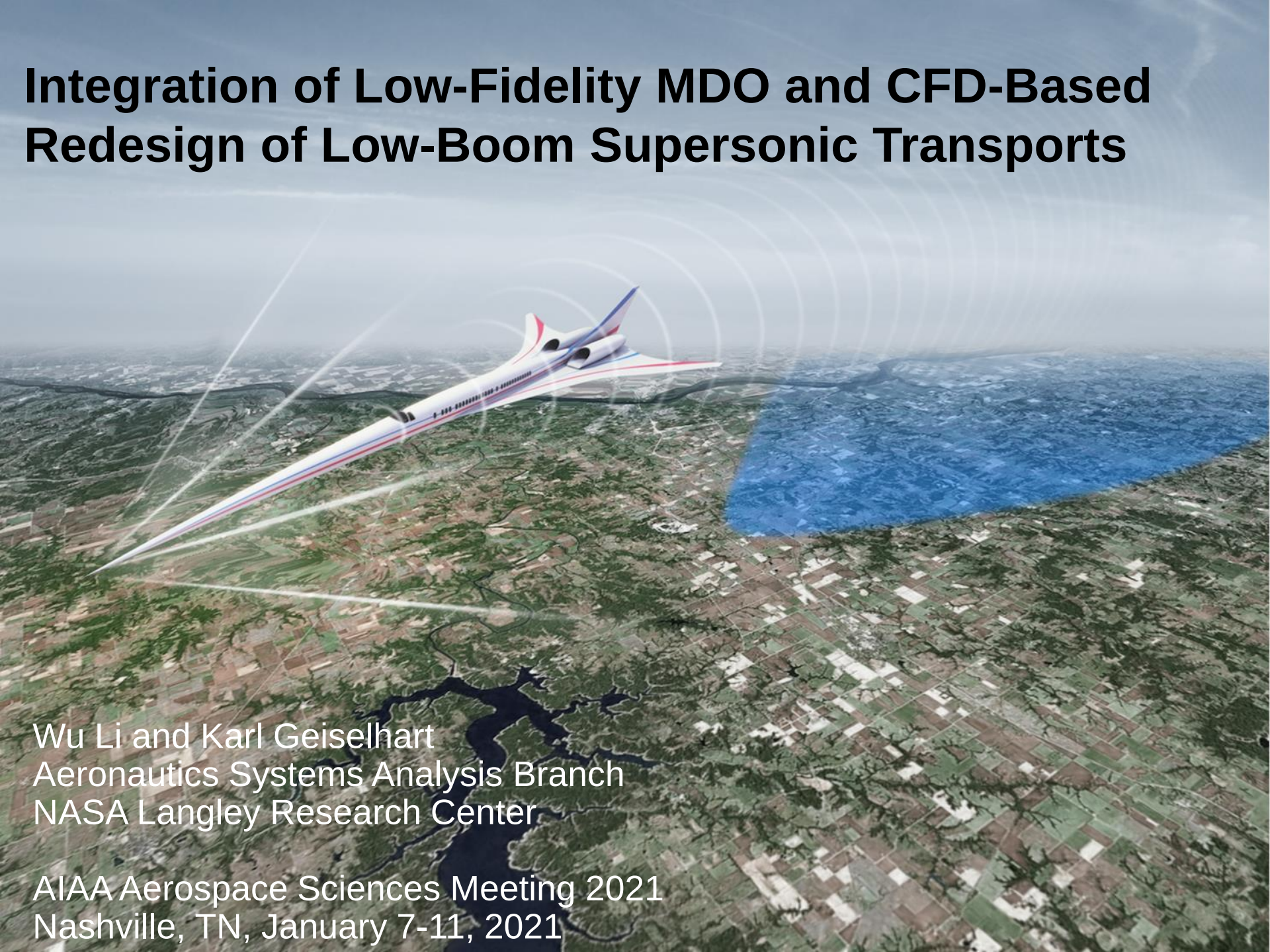


Integration of Low-Fidelity MDO and CFD-Based Redesign of Low-Boom Supersonic Transports



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Background Info



- Motivation
 - Determine the economic viability of supersonic transports for the public using CFD-based low-boom configurations
- Technical challenge about weight inconsistency
 - CFD-based low-boom design is generated for ***a fixed cruise weight*** estimated from a baseline that might be very different from the CFD-based low-boom design.
- Requirements for a low-boom supersonic transport
 - carry 40 passengers
 - cruise overwater at Mach 1.8 with range of 3,600 nm
 - fly a low-boom mission at Mach 1.6 with range of 2,500 nm
 - satisfy mission performance constraints
 - have the lowest maximum takeoff gross weight possible*

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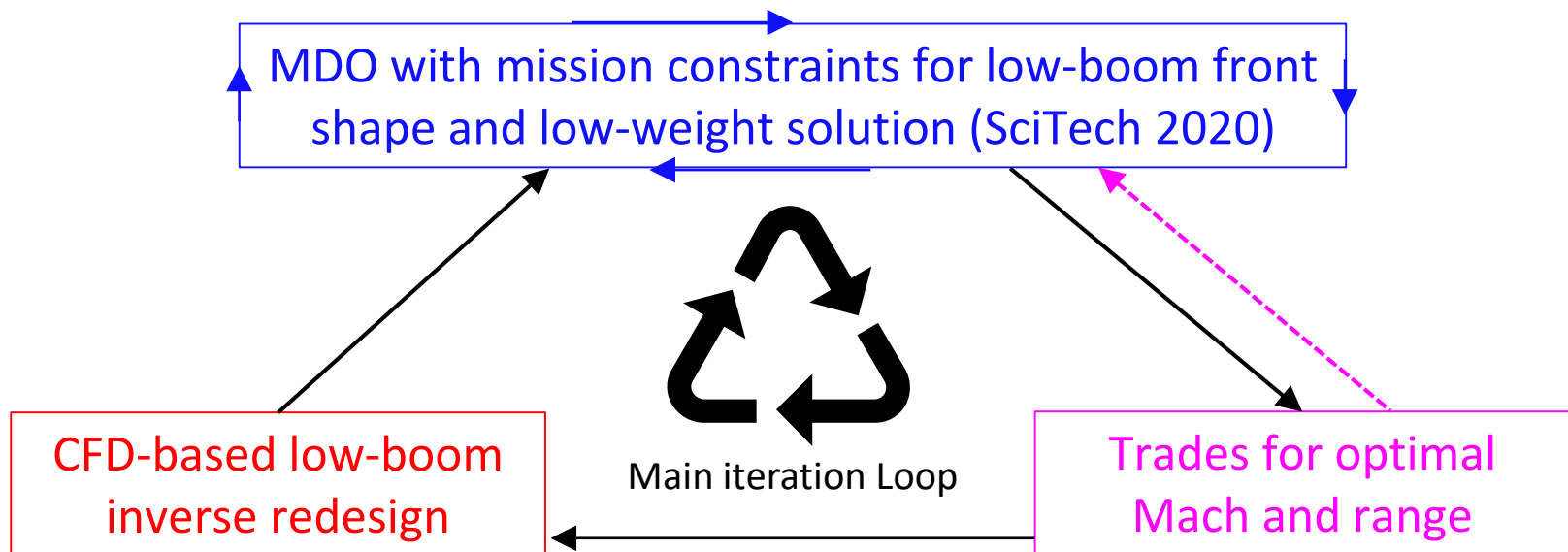
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- Requirements for a low-boom supersonic transport
 - carry 40 passengers
 - cruise overwater at Mach 1.8 with range of 3,600 nm
 - ~~○ fly a low boom cruise Mach of 1.6 with range of 2,500 nm~~
 - satisfy takeoff/cruise/landing performance constraints
 - have the lowest maximum takeoff gross weight possible*
 - attain the highest low-boom cruise Mach and longest range
 - have the potential of achieving a CFD-based ground signature below 70 PLdB

Block Coordinate Optimization Method



Optimization is performed with respect to one block of design variables listed below:

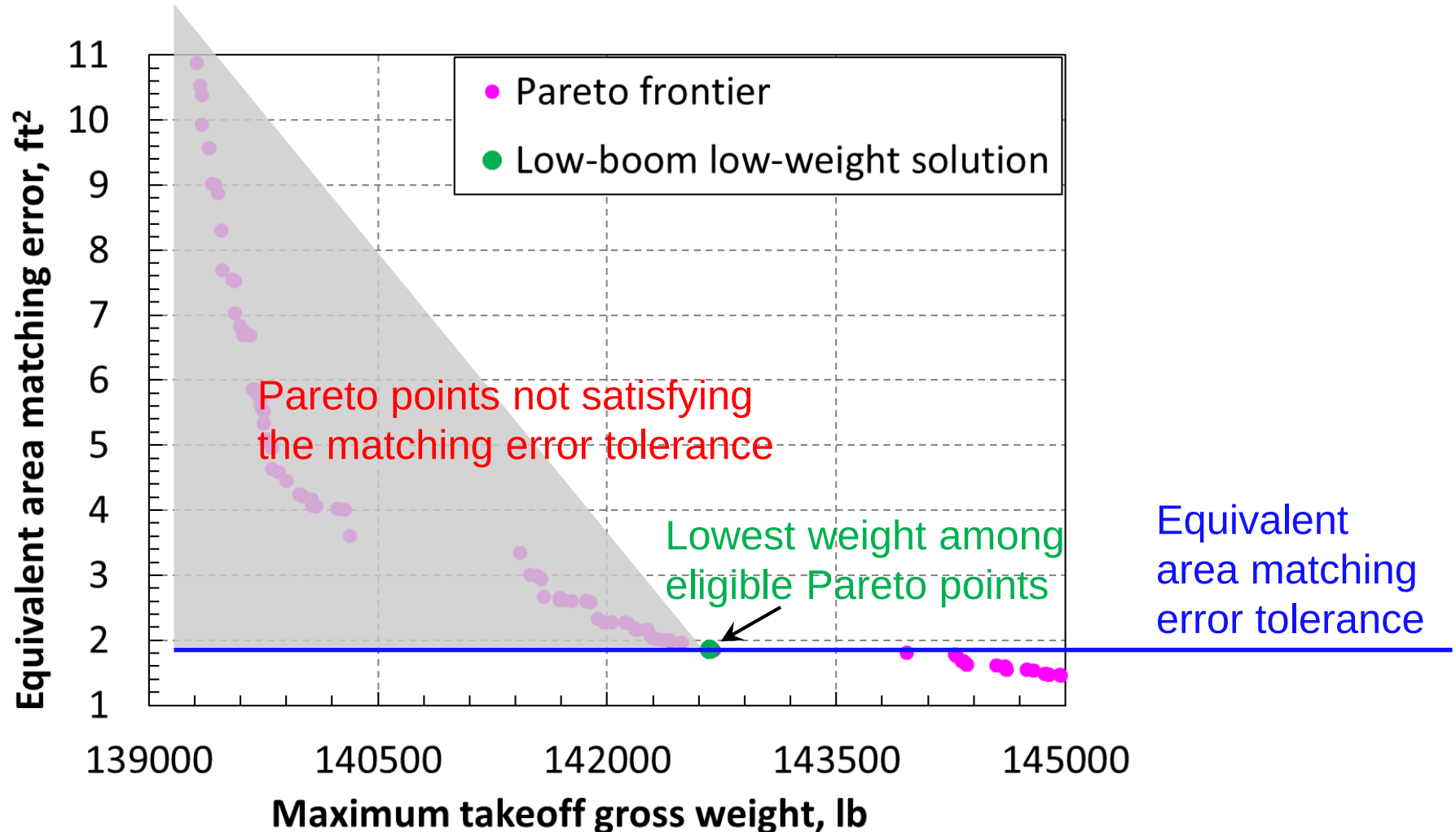
1. Bezier curve parameters for low-boom target optimization
2. Engine thrust scaling for engine thrust optimization
3. Fuselage nose shape parameters, wing parameters, and tail rotation angle for low-weight low-boom multiobjective optimization
4. Auxiliary parameters (such as flap deflection angles) for landing and takeoff performance optimization
5. Cruise Mach and cruise altitude for maximum low-boom cruise speed
6. Range and cruise altitude for maximum low-boom range
7. Wing parameters, tail rotation angle, and aft shape parameters for CFD-based low-boom redesign of low-fidelity MDO solution



Low-Boom Low-Weight MDO Solution



Solve a multiobjective low-boom MDO problem with the specified mission constraints. (SciTech 2020-0664)



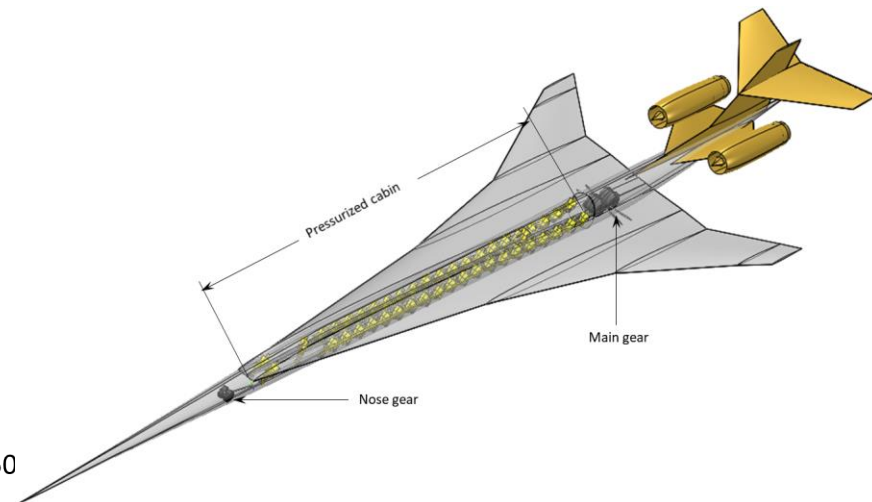
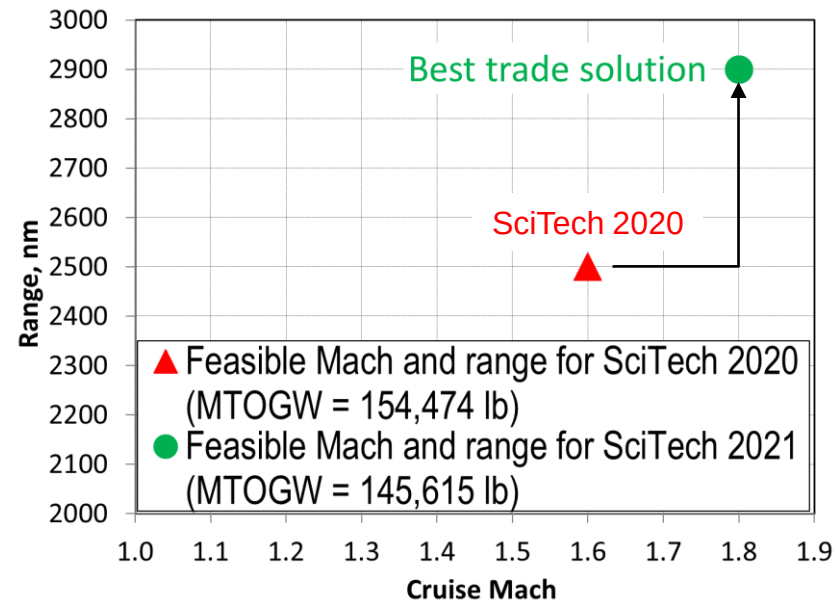
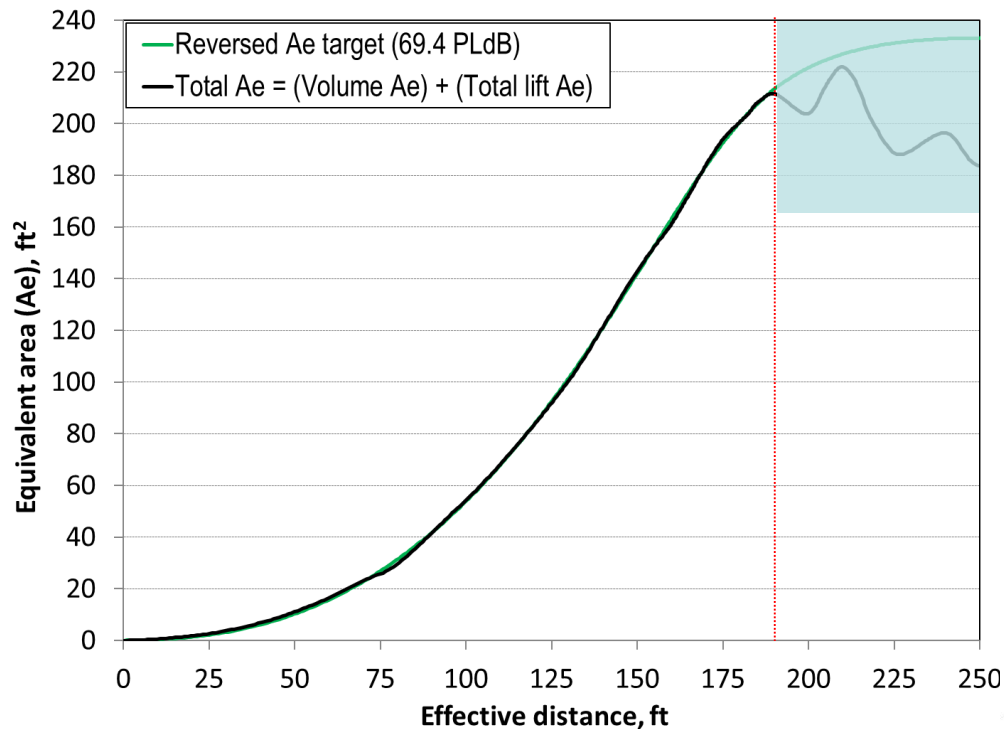
Best Trade Solution



1. Mach optimization: Increase Mach and altitude such that the dynamic pressure is constant, when target PLdB < 70
2. Range optimization for cruise Mach 1.8

$$\text{max}_{\text{Altitude}} \text{Range subject to (Target PLdB)} \leq 70$$

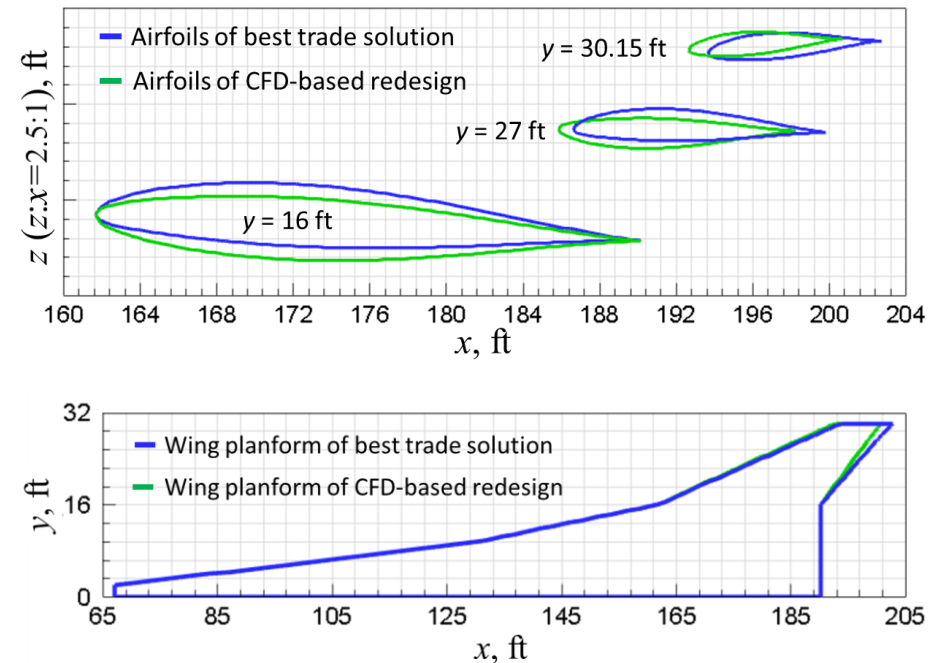
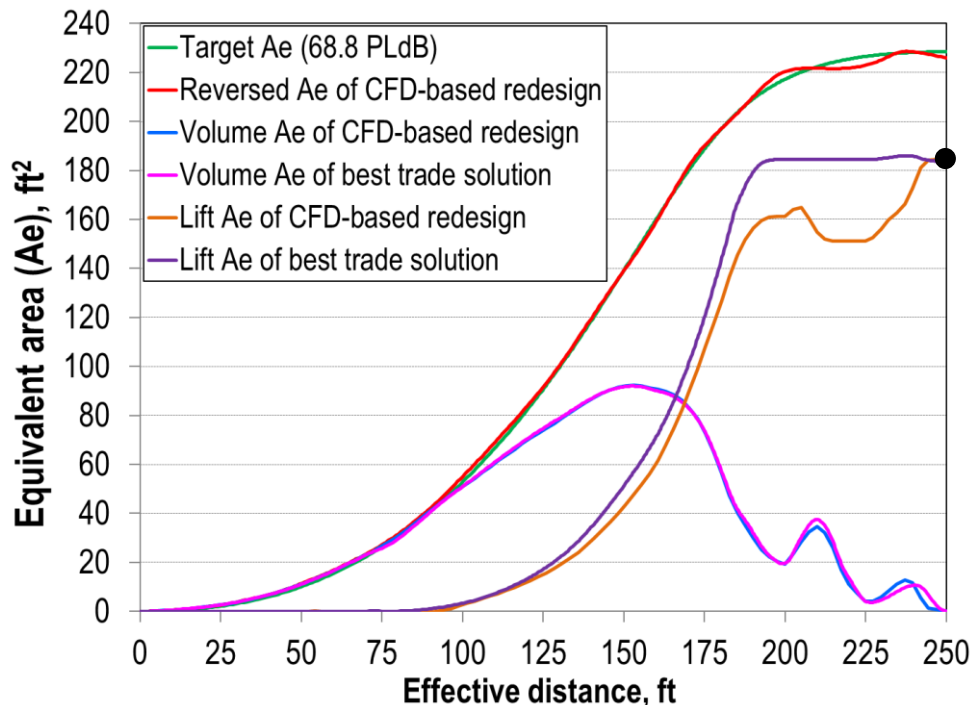
$$\text{and (Overland TOGW)} \leq (\text{Overwater TOGW})$$



CFD-Based Redesign of Best Trade Solution



- Use the same angle of attack as the best trade solution.
- Use the tail rotation angle to match CFD lift to the cruise weight of the best trade solution.
- Have the same cruise weight as the best trade solution.
- Minor shape modifications are quantified by the volume Ae differences.
- Airfoil and planform comparisons confirm minor shape modifications.
- The CFD-based low-boom design satisfies the mission constraints.



Concluding Remarks

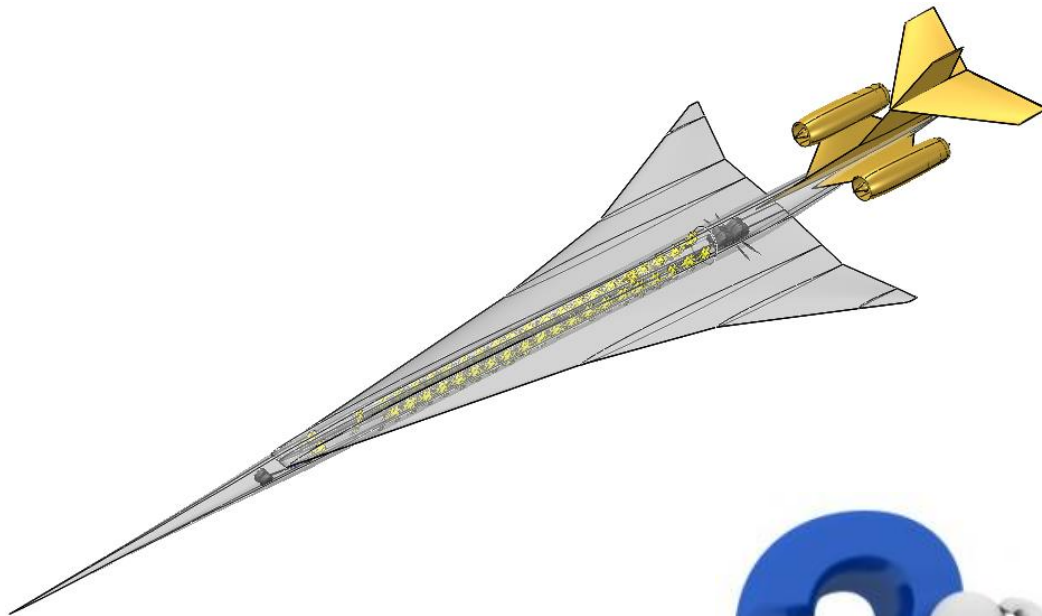


- It is extremely important to conduct system-level trades for cruise Mach, range, and low-boom target PLdB.
 - The MTOGW of 154K lb of the baseline is reduced to 145K lb for the best trade solution.
- Low-boom low-weight solution can be reshaped as CFD-based low-boom design with minor wing modifications.
 - CFD-based redesign has a reversed equivalent area distribution closely matching a low-boom target below 70 PLdB.
- Significantly narrowed the gap between a specified cruise weight for the CFD-based low-boom design and the actual cruise weight of the low-boom design.
- The block coordinate optimization method has the capability to enforce the CFD trim constraint at the start of low-boom cruise. See the paper for details.

Acknowledgments



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 - NASA Commercial Supersonic Technology (CST) Project
 - NASA Transformational Tools & Technologies (T³) Project



Takeoff gross weight = 145,164 lb

Fuselage length = 232 ft

Wing span = 58 ft

Wing area = 2930 ft²

Low-boom range = 2,950 nm

Overwater range = 3,600 nm

Cruise Mach = 1.8

Low-boom target = 69.9 PLdB

Approach velocity = 145 knots

Takeoff/landing field length < 8300 ft

