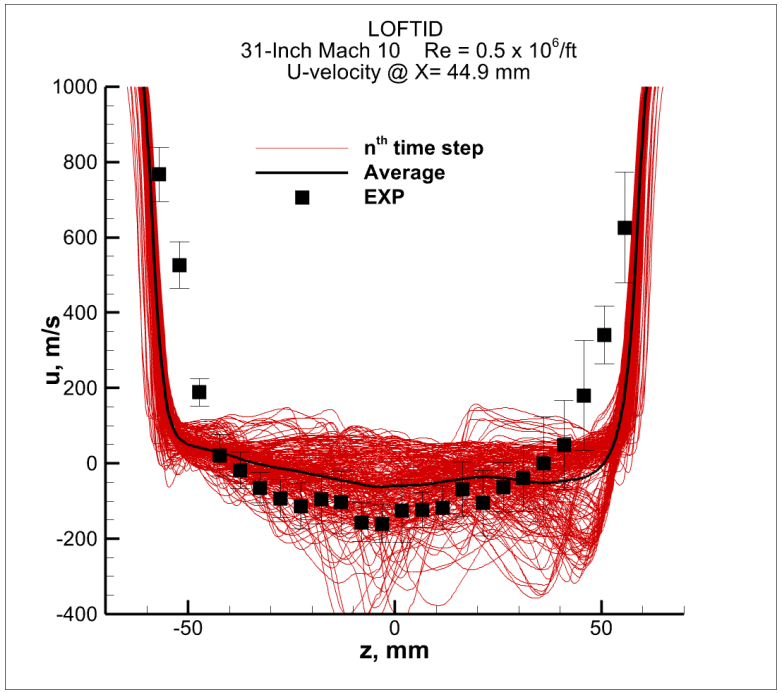

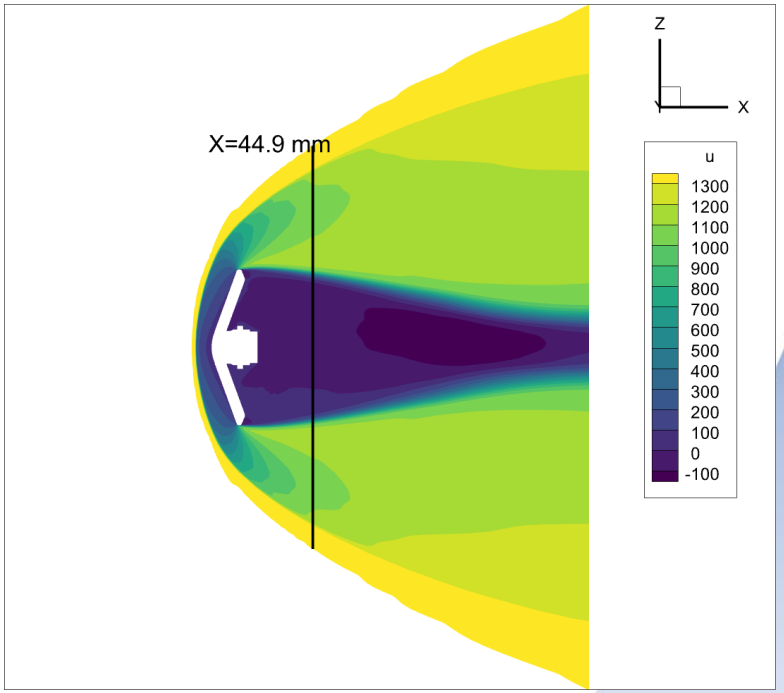

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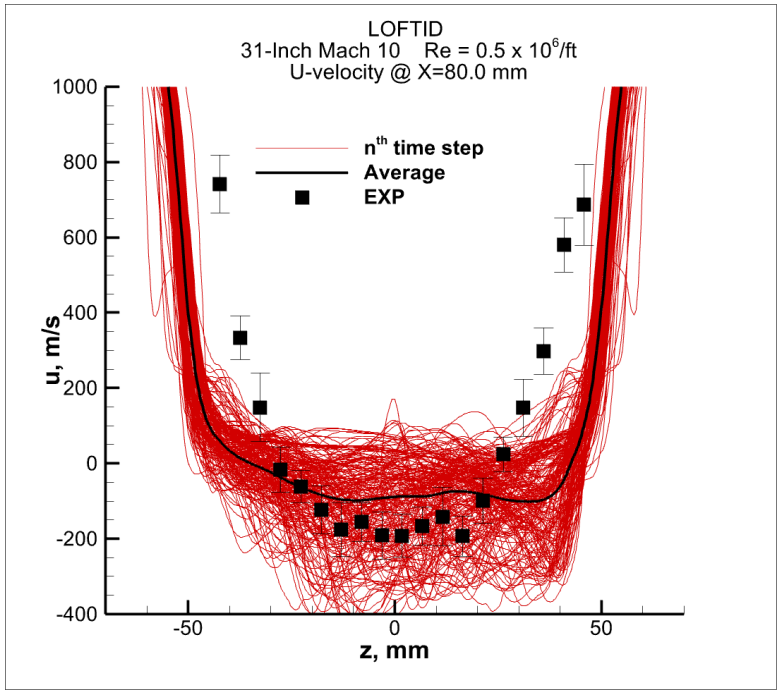

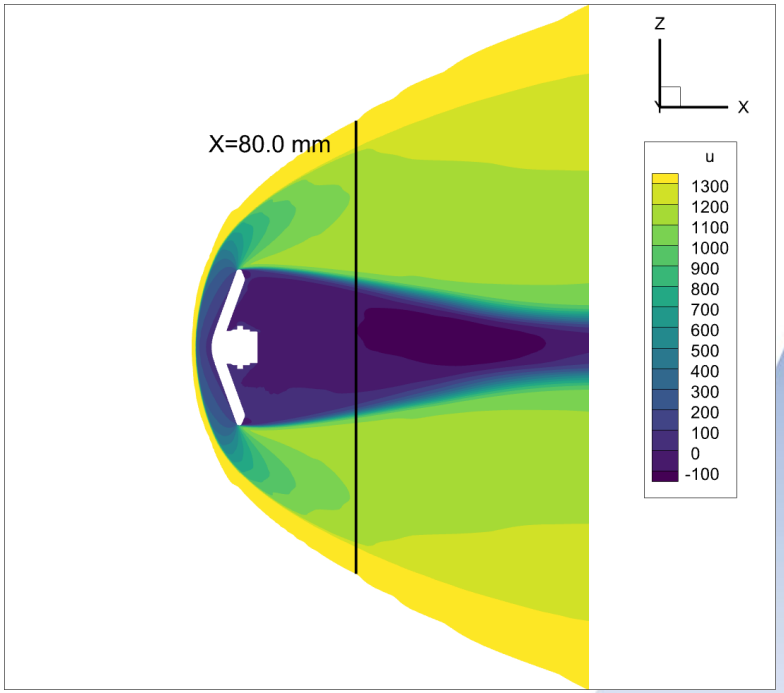

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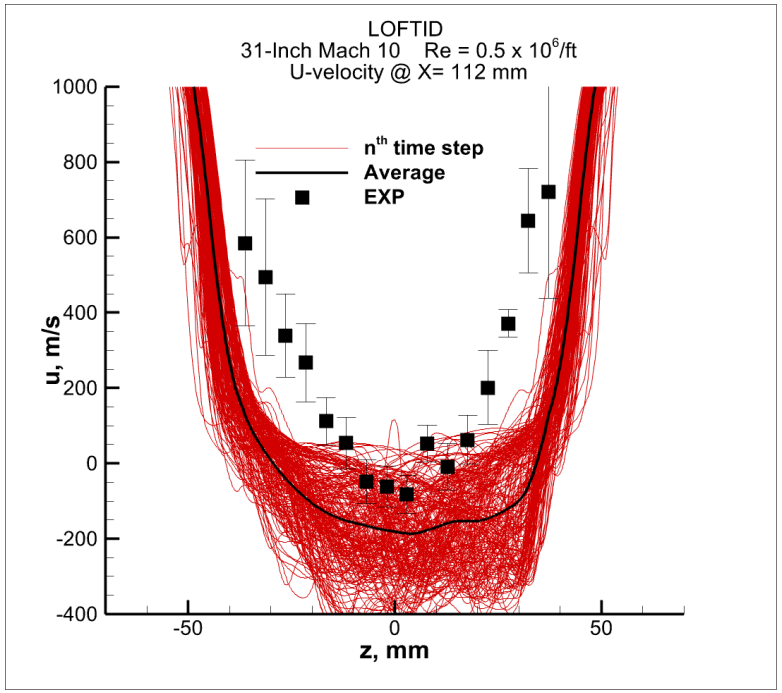

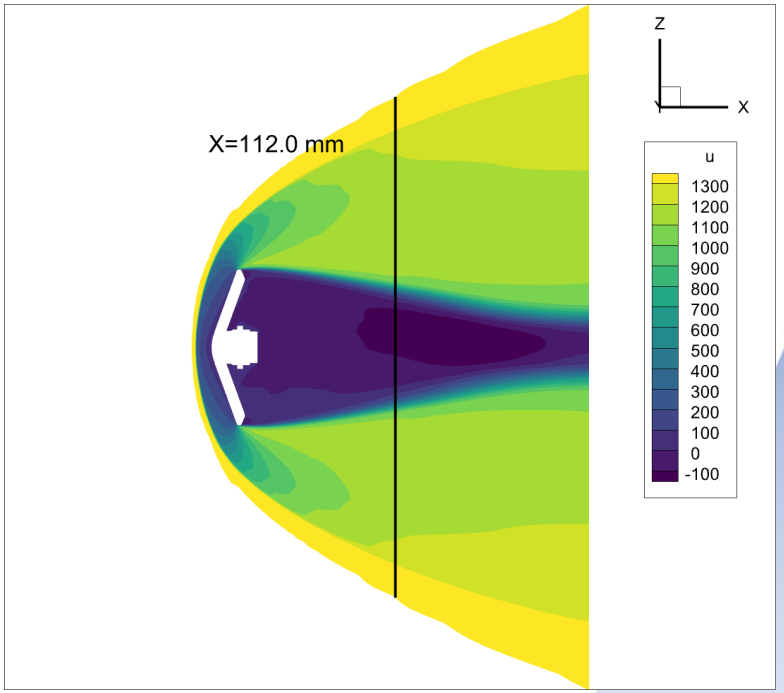

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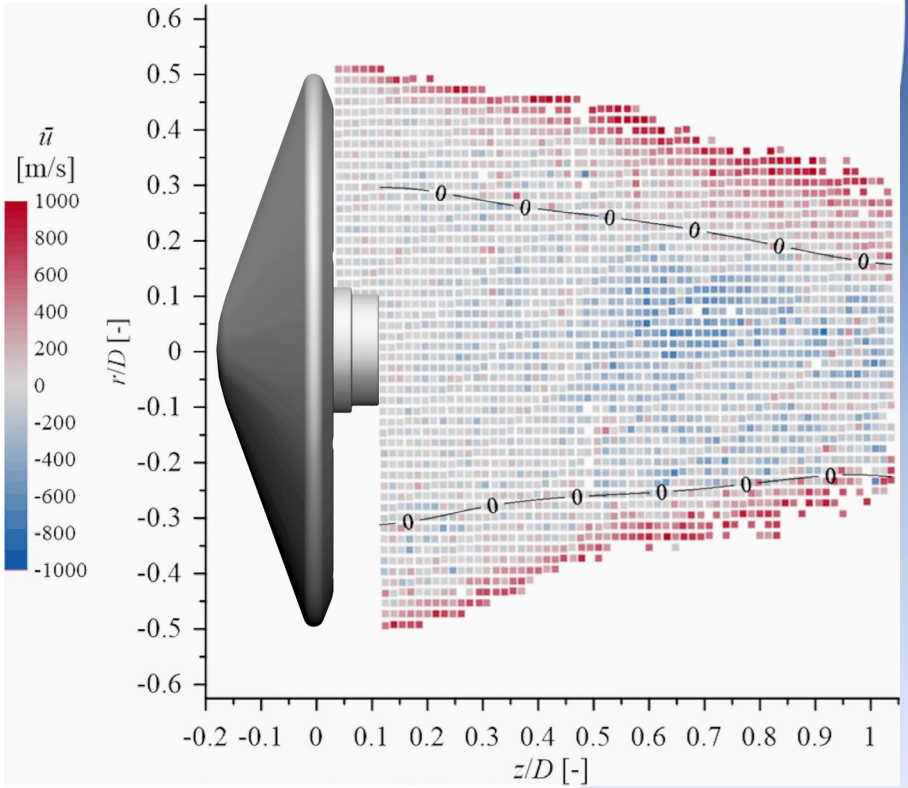

ESM Wake Flow

- Confirm completed solutions not evolving (no impact from additional iterations)
- Assess grid resolution
- Compute other Reynolds numbers
- Compare wake boundary locations with experimental data