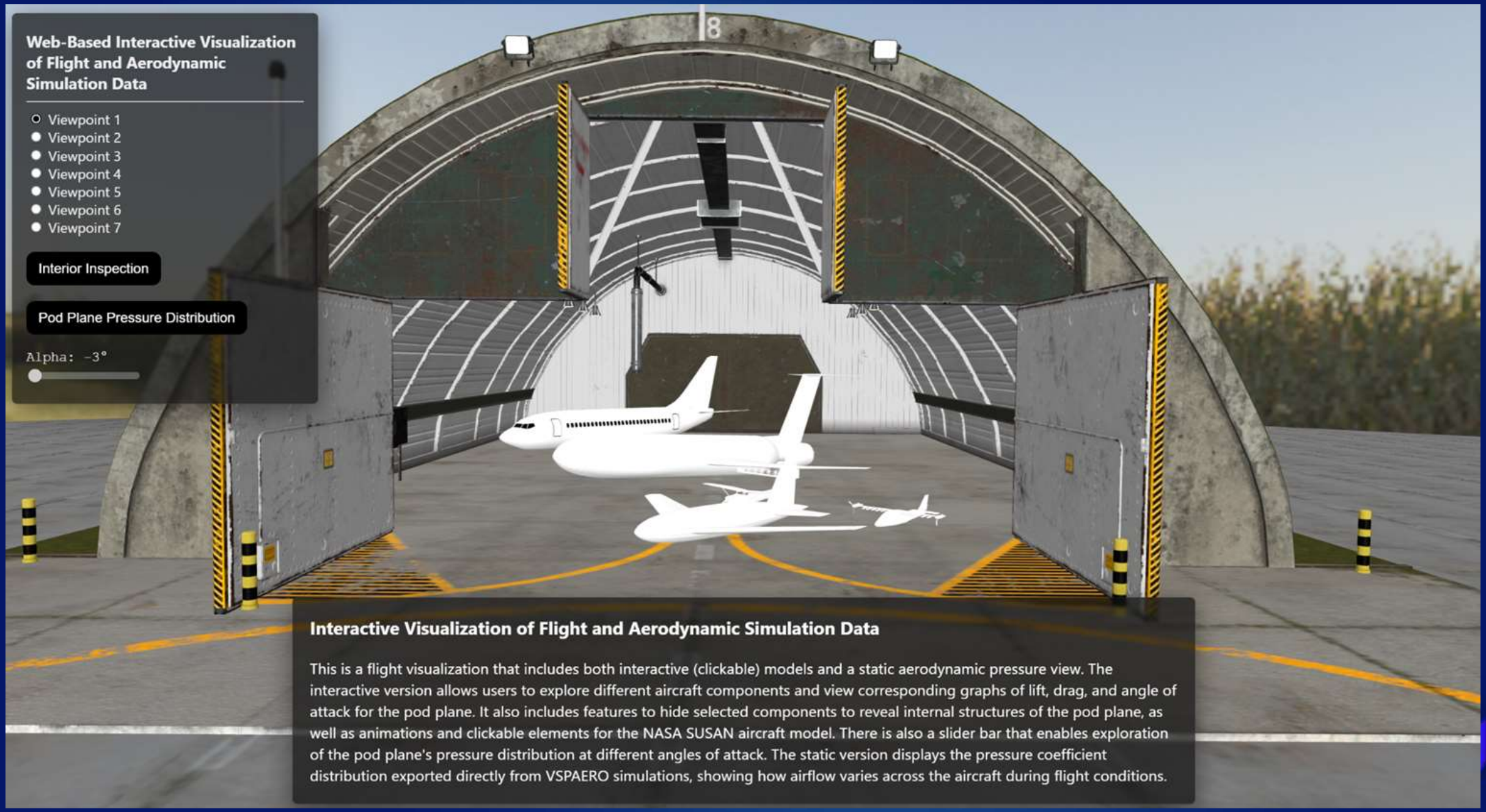


Interactive Web-Based Visualization for Aircraft Multidisciplinary Design, Analysis, and Exploration

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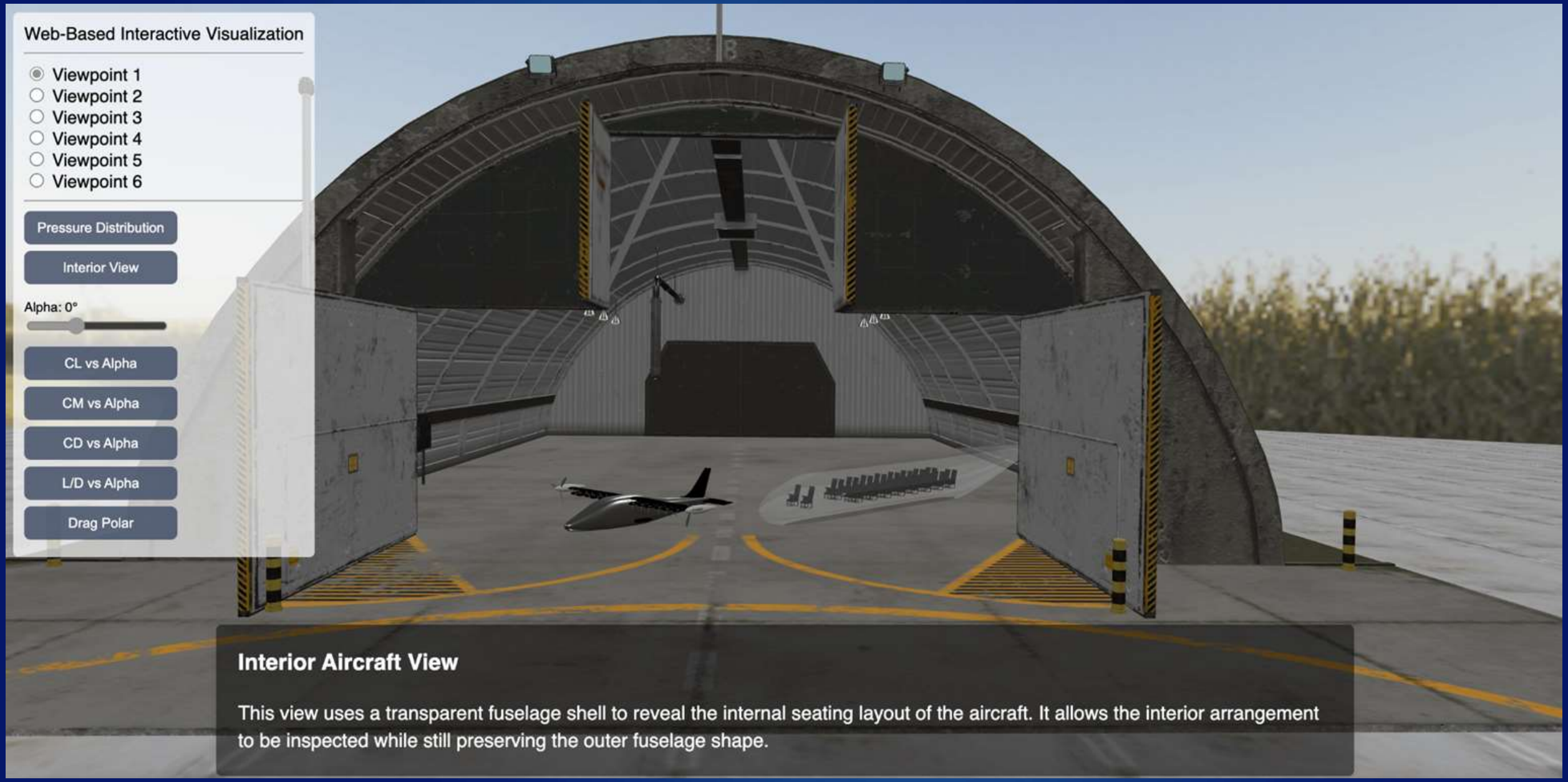

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Introduction



Introduction

- Motivation: Traditional aircraft CAD models offer limited accessibility and interactivity for immersive engineering exploration
- Objective: Enable component-level inspection, animated mechanisms, and future deployment in virtual reality (VR) environments
- Approach: Develop a visualization pipeline that integrates aircraft modeling, 3D animation, scientific data visualization, and web-based technologies to transform aircraft geometry into interactive, browser-compatible 3D models



Various Approaches

Approach	Aero-Aware Geometry	Interactivity	Web-Based	Complexity
Traditional CAD	✓	Low	✗	High
Aero Analysis	✓	Low	✗	Average
Game Engines	✗	High	Limited	High
Web Graphics	✗	High	✓	Average
Existing VR Platforms	✗	High	✗	Average
Proposed Pipeline	✓	High	✓	Average



Project Objectives



Project Objectives

1. Develop an interactive 3D aircraft visualization platform using OpenVSP, VSPAERO, Paraview, Blender, and X3DOM to explore aircraft geometry and internal components

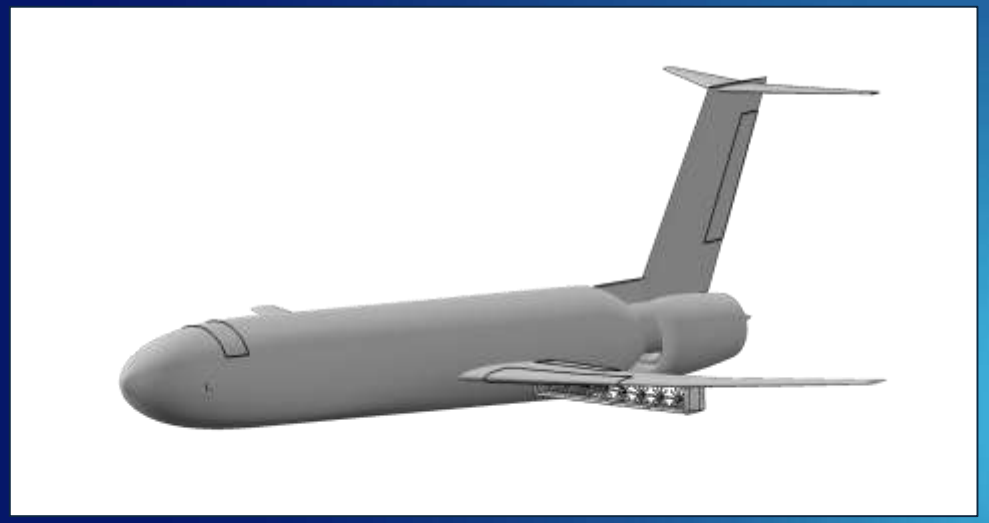
1. Integrate VSPAERO aerodynamic simulations with interactive sliders to visualize how changing flight conditions affects aerodynamic performance

1. Build a workflow for processing and displaying simulation data, with animated aircraft models and support for immersive VR capabilities

Aircraft Selection



NASA SUSAN Concept



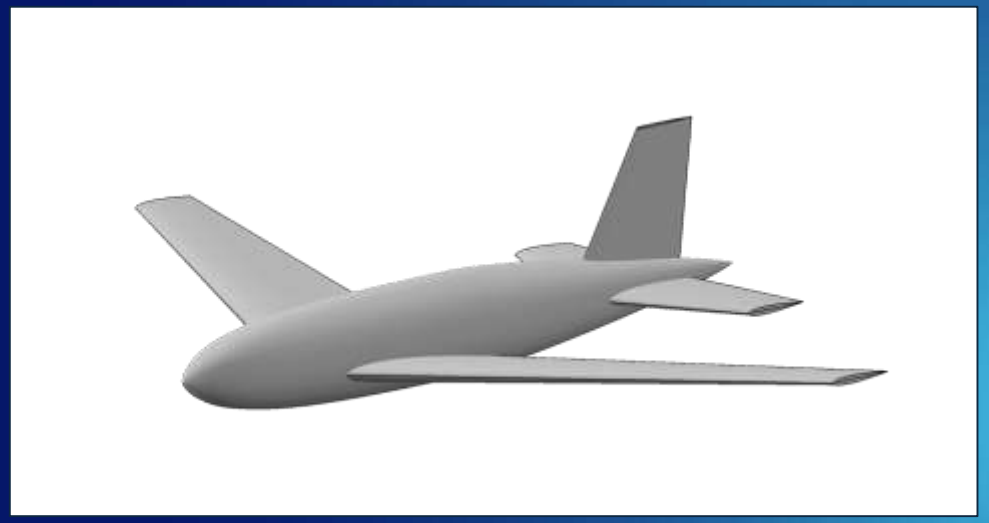
Electric-fan transport concept with 16 distributed electrofans and an aft turbofan - tests the pipeline on complex, multi-component propulsion and animation

NASA X-57 Concept



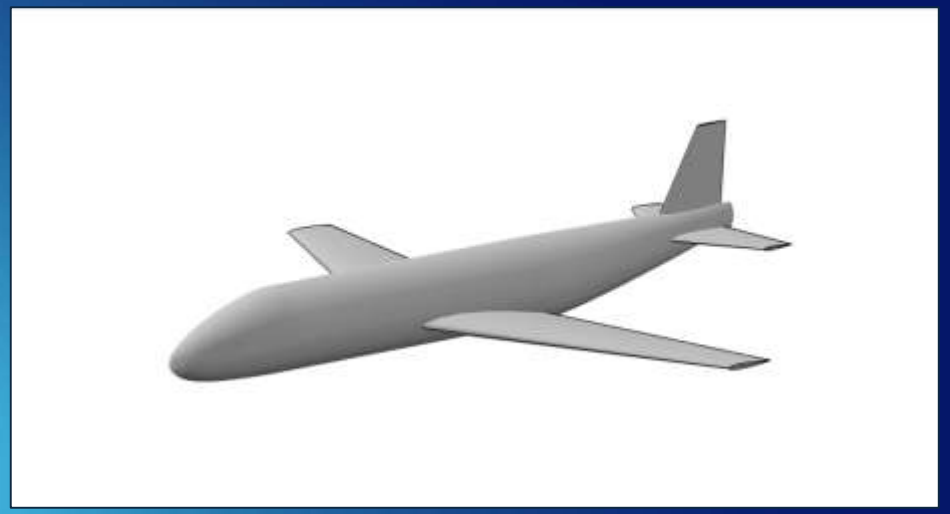
Distributed electric propulsion concept with 12 high-lift propellers and 2 cruise propellers - the most geometrically complex model (1.24M triangles), stress-testing web performance

Pod Plane Concept



Compact configuration from OpenVSP’s user modules - low triangle count (6,304) suited to VSPAERO analysis and interior inspection mode

NACA 2410 Concept



Airfoil-based transport configuration from OpenVSP’s user modules; lightweight model (5,548 triangles) used for pressure visualization and interior inspection

Aircraft Selection – Rationale

- NASA Concepts (SUSAN and X-57): Real NASA configurations with many independently animated components demonstrate component-level interaction at scale
- OpenVSP Concepts (Pod Plane and NACA 2410): Simpler geometries provide a clean baseline for aerodynamic analysis, pressure mapping, and the angle-of-attack slider
- Combined takeaway: Together, the four models span simple to highly complex geometry, validating that the pipeline generalizes across aircraft configurations



Process



Stage 1: OpenVSP Outer Mold Line Model

- OpenVSP: NASA-developed parametric tool for creating, analyzing, and modifying aircraft geometry
- Parametric outer mold line (OML) modeling of each aircraft in NASA’s OpenVSP






Stage 1: OpenVSP Outer Mold Line Model

- Aircraft built component by component: fuselage, wings, tail surfaces, and propulsion systems
- Configurations modeled: NASA SUSAN, NASA X-57, Pod Plane, and NACA 2410
- Components exported as individual OBJ files to preserve independent manipulation of each component in X3DOM

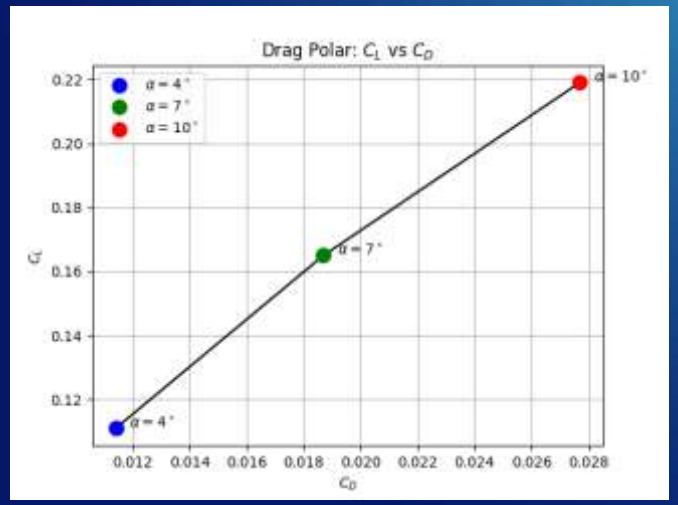
Stage 2: VSPAERO Aerodynamic Analysis

- VSPAERO: Inviscid aerodynamic analysis tool for rapid aircraft analysis and simulation, integrated with OpenVSP
- Finalized OpenVSP models prepared and analyzed directly in VSPAERO, with no separate meshing step
- Solver iterations, angle-of-attack sweep, and mesh tessellation density adjusted to improve convergence and data quality

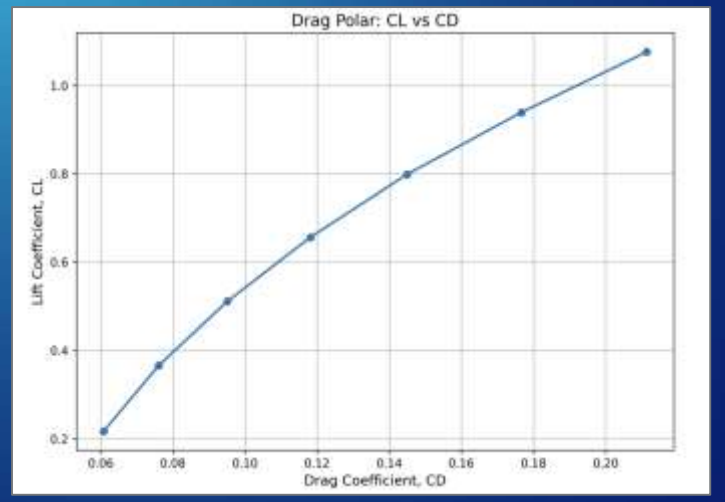
Stage 2: VSPAERO Aerodynamic Analysis

- Simulations run across multiple configurations, including the Pod Plane and NACA 2410
- Outputs generated for lift (CL), drag (CD), moment (CM), and surface pressure coefficient (Cp) at each specified angle of attack
- Results exported in ADB and CSV formats, then converted to VTK for ParaView and imported into Matplotlib for further analysis

Pod Plane



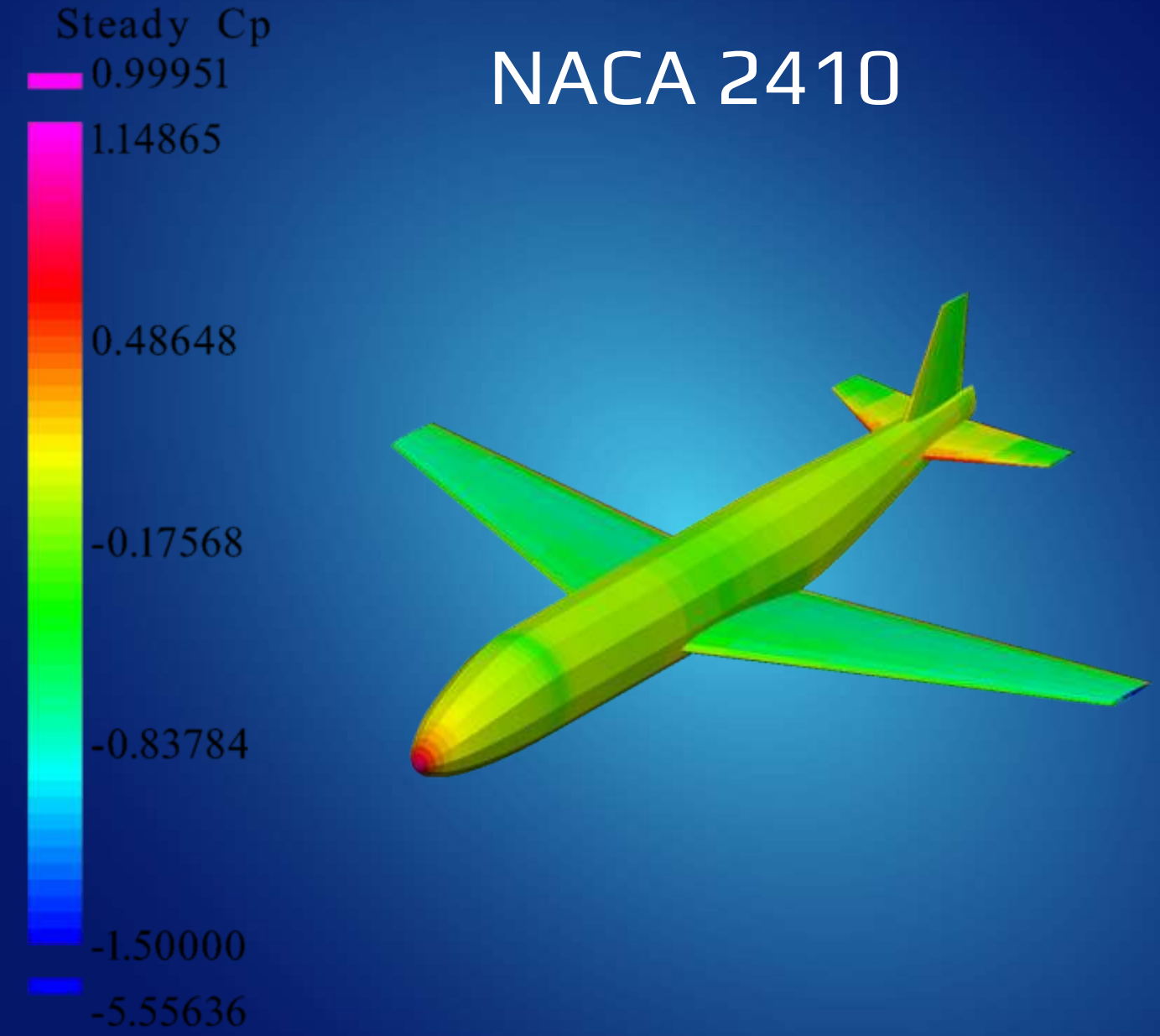
NACA 2410



Pod Plane



NACA 2410


Steady Cp
0.99951
1.14865
0.48648
-0.17568
-0.83784
-1.50000
-5.55636

Stage 3: Blender Animations

- Imported OpenVSP components as individual OBJ files, preserving component separation
- Scaled aircraft assembly to real-world dimensions using wingspan as a reference
- Separated propellers into individual meshes and aligned them with their rotation axes
- Applied counter-rotating animations to propeller pairs, including X-57 cruise propellers and tail turbofans
- Created custom hinge axes and keyframe animations for the rudder and horizontal stabilizer
- Baked animations into keyframes for glTF compatibility and exported the complete assembly in GLB format

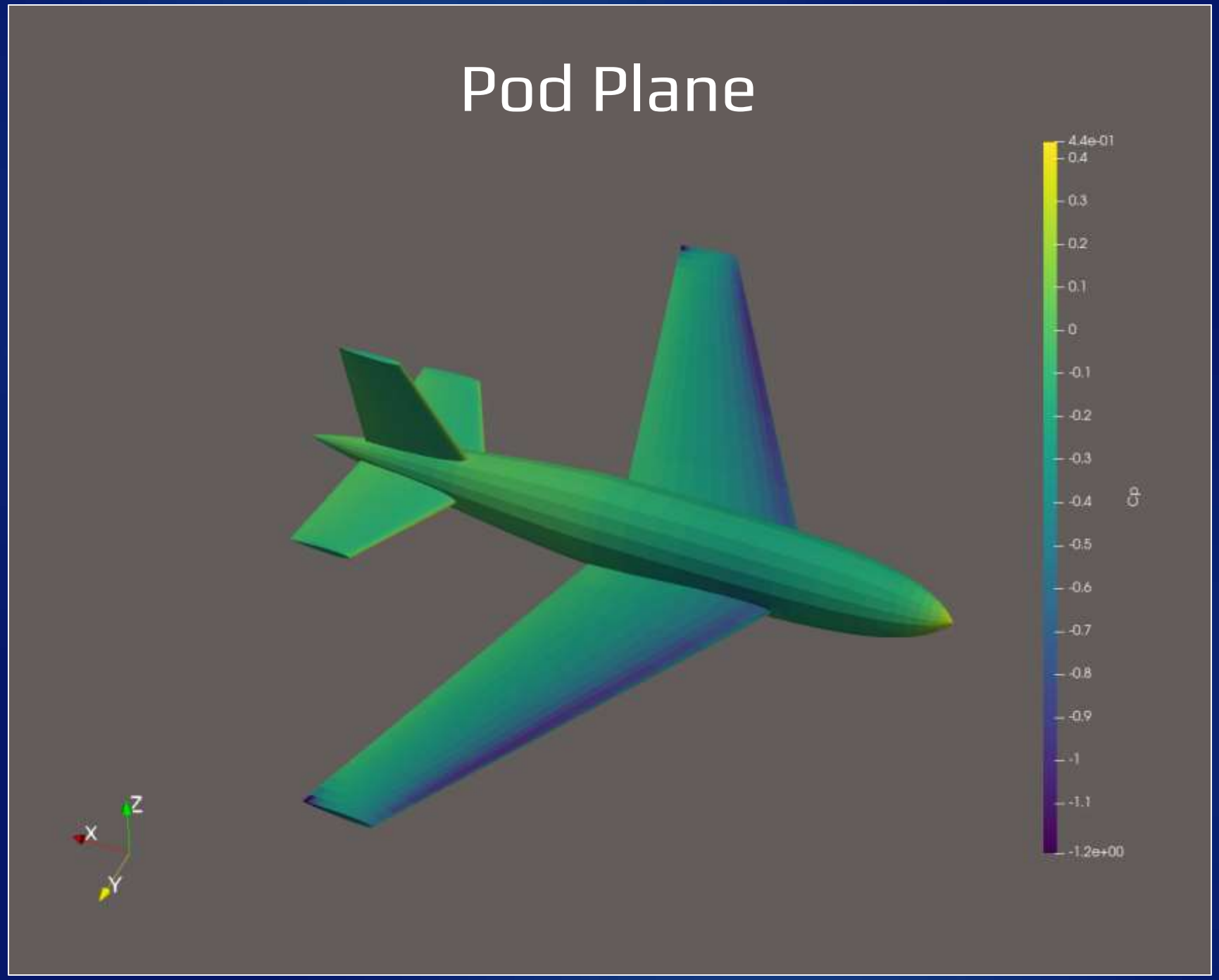
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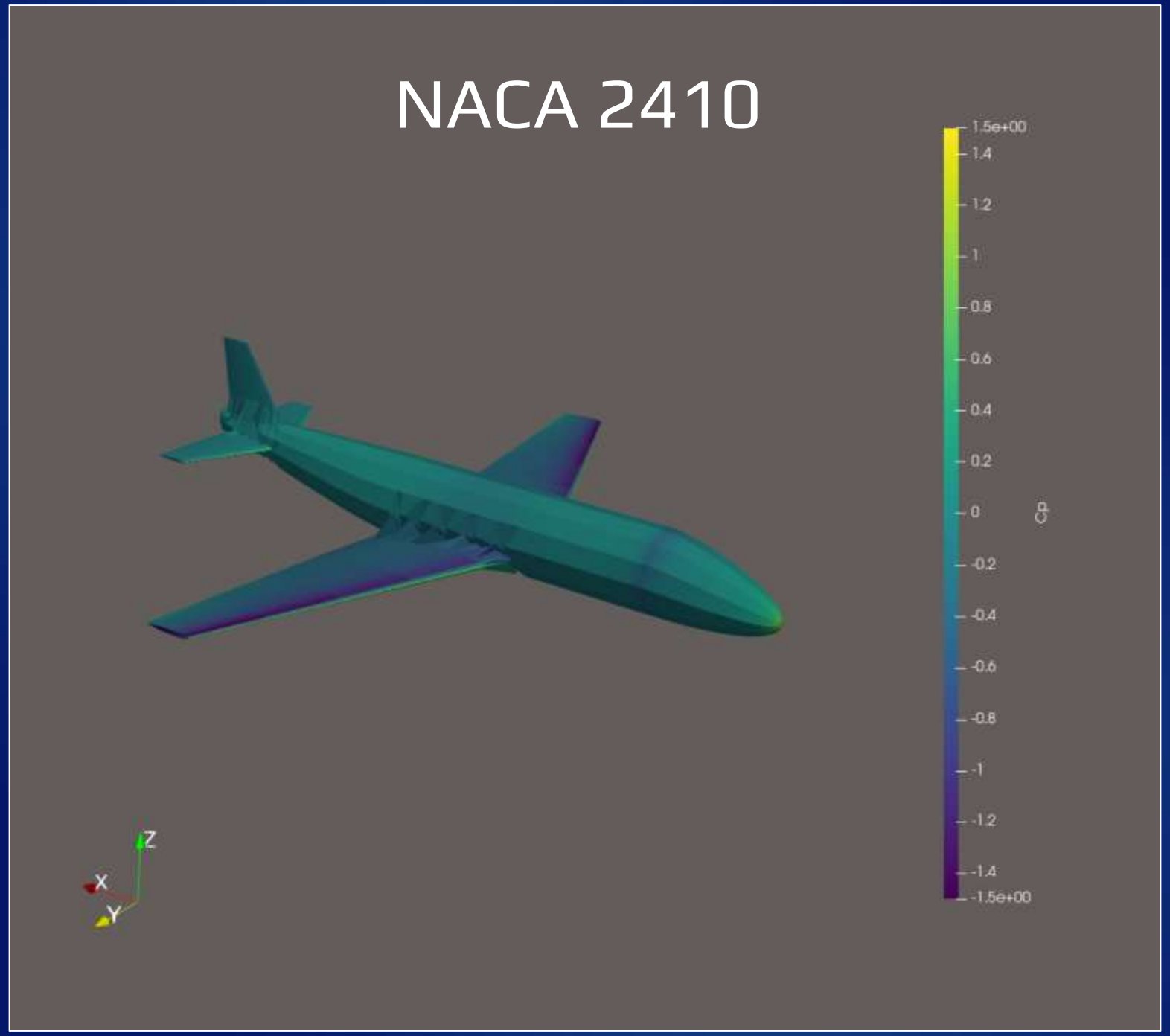
Stage 4: ParaView Pressure Field Visualization

- Used Python scripts and Command Prompt to process simulation data for ParaView
- Converted VSPAERO ADB output to VTK format, preserving mesh geometry and aerodynamic data
- Mapped pressure coefficients (Cp) onto aircraft surfaces using color contours and legends
- Adjusted camera angles and contour settings to highlight pressure gradients
- Exported pressure visualizations for integration into the X3DOM scene

Pod Plane



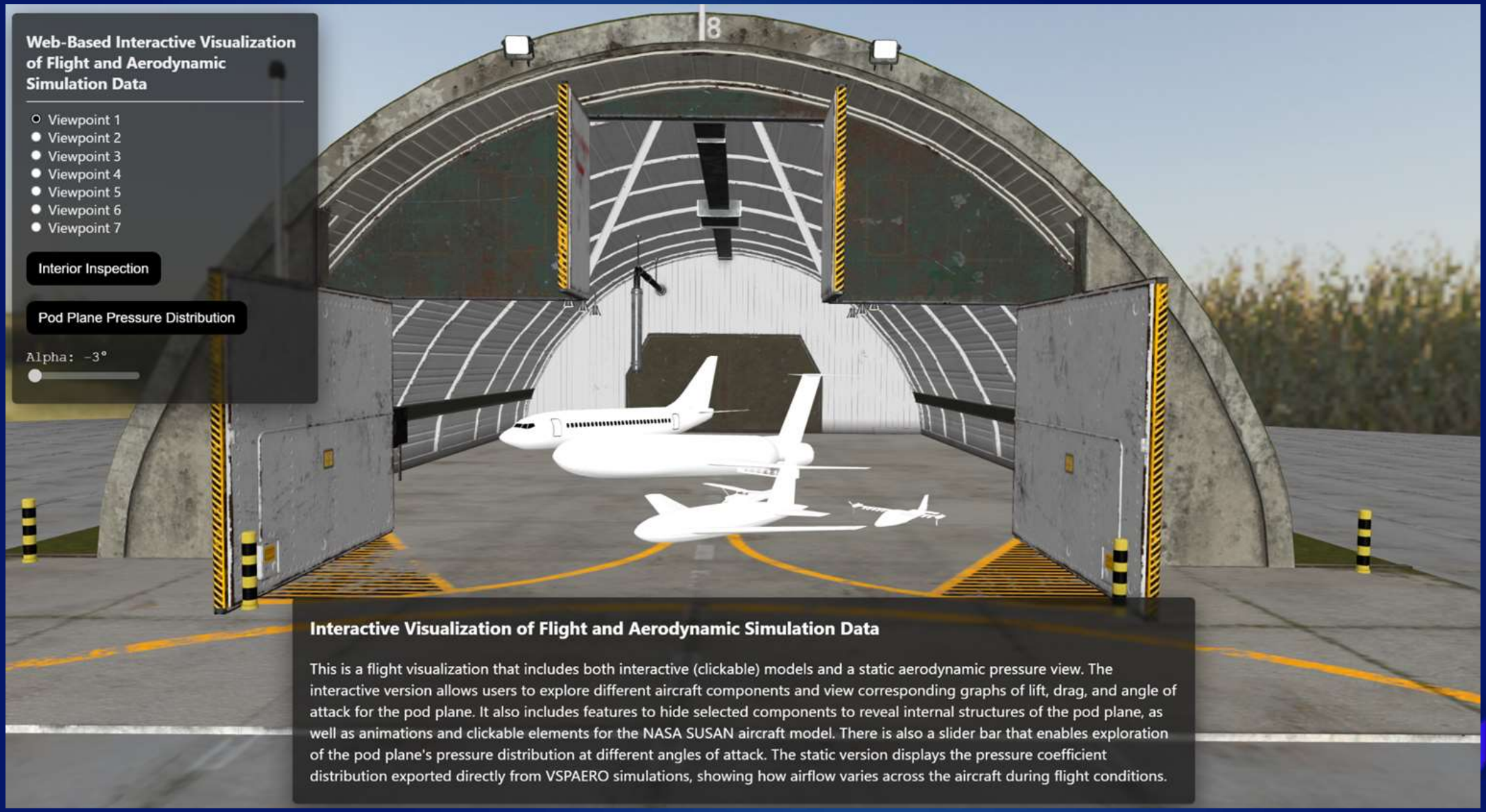
NACA 2410

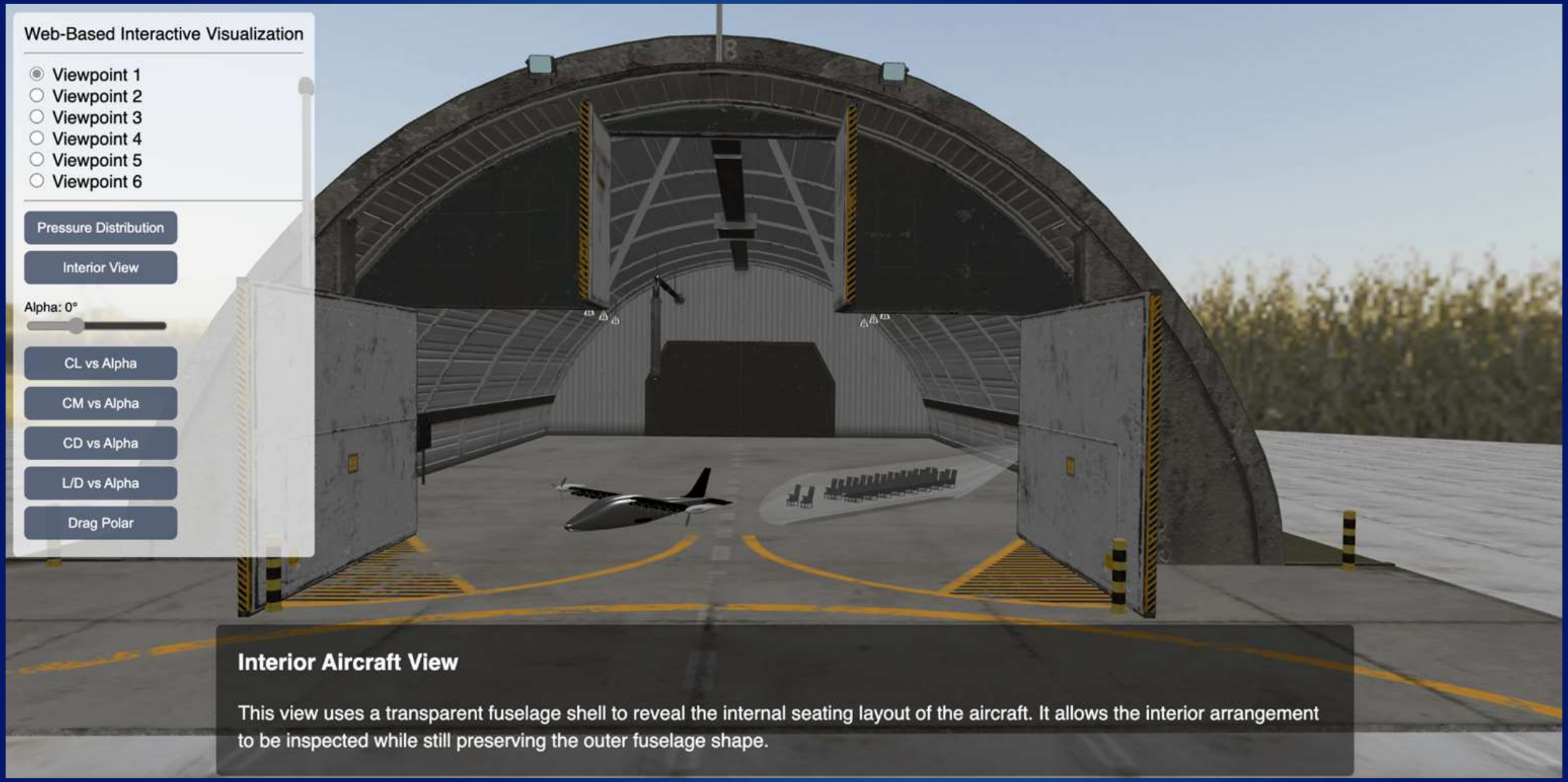


Stage 5: X3DOM Interactive Web Deployment

- X3DOM: Web-based 3D framework used to display OpenVSP aircraft models directly in the browser as interactive 3D visuals, with no installation required
- GLB components assembled in an X3DOM scene and aligned to a standardized ground plane
- Component hover highlighting, selection, and information panels for inspecting individual parts
- ParaView pressure visualizations integrated with an angle-of-attack slider, alongside embedded Matplotlib performance graphs
- Deployed in AOE 4066 Air Vehicle Design, where senior student teams built visualizations for their own aircraft concepts



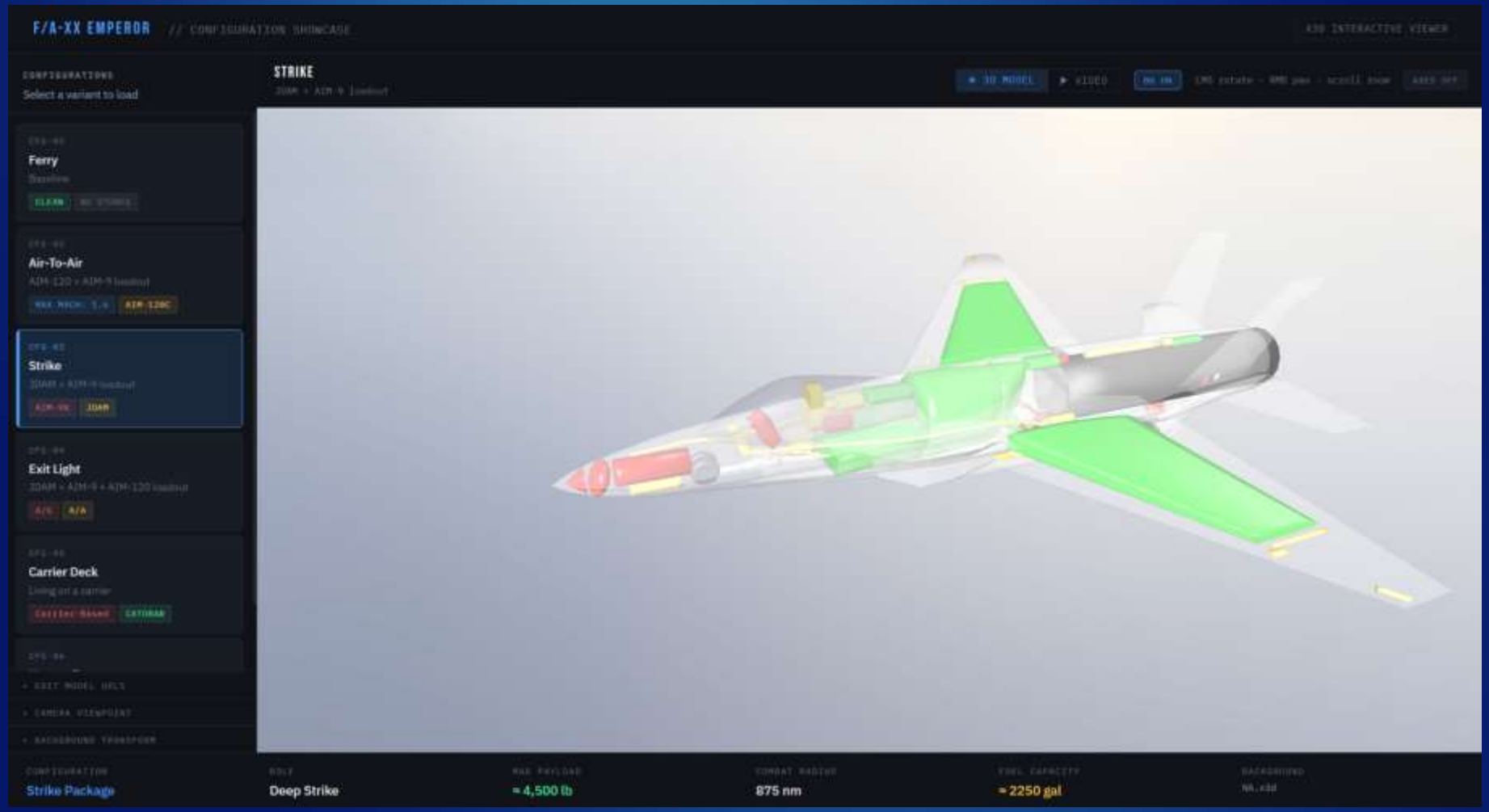

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Pipeline Deployment in AOE 4066 Air Vehicle Design



Fighter Concept Aircraft



Box-wing Firefighting Amphibious Aircraft Concept



Supersonic Airliner Concept



Concluding Notes



Conclusion

- All aircraft components assembled correctly in X3DOM
- Clickable component with highlighting and descriptive text display
- Performance graphs individual to the aircraft
- Validated scene layout capabilities
- Overall workflow proven stable, extensible, and ready for future applications

Future Applications

- Can be expanded to support real-time aircraft design and testing by quickly visualizing how design changes affect aerodynamic performance
- Can be adapted for other aerospace vehicles and simulations, allowing engineers to compare multiple designs in an interactive environment
- Can include internal aircraft components alongside external geometry, giving engineers a more complete understanding of full vehicle design and performance



Thank You!

Web3D 2026

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