Wing Rib Lightweighting: 25-30% Mass Reduction for Regional Aircraft

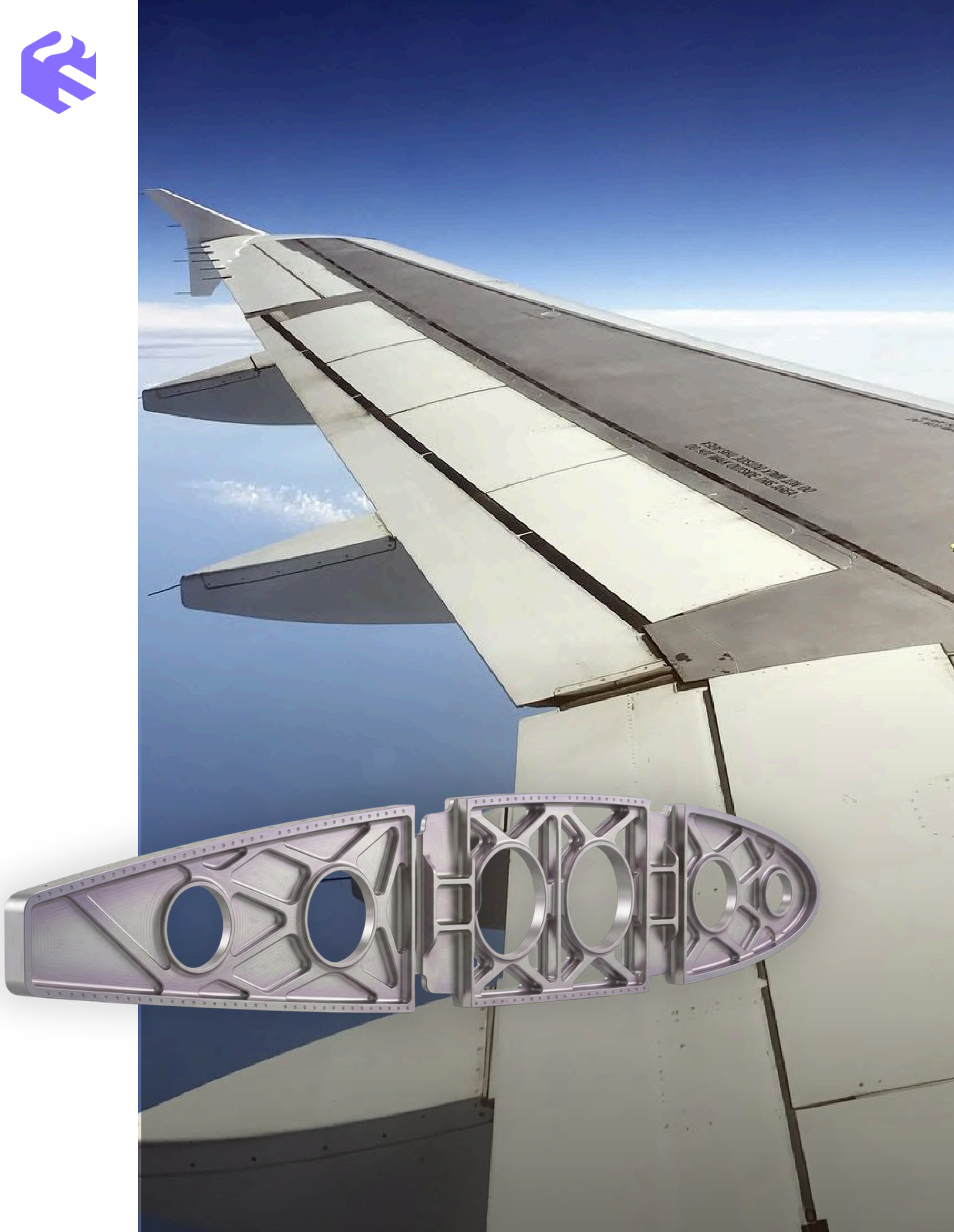
This case study details the optimization of a primary **structural wing rib** for a regional turboprop aircraft program, across a five-position span variant family. The primary objective was to reduce component mass while satisfying CS-25 structural requirements, evaluating both die casting and 5-axis machining as candidate manufacturing routes. Using Cognitive Design, the team achieved a **28% average mass reduction** per rib position, **generating 50+ design candidates** in parallel versus the 2–3 concepts a conventional workflow allows, and reduced per-variant engineering lead time from 2 weeks to 2 days following initial workflow buildup.

Engineering Challenge

On regional aircraft programs, wing ribs must carry CS-25 structural loads while respecting aerodynamic profiles, fuel-system interfaces, and manufacturing constraints across a family of span positions. Each variant has a different chord length, rib height, and local load intensity, so the hard part is not optimizing one rib in isolation; it is exploring the full family fast enough to find designs that are lighter, compliant, and practical to produce.

The challenges the team set out to address:

- **Variant complexity under time pressure**: Conventional workflows treat each rib as a separate project, rebuilding geometry, meshing, applying loads, and reviewing results sequentially. Across five positions, this can turn into months of non-recurring engineering before the full design space is properly explored.
- **Late manufacturability feedback**: Draft angles, split lines for die casting, and tool-access envelopes for 5-axis machining are often checked only after the structural concept is already committed, forcing rework late in the cycle.
- **Balancing weight, margin, and process choice**: Legacy ribs carried excess safety margin, but reducing mass while comparing die casting and machining required structural, DFM, and process constraints to be evaluated together from the start.



The Solution: Cognitive Design Workflow

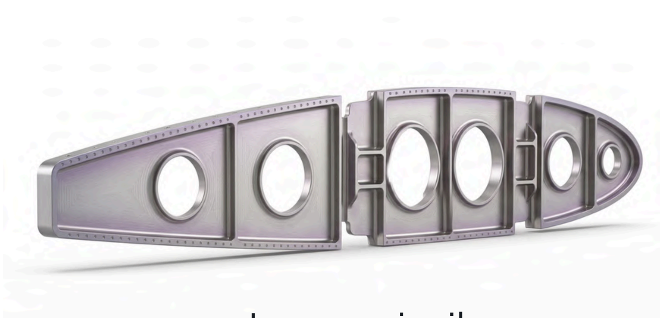
1. Design Space & Load Cases
We imported the legacy rib geometry and defined Preservation Zones: spar attachment lugs, chord riveting flanges, fuel bay access cutouts, and inspection hole locations. Load cases: CS-25 limit load x 1.5 (ultimate), gust load per §25.341 (n = 2.5g), fuel pressure (0.35 bar), and landing impact (n = 1.5g). Al-7075-T6 (yield 503 MPa) was selected over the Al-2024-T3 baseline (345 MPa). Die casting and 5-axis machining were defined upfront as the two manufacturing routes, with their respective DFM constraints embedded from the first iteration.

2. Generative Exploration
Using the Design Exploration module, we ran a **Design of Experiments (DoE) generating 50+ variants in parallel**, compared to the 2–3 concepts a conventional workflow allows in the same timeframe. Each variant was evaluated simultaneously against mass, Von Mises stress, manufacturability score, cost, and carbon footprint. The die casting route was selected given the program's production volume, justifying tooling investment and the lowest cost-per-part at scale.

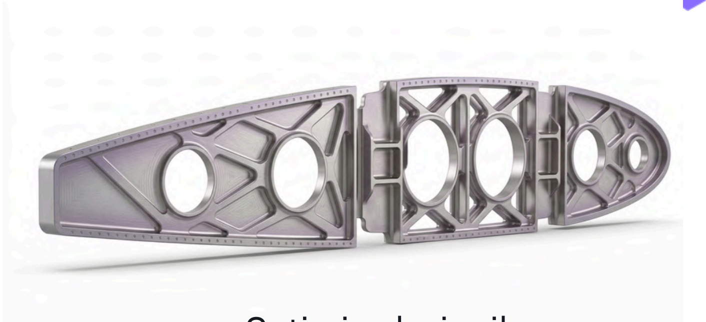
3. Performance & Manufacturability (MDD & SDD)
Manufacturing-Driven Design (MDD) constraints were applied concurrently for both routes: draft angles of at least 3 degrees on all vertical faces, split-line locked at mid-height, 2.5 mm minimum wall, and uniform corner radii to prevent shrinkage porosity on the die cast candidate. Simultaneously, **Simulation-Driven Design (SDD) using meshless FEA** drove real-time reinforcement of web sections near spar attachment lugs where stress concentrations were highest. A targeted refinement pass followed, increasing strut thicknesses at chord flanges and adjusting fillet radii at spar lug interfaces to reduce stress concentration factors without adding mass.

4. Validation / Final FEA
Final FEA confirmed the optimized Al-7075-T6 design maintained a safety factor of 1.5 under CS-25 ultimate load. Peak Von Mises stress of 440 MPa remained below the yield limit of 503 MPa, versus a legacy safety factor of 2.8, confirming significant over-design margin in the original part.

5. Workflow Automation
Following validation of the mid-span reference rib, the complete workflow was converted into a **reusable parametric template**. Updating only the input geometry and variant-specific load magnitude, the full chain from topology optimization through MDD constraints, SDD validation, and Design Explorer KPI logging recomputed automatically for each of the four remaining rib positions, with no additional configuration required.



Legacy wig rib



Optimized wig rib

Key Metrics Comparison

Metric	Legacy (Al-2024-T3, Die Cast)	Optimized (Al-7075-T6, Die Cast)	Improvement
Mass (mid-span rib)	3.15 kg (Est.)	2.27 kg (Est.)	28% reduction
Max Von Mises Stress	180 MPa	440 MPa	Safe (yield: 503 MPa)
Safety Factor	02/08/2026	01/05/2026	CS-25 compliant, no over-design
Concepts Explored per Rib	2–3 (manual, sequential)	50+ variants (parallel DoE)	20x more design options