Conceptual Design of Low Sonic Boom Aircraft Using Adjoint-Based CFD

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1 Introduction

We present a multi-level, multi-disciplinary approach using rapid low-fidelity and accurate high-fidelity methods for the conceptual design of aircraft with low drag and low sonic boom. Prior work in this area has focused on the shape of the signature in the nearfield or on the ground to directly drive the high-fidelity aircraft model. In the current approach, a multi-shock F-function parameterization is used to reduce the dimensionality of the low-fidelity sonic-boom minimization problem, while simultaneously mapping the associated noise to an inverse-design pressure signal target at the high-fidelity level. This decoupling of the difficult sonic-boom minimization problem from the expensive high-fidelity shaping leads to an arguably more efficient approach that directly addresses the metric of greatest interest in low sonic boom design: the perceived noise level on the ground.

2 Design Approach

At the low-fidelity level, favorable nearfield pressure signals are sought using a multi-shock inverse design method driven by a multi-objective genetic algorithm. Constraints are imposed to ensure lift and volume requirements are satisfied while minimizing drag and perceived noise level. Promising designs are selected from the resulting Pareto-optimal front and used as near-field pressure targets in high-fidelity, adjoint-driven gradient optimizations, where penalty weightings are used to include drag minimization and trim requirements in the objective function. Integration with the PASS conceptual design system enables the incorporation of conceptual-level mission constraints such as weight and balance, low-speed performance and engine performance into the optimization. Previous work has demonstrated the capability of the high-fidelity toolset with regards to accuracy [1] and shape design [2]. While earlier research in this area explored the use of multi-fidelity approaches [3, 4], the development of an adjoint design capability and the dramatic increase in available computational resources enables direct shaping of the high-fidelity model to the subtle sensitivities present in low sonic-boom design.

References

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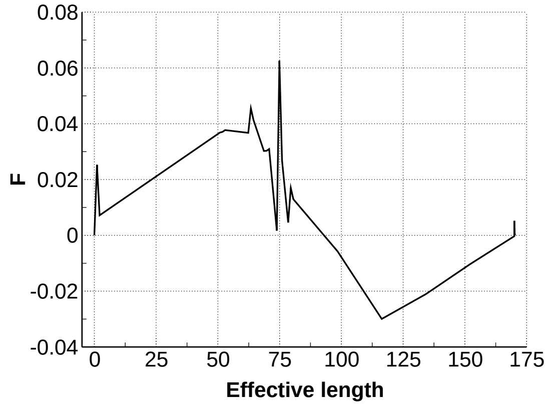
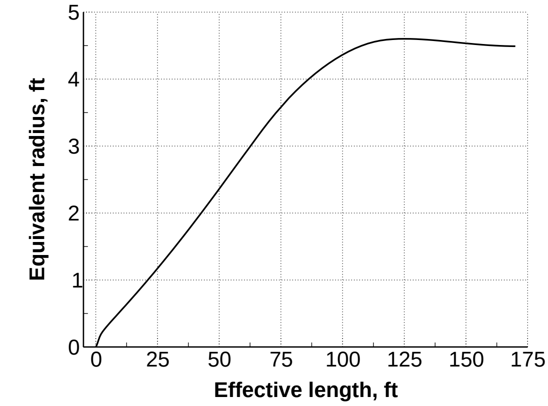
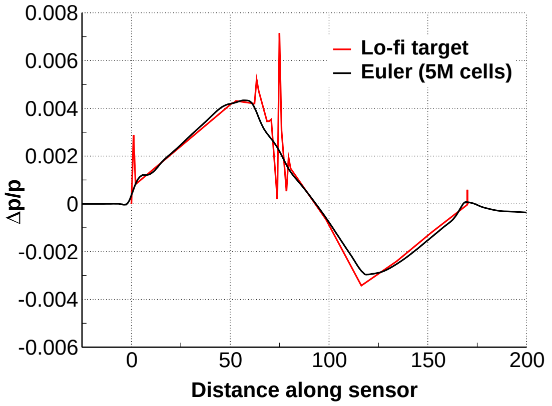
[4] Seongim Choi, Juan J. Alonso, Ilan M. Kroo, and Mathias Wintzer. Multifidelity design optimization of low-boom supersonic jets. *Journal of Aircraft*, 45(1):106–118, January-February 2008.



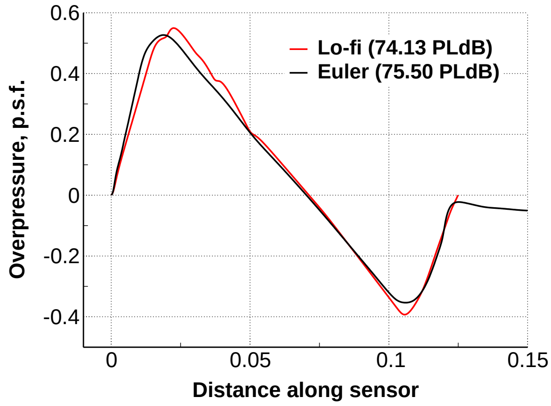
(a) F-function with 7 shocks produced using low-fidelity exploration tool



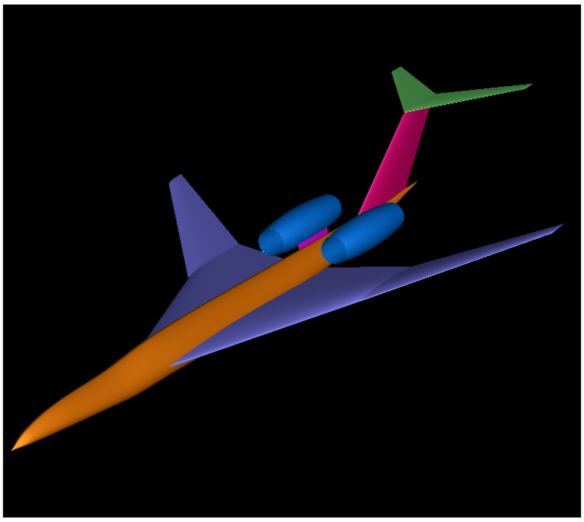
(b) Constrained radius distribution synthesized from F-function; final radius specified by lift requirement



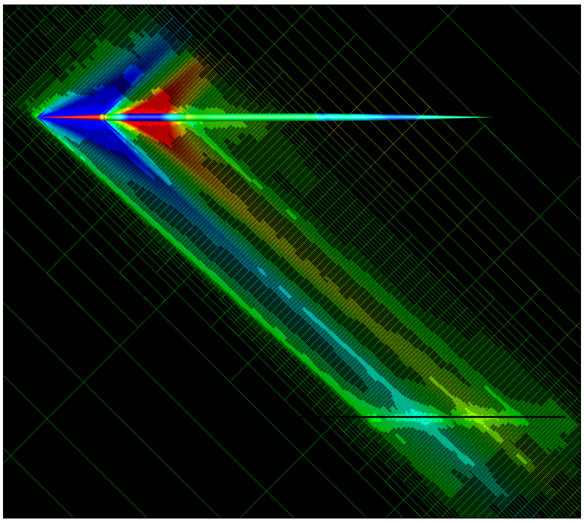
(c) Nearfield target pressure signal synthesized from F-function, compared with nearfield pressure sampled from Euler solution. Offset distance $h/L = 2$



(d) Ground signal produced after propagation of nearfield signals to the ground (ground altitude at 0 ft. above sea level)



(e) Parametric model used during high-fidelity inverse-design phase



(f) Mesh cut of Euler flow solution after optimization. 15M grid cells

Figure 1: Wing-body-nacelle-tail configuration at altitude of 45,000 ft, M_∞ 1.5, weight of 55,000 lb and effective length of 170 ft. 11 design variable for 7-shock, low-fidelity sonic boom minimization phase, 152 shape design variables for high fidelity inverse design phase