

EXPERIMENTAL ASSESSMENT OF GUST LOAD ALLEVIATION TECHNOLOGIES FOR HIGH ASPECT RATIO ULTRA EFFICIENT REGIONAL AIRCRAFT WING

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ABSTRACT

The HERWINGT (Hybrid Electric Regional Wing Integration Novel Green Technologies) project investigates advanced wing technologies for next generation regional aircraft, focusing on the Ultra Efficient Regional Aircraft (UERA) concept and its high aspect ratio wing configuration. A comprehensive trade off study assessed the aeroelastic implications of increasing the wing aspect ratio up to 16, targeting fuel-burn reduction while mitigating the structural weight penalties associated with higher aerodynamic loads. Parametric analyses, combined with preliminary evaluations of active load alleviation strategies, established the structural and aero servo elastic requirements for an experimental demonstration of gust load alleviation (GLA) in the Politecnico di Milano (POLIMI) wind tunnel.

Building on these findings, a dedicated wind tunnel campaign was developed to validate active GLA controllers on a stiffness scaled, flexible wing representative of the UERA AR 16 configuration. GLA campaign (Demo D1 9) model consists of about 3m half span wing installed vertically and equipped with two control surfaces—an aileron and a Load Control (LC) tab—used in combination for loads alleviation.

The wind tunnel model was derived from the UERA AR 16 reference configuration through an iso frequency scaling methodology that preserves reduced frequency content and time scale equivalence, enabling direct implementation of real time control laws developed for the full scale aircraft. The structural architecture features a spar replicating the spanwise stiffness distribution of the UERA AR 16 wing, complemented by 3D printed aerodynamic surfaces, movable control surfaces and ballast masses for modal tuning.

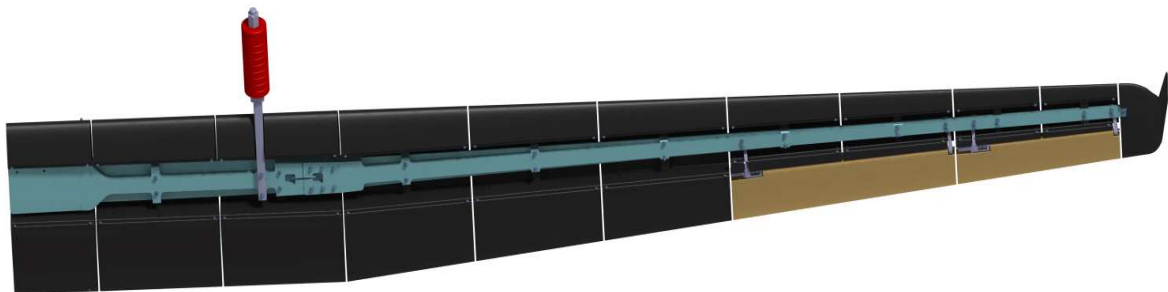


Figure 1 - GLA UERA wing wind tunnel model (CAD) PoliMi

For GLA testing, the flexible wing is mounted in a free free half aircraft configuration, coupled with a rigid half fuselage to allow symmetric plunge and pitch motions representative of level flight. A dedicated gust generator, capable of producing sinusoidal and $1 \cos$ gust profiles

compliant with CS certification requirements, excites the model through the simultaneous deflection of six vanes, generating controlled flow perturbations in a closed chamber environment.

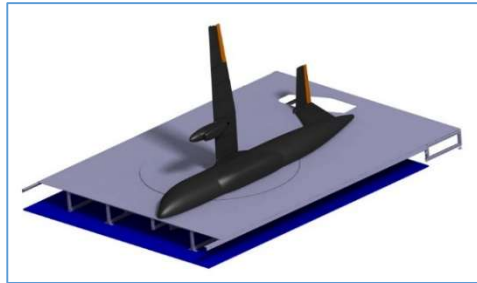


Figure 2 - GLA aero-servo-elastic wind tunnel model and installation in test room at PoliMi

The GLA campaign is structured into progressively complex phases.

Phase 1 consists of Ground Vibration Testing (GVT) to identify the wing’s modal parameters—natural frequencies, damping ratios, and mode shapes—using electrodynamic or impact excitation and accelerometer arrays. Frequency response functions are analyzed using RFP or PolyMAX methods, and the finite element model is updated through MAC and frequency error metrics.

Phase 2 identifies the open loop discrete gust responses of flexible wing model under a set of discrete gust excitations at different amplitudes and frequencies, incrementally increasing airspeed. Aim is tracking wing spanwise sensible points accelerations, displacements and monitoring wing internal loads evolution in five spanwise instrumented sections. Moreover, it allows the validation of theoretical predictions of gust loads amplitude performed at A/C level and test requirements at wing model level.

Phase 3 evaluates closed loop GLA using multiple control strategies—including SOF, LQR, H infinity —assessing internal spanwise loads reduction for several gust input amplitudes frequencies combinations at increasing flight speed and different active device configurations, closed loop loads damping, actuator activity, and robustness across the aerodynamic envelope.

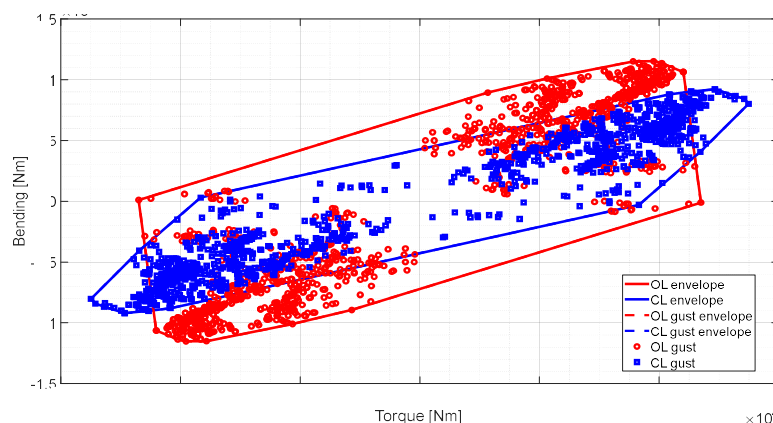


Figure 3- WRBM structural gust loads envelope (B_m vs T_q) - Comparison GLAS Open Loop - Closed Loop

The GLA campaign (Demo d1-9) is embedded within HERWINGT project timelines.

Overall, the campaign provides a critical experimental platform for validating GLA technologies for high aspect ratio wings. By combining dynamically scaled aeroelastic modelling, advanced loads control strategies and a comprehensive test methodology, the campaign supports the maturation of aero servo elastic technologies essential for structural mass reduction, improved gust resilience, and enhanced safety margins in future ultra efficient regional aircraft. Moreover, it will be an important starting step for future A/C level full scale flight demonstrations as planned by UE Clean Aviation next development phases.