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SPACE LAUNCH SYSTEM

2022 AIAA SciTech Forum

Cross-Validation of Computational and Experimental Distributed Surface Pressures on the Space Launch System

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OUTLINE

- I. Background**
- II. Process**
- III. Comparisons**
- IV. Lineloads**
- V. Summary**

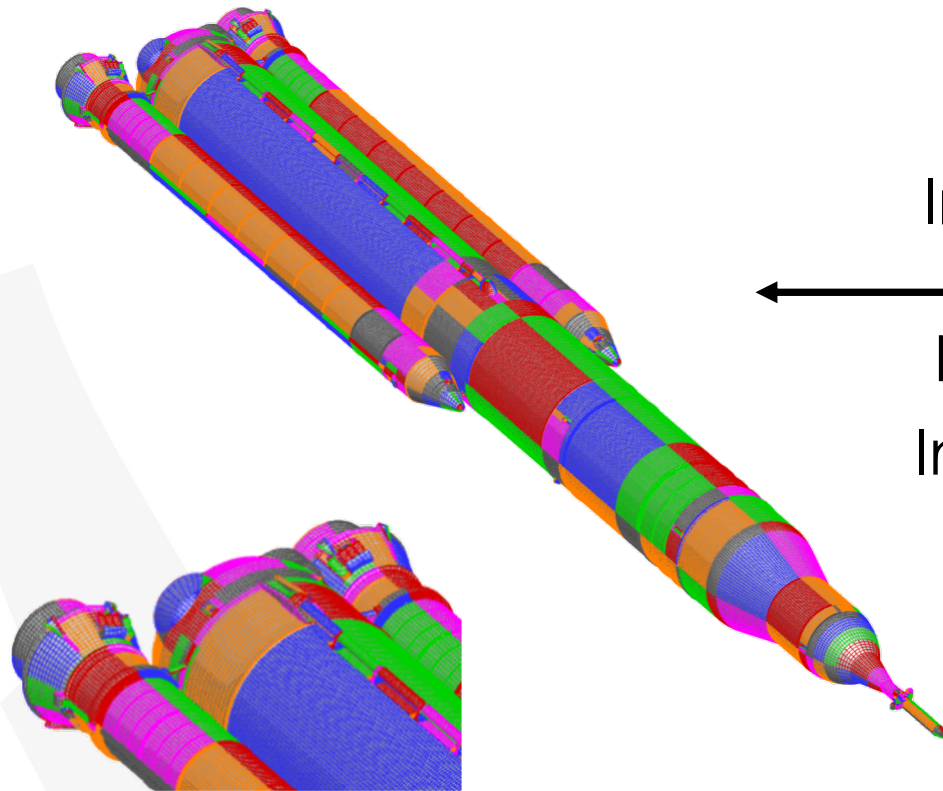
BACKGROUND

- **Pressure-sensitive paint (PSP) can provide spatially-resolved pressure distributions from wind tunnel experiments**
- **PSP pressure distributions can be used to compare to CFD data**
- **Validation CFD datasets exist for some NASA PSP runs of the SLS**

BACKGROUND

- PSP surface grid is composed of many zones of rectangles

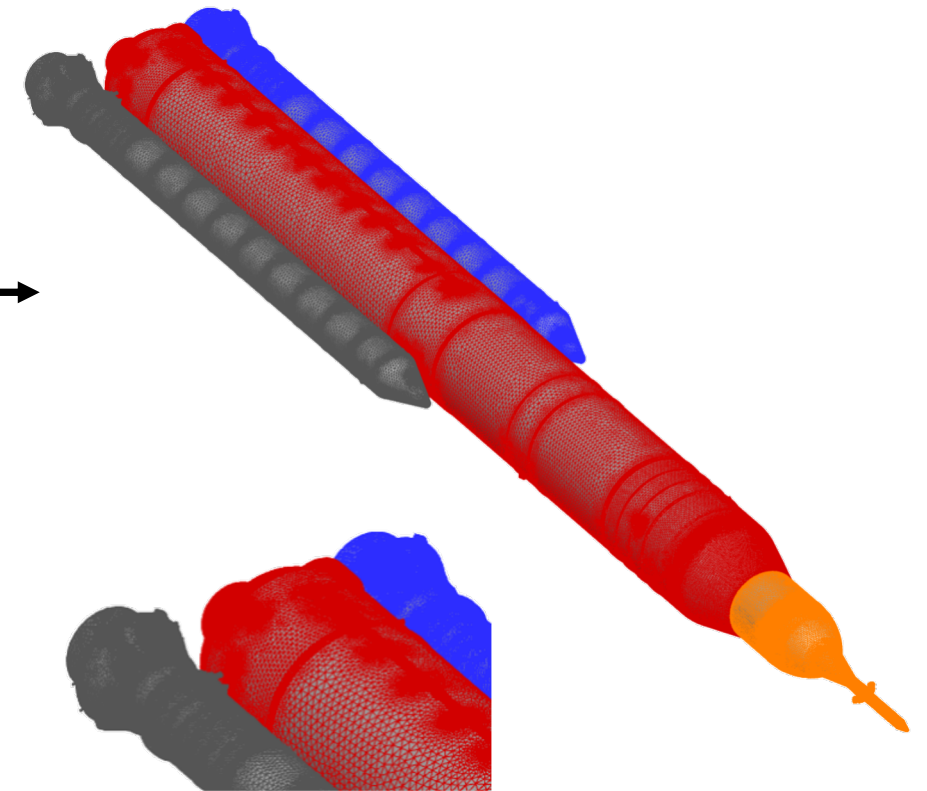
- CFD surface grid is composed of a few zones of triangles



Interpolate



PyTecplot,
Inverse Dist.



1. Match PSP runs with corresponding CFD runs

- Validation CFD data from ARC
- Use scripts to determine PSP/CFD pairs that match

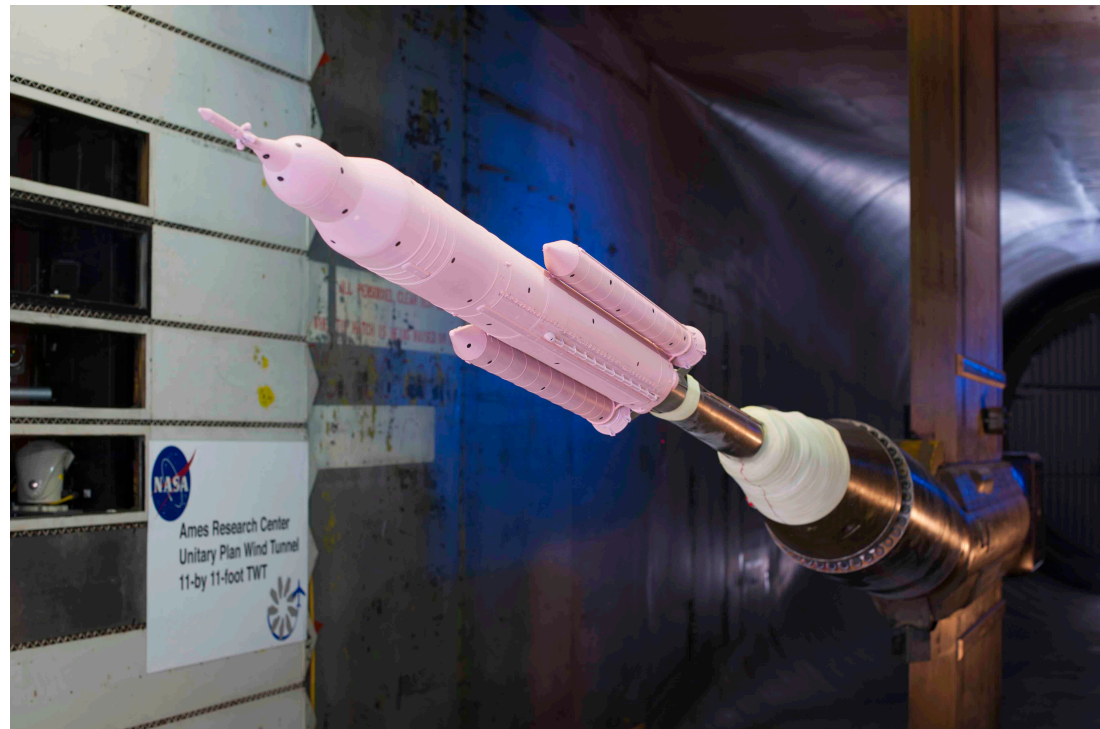
2. Map CFD and PSP data to the opposite grid using PyTecplot

- CFD data → PSP grid
- PSP data → CFD grid

3. Compare results

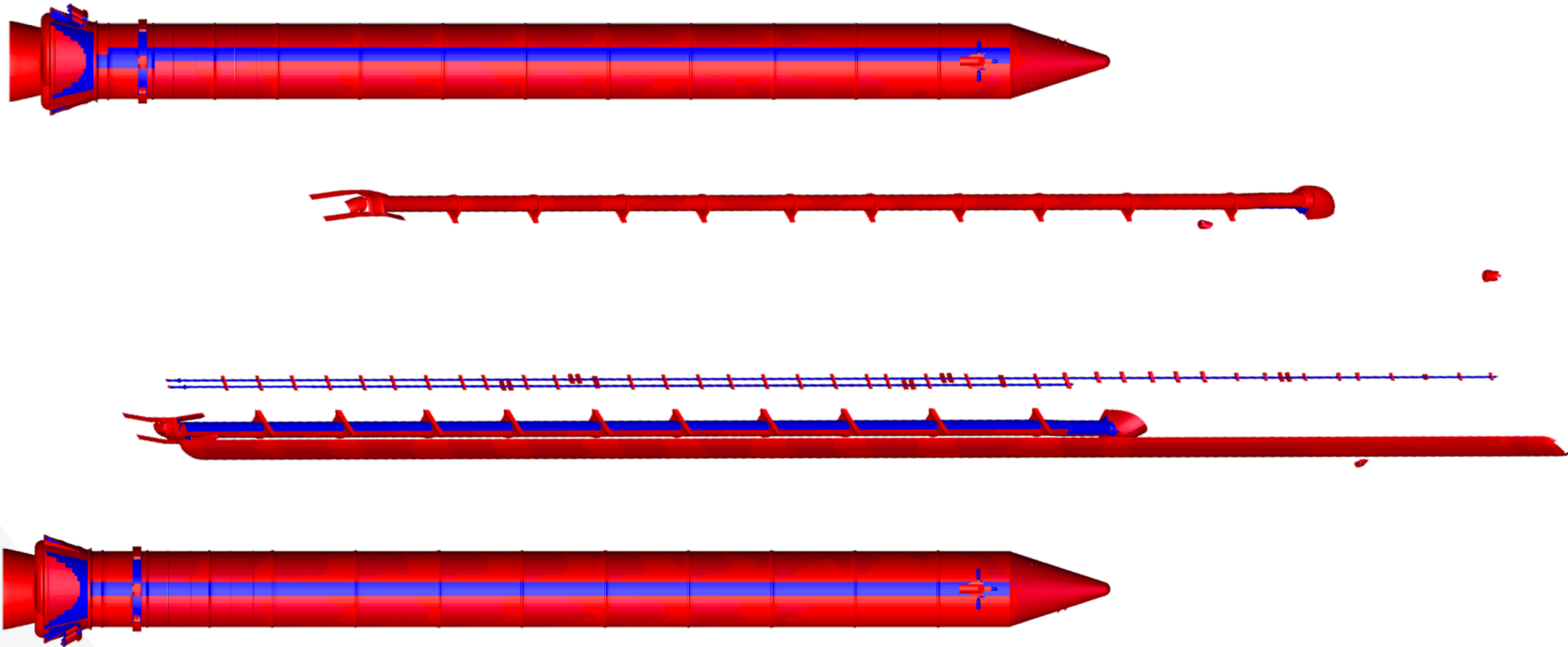
- Surface pressure distributions
- Pointwise C_p comparisons
- Lineloads

- **NASA Ames 11- by 11-Foot Transonic Wind Tunnel (11-Ft TWT)**
Test 11-0323 selected to evaluate comparison methods
 - Availability of data, used as a previous reference
 - Comparisons performed on SLS Block 1B Crew configuration



➤ Not all regions have PSP data available

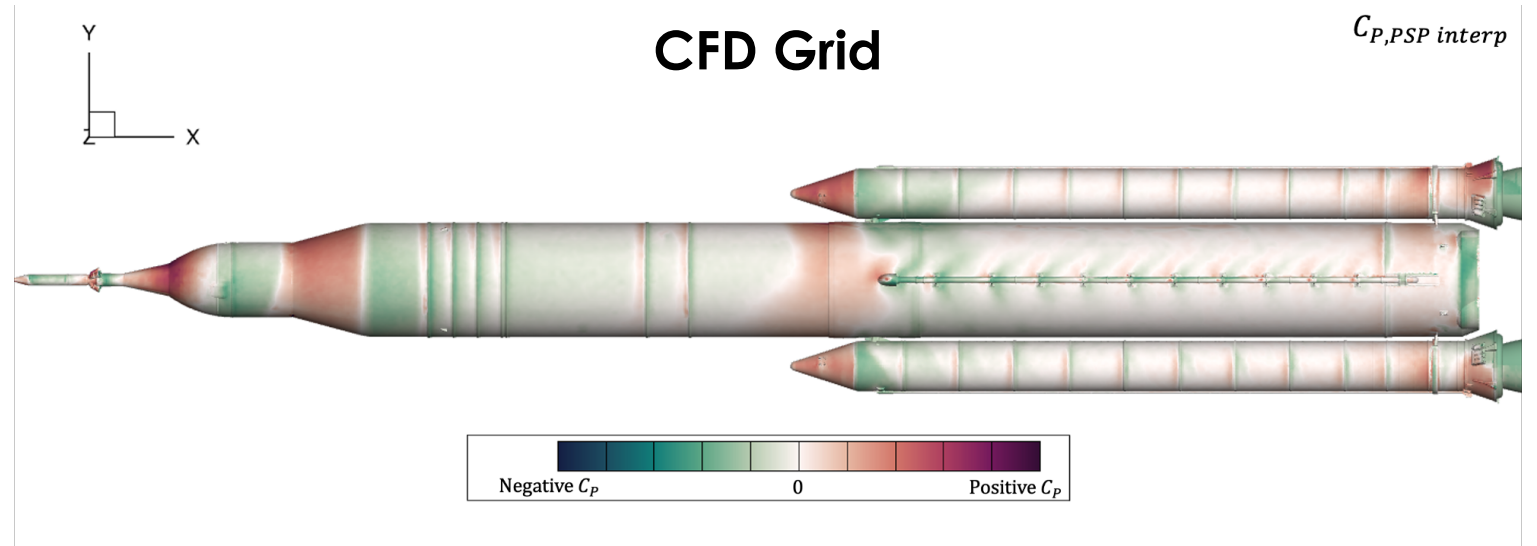
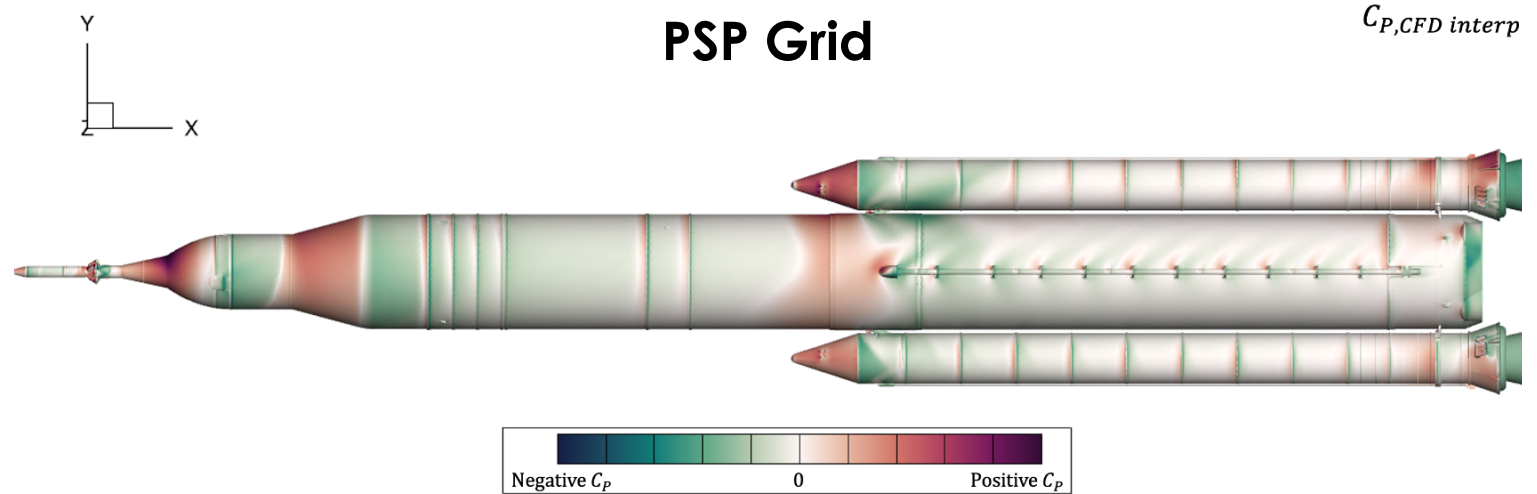
- Blanked (no data) regions in blue
- Regions with data in red



COMPARISONS

➤ Representative condition selected from analysis

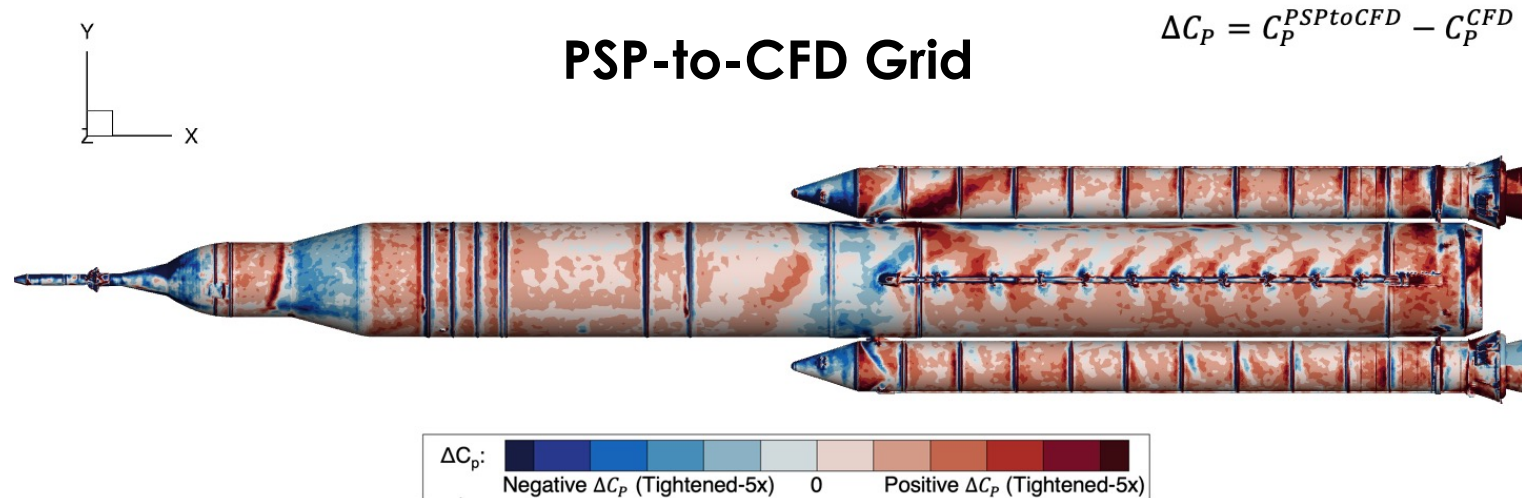
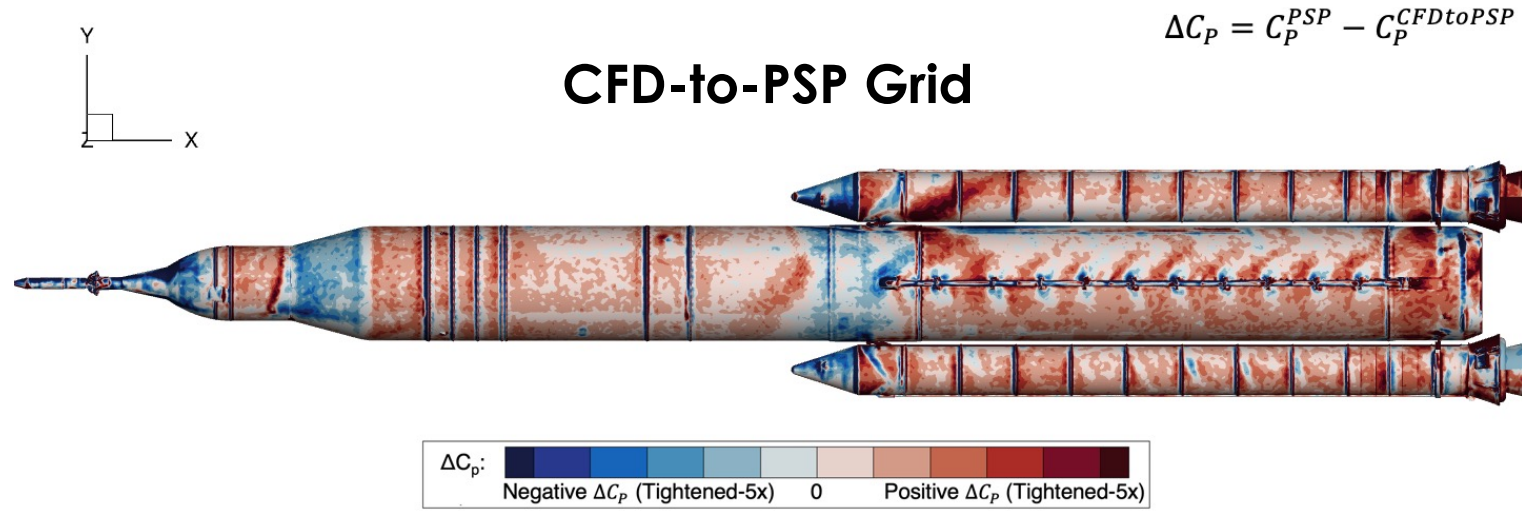
- Mach = 1.30
- Alpha = 0°
- Beta = 8°
- $Re_D = 1.08 \times 10^6$



COMPARISONS

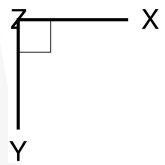
➤ Surface pressure differences calculated for each grid

- However, differences between methods are of a small magnitude
- Mach = 1.30
- Alpha = 0°
- Beta = 8°
- $Re_D = 1.08 \times 10^6$



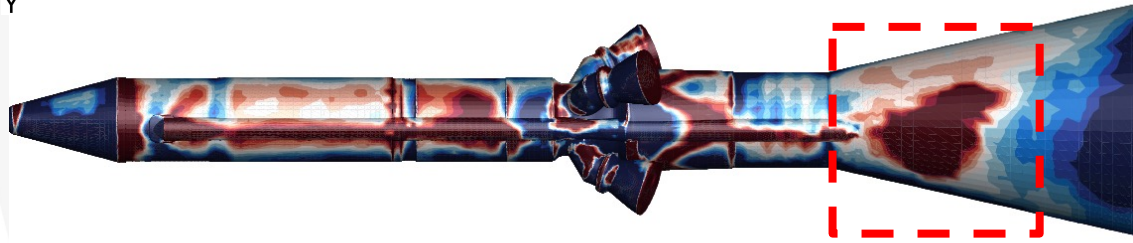
COMPARISONS

- **CFD-mapped data has a higher resolution than PSP-mapped data**
 - Behavior evident in several locations



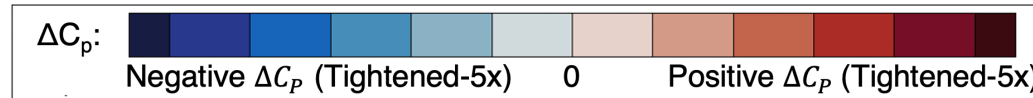
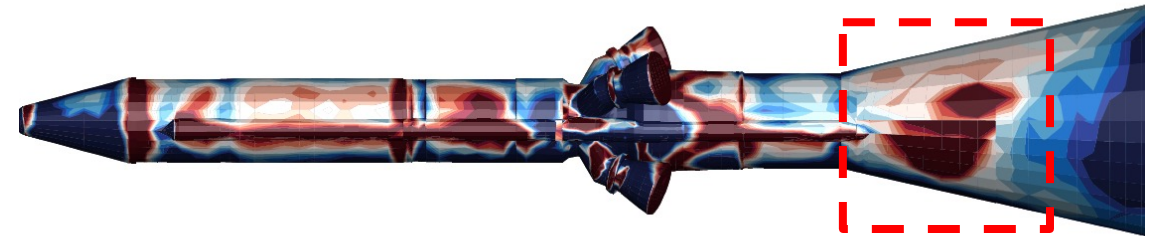
PSP-to-CFD Grid

$$\Delta C_p = C_p^{PSPtoCFD} - C_p^{CFD}$$



CFD-to-PSP Grid

$$\Delta C_p = C_p^{PSP} - C_p^{CFDtoPSP}$$

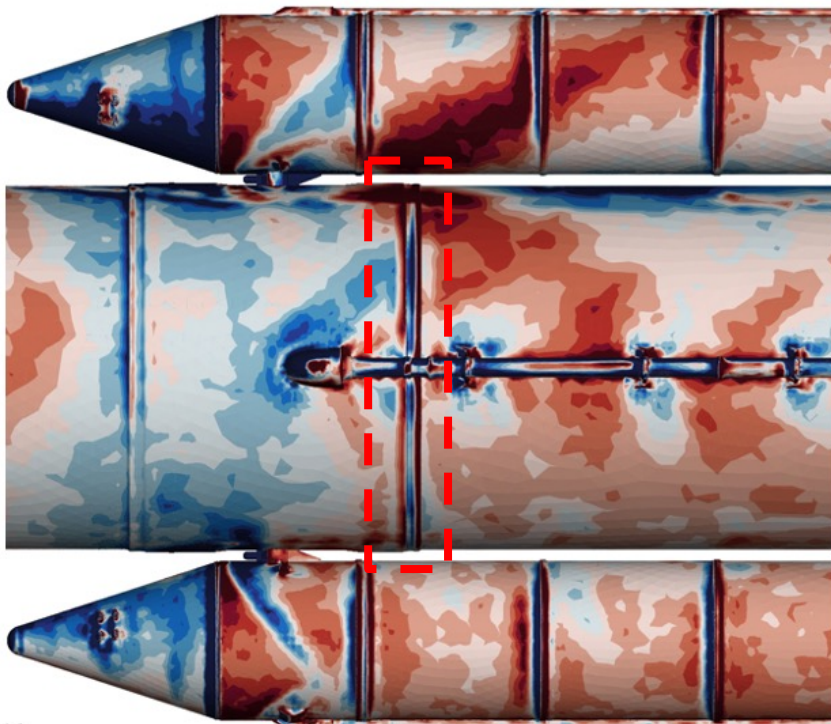


Mach = 1.30, Alpha = 0°, Beta = 8°, Re_D = 1.08x10⁶

COMPARISONS

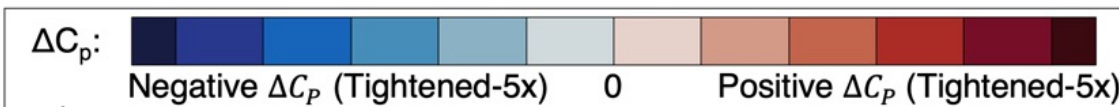
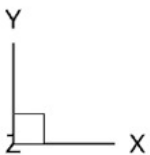
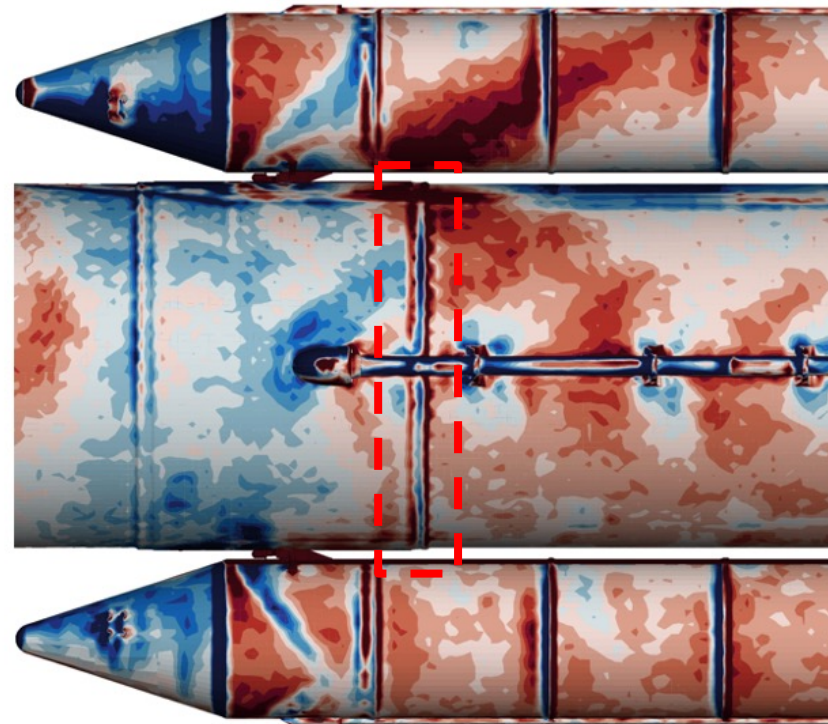
PSP-to-CFD Grid

$$\Delta C_p = C_p^{PSPtoCFD} - C_p^{CFD}$$



CFD-to-PSP Grid

$$\Delta C_p = C_p^{PSP} - C_p^{CFDtoPSP}$$

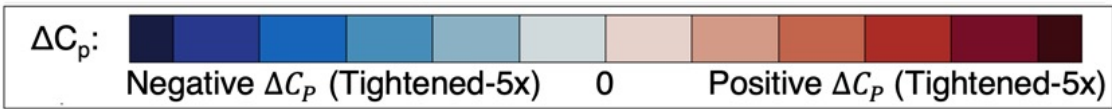
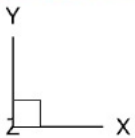
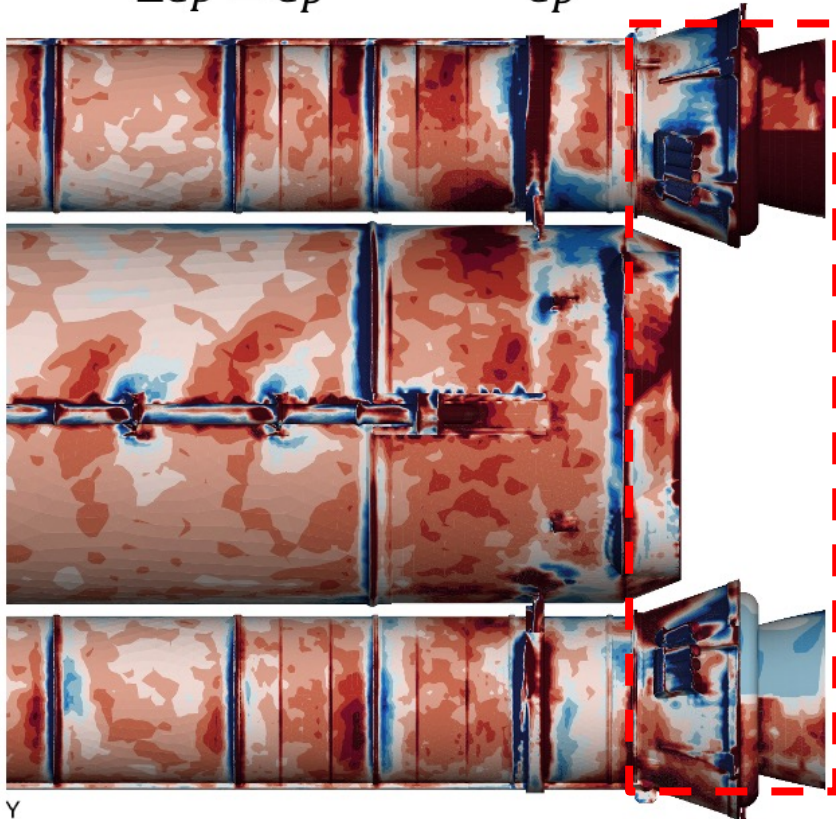


Mach = 1.30, Alpha = 0°, Beta = 8°, Re_D = 1.08x10⁶

COMPARISONS

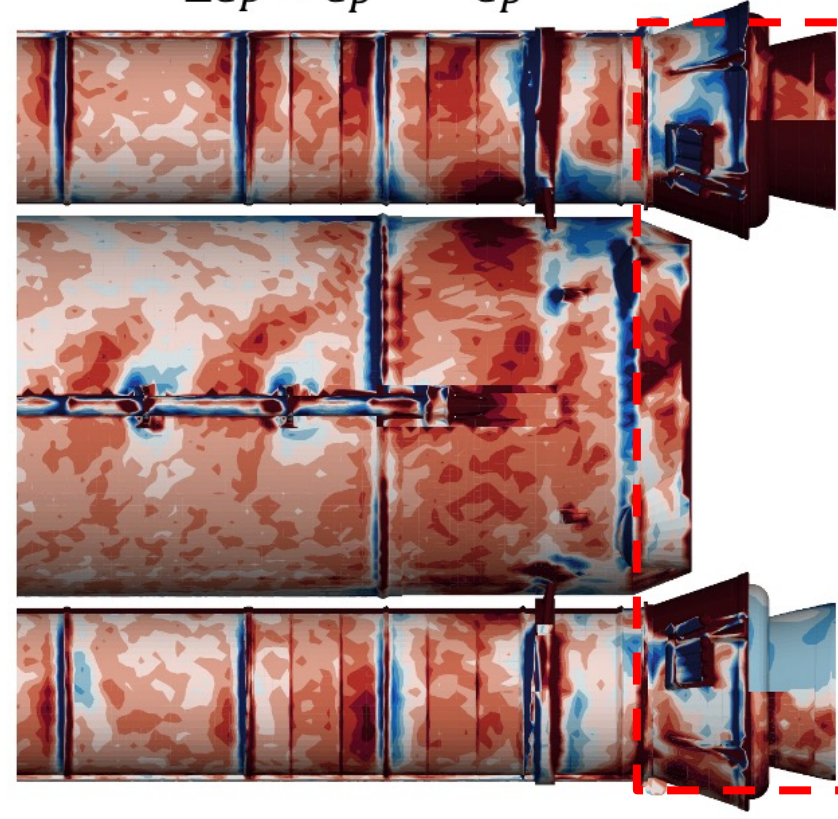
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CFD-to-PSP Grid

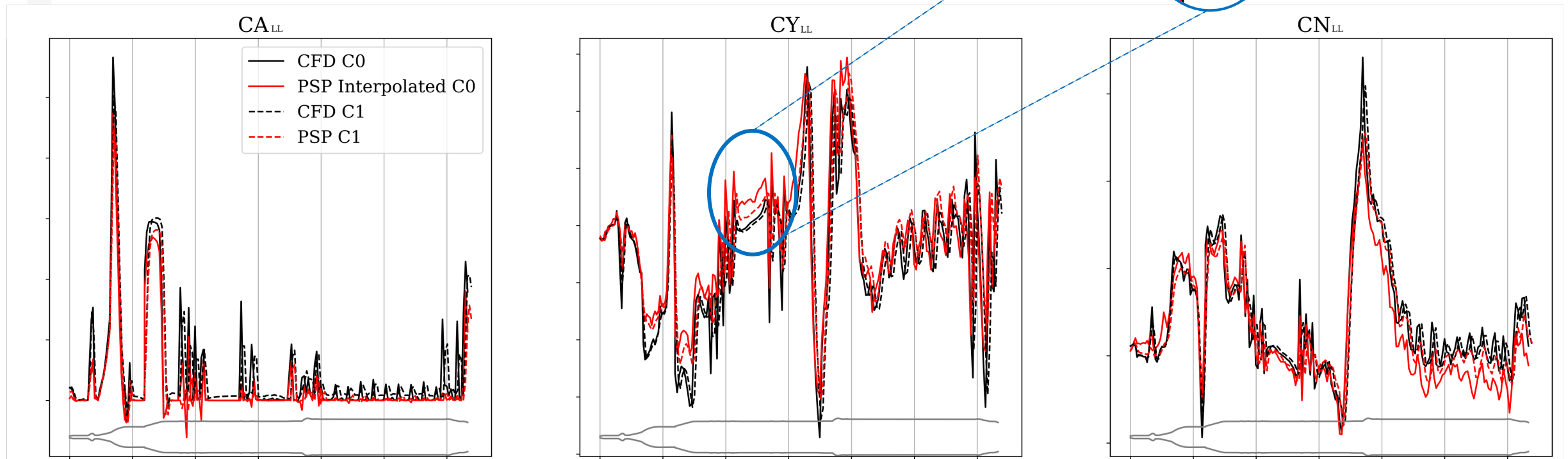
$$\Delta C_p = C_p^{PSP} - C_p^{CFDtoPSP}$$



Mach = 1.30, Alpha = 0°, Beta = 8°, $Re_D = 1.08 \times 10^6$

LINELOADS

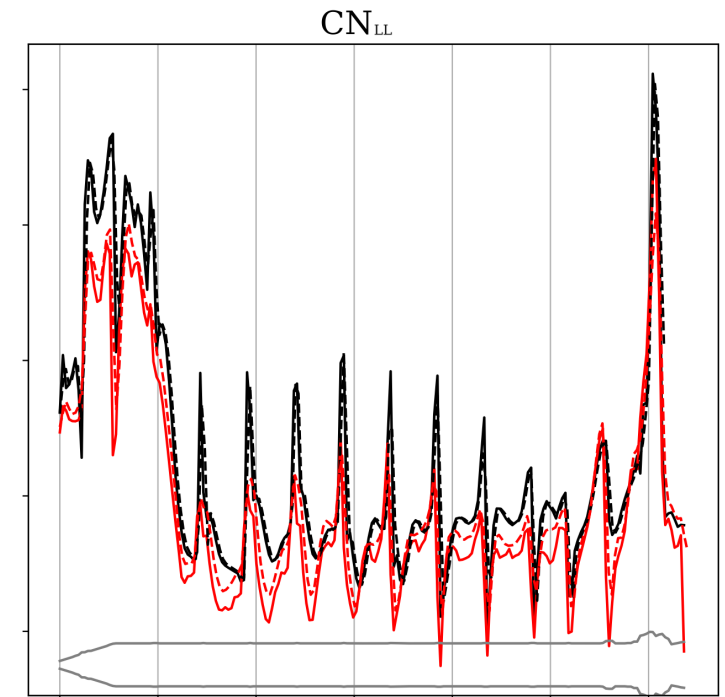
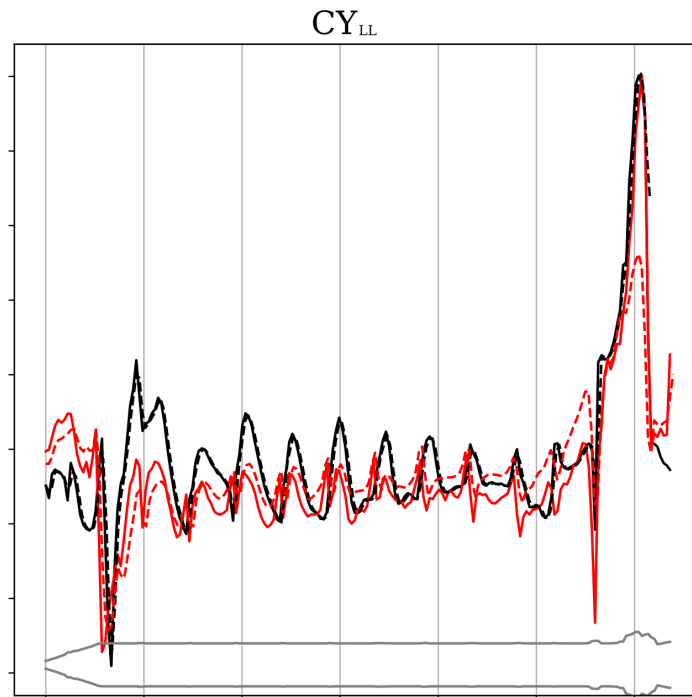
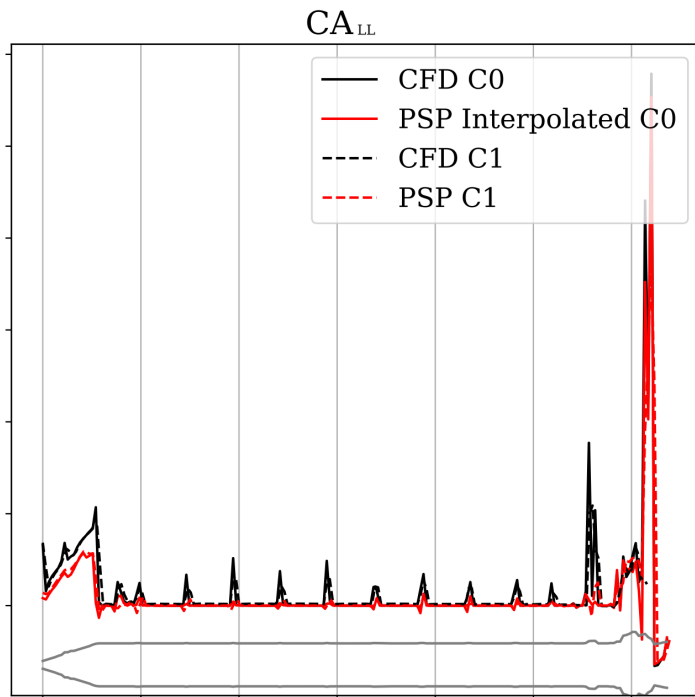
- Meeroff et al. – 201 bins per component (C1, dashes)
- Current – 201 bins per component (C0, solids)
- C1 = Trapezoid rule technique
- C0 = Midpoint rule technique



Core Lineloads, Mach = 1.30, Alpha = 0°, Beta = 8°, $Re_D = 1.08 \times 10^6$

LINELOADS

- Meeroff et al. – 201 bins per component (C1, dashes)
- Current – 201 bins per component (C0, solids)
- C1 = Trapezoid rule technique
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LSRB Lineloads, Mach = 1.30, Alpha = 0°, Beta = 8°, Re_D = 1.08x10⁶

- **Performed PSP to CFD comparisons on the SLS**
 - Validated previous work performed by other groups using a different workflow
 - Interpolating onto CFD surface grid provides higher resolution, enables lineload calculations with existing tools
 - Interpolating onto either surface grid yields comparable surface pressure fields
- **Next steps**
 - Continue to develop and improve methods
 - Validate workflow for other tests and configurations



QUESTIONS

