Research Engineer – Imperial College 10ft x 5ft Wind Tunnel

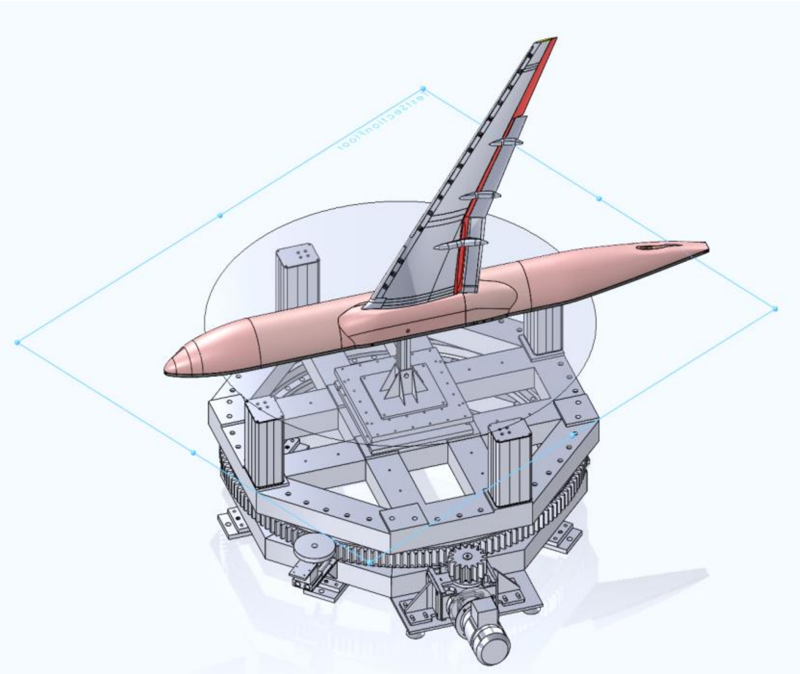
Topic – NASA-Boeing High-Lift Common Research Model

Collaborators – Willam McArdle, Ashley Evans (Boeing UK)

Keywords – Modular Composite Wing; CFD Validation Data; Model Motion System; Wind Tunnel

Summary –

Developed a NASA-Boeing experimental wing into an instrumented, modular, rapid prototyping, low-cost composite structure for acquiring CFD validation data. £100k grant from Boeing UK.



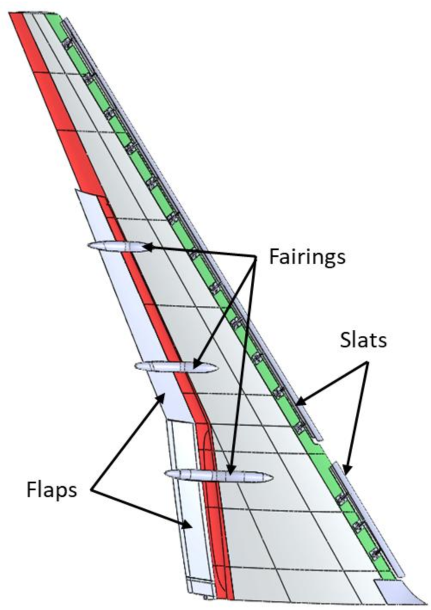


Figure 6: (Left) CAD model of the CRM-HL mounted on a 360° model motion system. The blue plane represents the wind tunnel floor. PIV to be used for flow visualisation. (Right) CRM-HL wing underside with wing torsion box, leading edge (green), trailing edge (red) and high-lift devices (flaps and slats). Wing span = 1.05m, Fuselage length = 2.50m.

Problem –

The NASA CRM-HL is a high-lift research configuration developed to benchmark aerodynamic performance in complex, realistic wing designs. While valuable for CFD and wind tunnel studies, its surface geometry isn't directly suited for manufacturing. Building a physical prototype demands reworking the model to meet structural, modular, and testing requirements—without compromising aerodynamic fidelity.

Solution –

I reconstructed the CRM-HL as a 3D CAD model from NASA's open-source surface geometries and redesigned it for modular, rapid prototyping. This would allow for easy replacement of sensitive components like the leading and trailing edges. Load-bearing components (wing box, spars, ribs) were composite, while the rest was 3D printed for in-house assembly. I determined the location and number of pressure taps to balance resolution and structural feasibility, embedding them directly into the print. Preliminary FEA ensured the structure could handle testing loads with embedded taps and instrumentation like strain gauges.

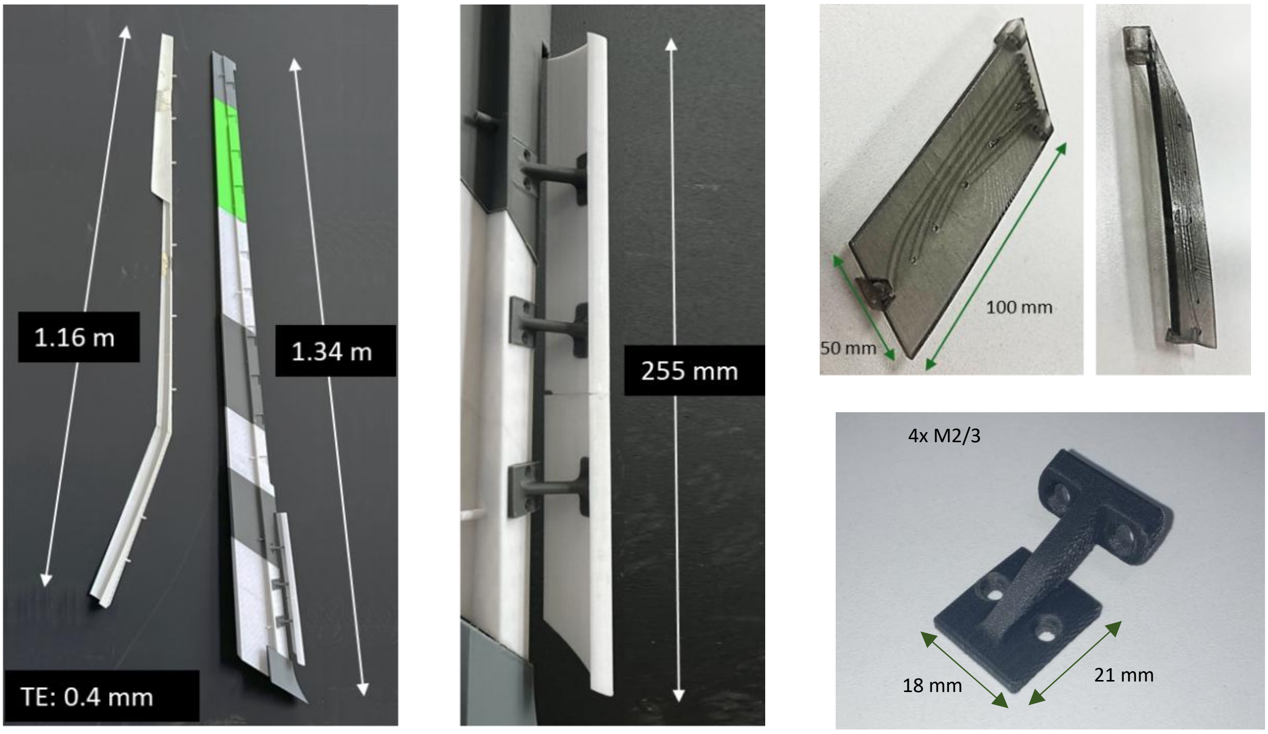


Figure 7: (Left, Middle) SLA resin printed trailing edge, leading edge, strake, slat with printed internal taps, and slat brackets. Thickness at TE is 0.4mm. (Top right) SLA internal printed taps example - internal diameter = 1mm, plate thickness = 1.87mm. (Bottom right) SLA resin printed bracket for slat attachment to the leading edge of the wing.

Model Motion System –

To enable aerodynamic testing at various angles of attack, I designed a novel Model Motion System (MMS) capable of full 360° rotation of the CRM-HL model inside the wind tunnel. The MMS was built entirely from steel to ensure high structural rigidity and suppress mechanical noise that could interfere with the precision of the load balance measurements. This robust design should allow for smooth, repeatable motion while maintaining measurement accuracy for lift and drag forces.

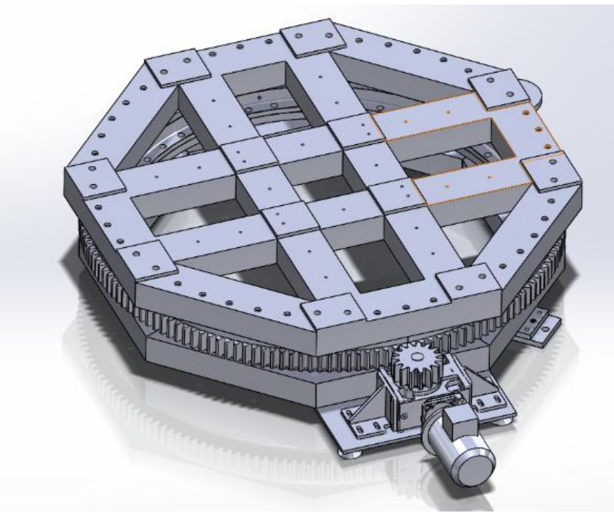


Figure 8: CAD model of the MMS. Diameter = 1.6 m. Gear ratio = 1590.

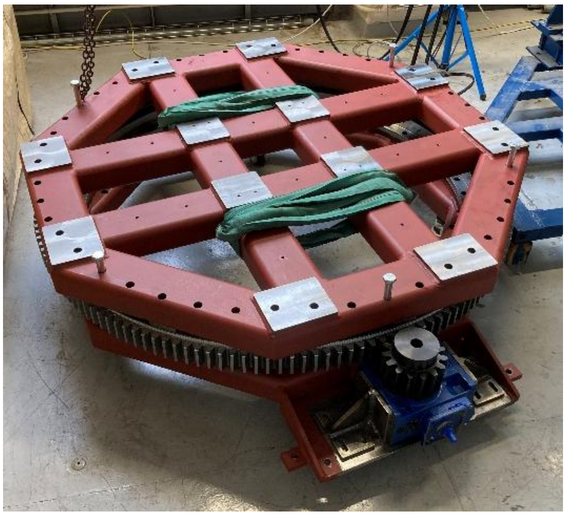


Figure 9: Manufactured MMS. Material: 17-4 PH SS. Surface flatness +/- 0.2mm