Design Exploration & Automation for Structural Brackets

This case study details the optimisation of a family of structural brackets using Cognitive Design's automated parametric workflow. By replacing a manual, variant-by-variant engineering process with a single reusable workflow covering topology optimisation, simulation-driven design, and manufacturing-driven design across three processes, the engineering team **reduced concept exploration lead time by 80%**, from weeks to hours.

The project generated 15+ validated design alternatives per bracket variant, each evaluated simultaneously against structural performance, manufacturing feasibility, cost, and carbon footprint, with the best die-cast iterations achieving up to **40% weight reduction**.

Engineering Challenge

Structural brackets are ubiquitous in mechanical assemblies, yet their design remains disproportionately time-consuming when handled through conventional workflows. Engineering teams face several compounding bottlenecks:

- **High Engineering Overhead**: Each bracket variant requires dedicated CAD modelling, FEA validation, and manufacturing review. Across a family of parts, this accumulates into weeks of non-recurring engineering effort.
- **Process Selection Uncertainty**: Without the ability to rapidly evaluate multiple manufacturing routes, teams default to familiar processes rather than optimal ones, leaving cost and mass savings unrealised.
- **Sequential Iteration**: Manufacturability checks occur late in the process, after topology results are already committed, forcing costly redesign loops.
- **Workflow Redundancy**: Despite sharing common geometry logic, each bracket in a family is treated as an independent project, with no mechanism to reuse validated workflows across variants.

The Solution: Cognitive Design Workflow

Rather than treating each bracket as an isolated redesign project, CDS structured the engagement around three successive phases: workflow buildup, design exploration, and workflow reuse across the bracket family.

Phase 1: Workflow Buildup

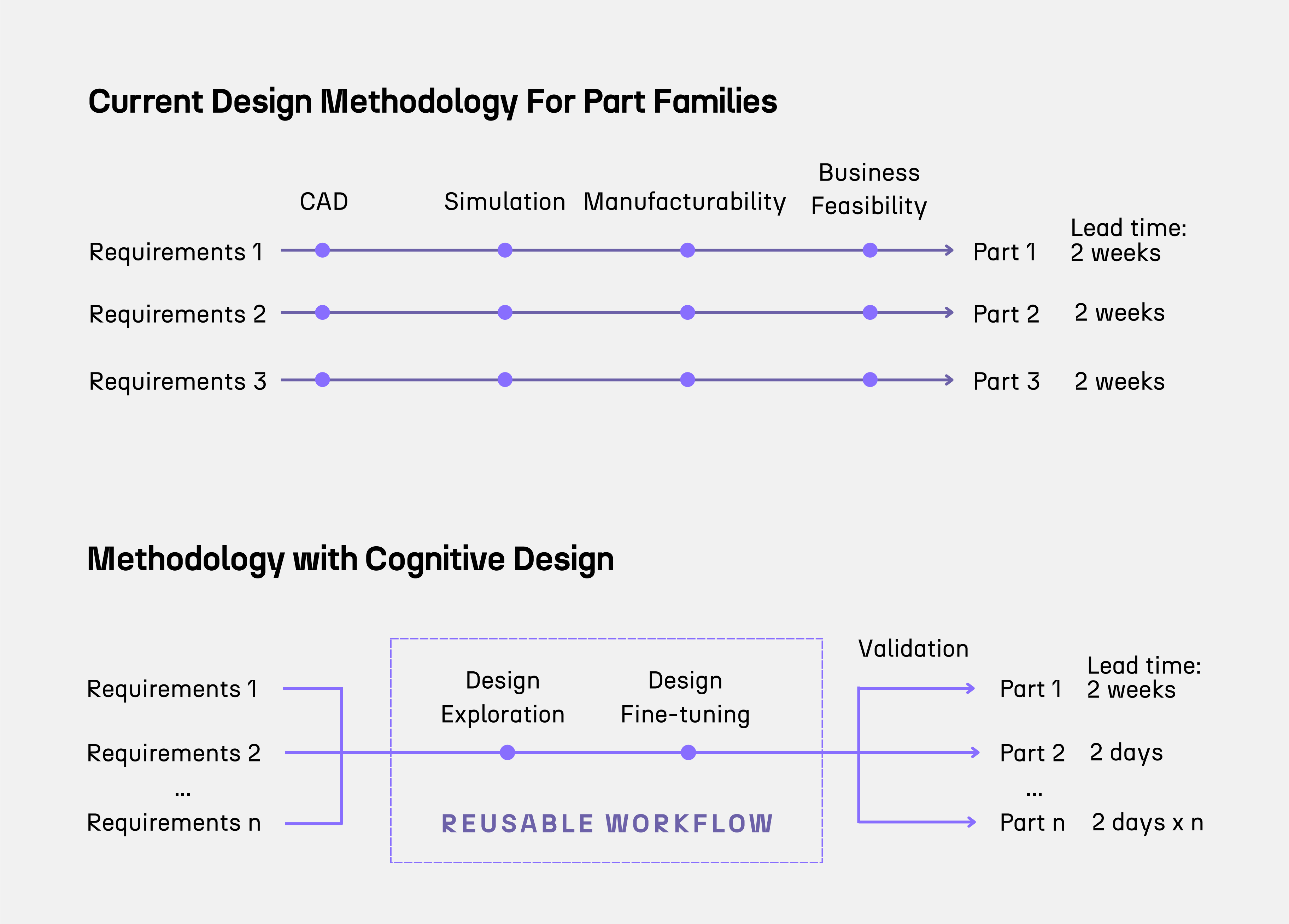
The legacy machined aluminum part was imported into Cognitive Design as the design baseline, with its structural performance, cost, and CO_2 footprint recorded as reference values. A node-based workflow connected simulation setup, generative synthesis using both topology optimization and Topology Weaving, and a two-pass refinement covering simulation-driven geometry adjustment and process-specific manufacturing constraints for additive manufacturing, die casting, and CNC machining.

Phase 2: Design Exploration

Every iteration was automatically tracked in the Design Explorer with a full KPI set covering performance, cost, CO_2, and manufacturability scores. The optimal variant was selected based on the target priority, then exported as a clean STEP file for downstream validation.

Phase 3: Part Family Design Automation

The transition to the second bracket demonstrated the core reuse value of the methodology. The complete workflow was duplicated. Every other stage recomputed without additional configuration, compressing what would conventionally be a full redesign cycle into a simple configuration exercise.



Design Workflow with Cognitive Design: Workflow Build-Up

Set up the Design Space and Load Cases from the Legacy Part

The reference bracket was loaded into Cognitive Design to serve as the design baseline. Material and simulation parameters were then configured to match the existing machined aluminum part, capturing its cost and carbon footprint as reference values.

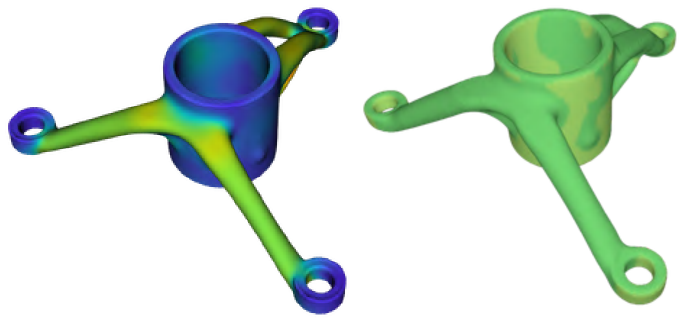
Instead of treating each bracket variant as an independent project, **a single workflow was built** to cover the entire part family, with input geometry as the only variable changing between runs.

Generate an Advanced Topology-Optimized Design

With the design space and load cases established, an initial generative synthesis of the structural bracket was performed:

- The most efficient structural paths were identified to carry the applied loads with minimal mass.
- Several topological variants were **evaluated simultaneously**, enabling rapid convergence toward a structurally efficient concept.
- On select iterations, **Topology Weaving** (proprietary CDS Generative Design approach) was applied alongside standard topology optimization, allowing a direct comparison between both approaches.

This phase yielded a first version of a structurally optimal structural bracket, serving as the foundation for the refined design.

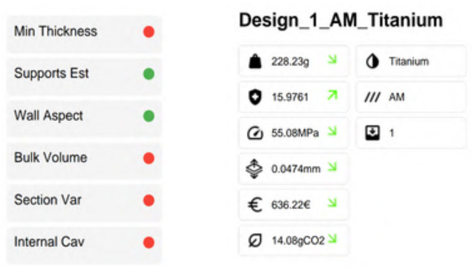


Refine Geometry to Meet Performance and Manufacturing Objectives

The initial generative output was then refined into a manufacturable, high-performance structural bracket geometry through two successive passes:

- **Simulation-Driven Design** was applied first, using stress results to locally adjust wall thickness and reduce peak von Mises stress across the structure.
- **Manufacturing-Driven Design** was then run for each target process, addressing minimum thickness, feature spacing, undercut filling, and axis-accessibility for AM, die casting, and CNC machining respectively.

This two-step refinement ensured that structural performance and fabrication feasibility were addressed in sequence, not as competing afterthoughts.



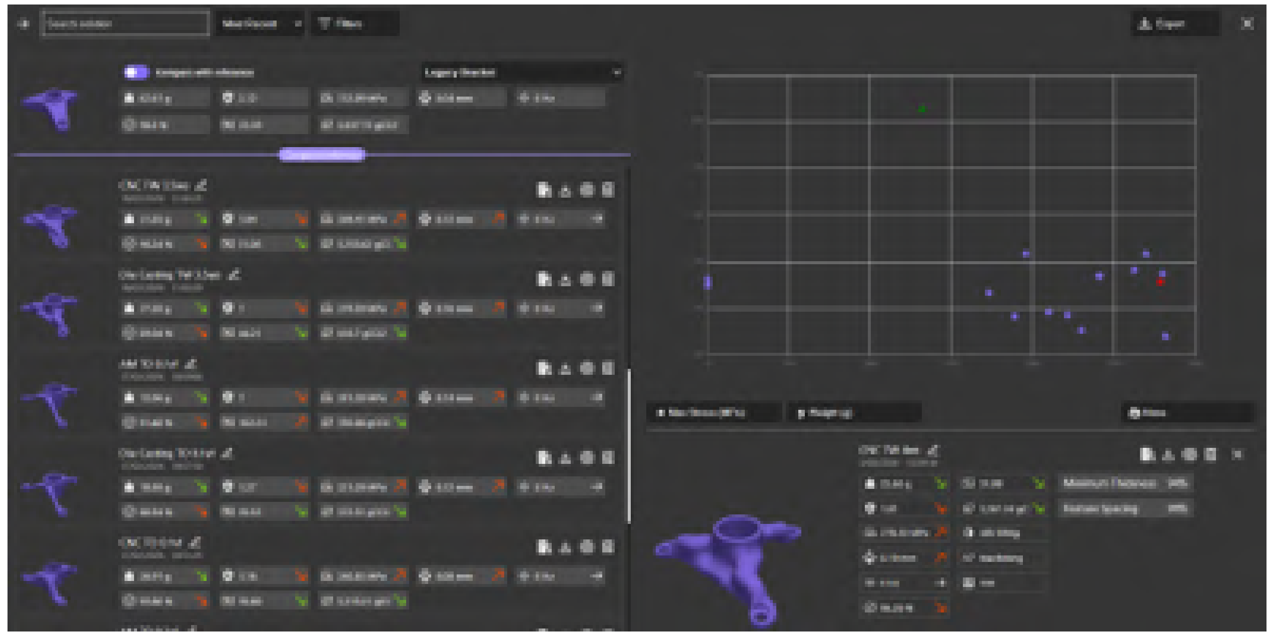
Track Iterations and KPIs in the Design Explorer

Every design iteration was logged in the Design Explorer, building a **structured record** of performance and manufacturability data across the full variant set:

- Mass, displacement, safety factor, cost, CO2, and process-specific manufacturability scores were **captured automatically**, without manual extraction.
- Interactive graphs and filters allowed **tradeoffs to be assessed visually**, with the legacy bracket pinned as a reference to benchmark all generated variants against it.

This formalized the exploration loop and provided clear, traceable justification for the final design selection.

Design Workflow with Cognitive Design: Design Exploration



Design Explorer view

Compare Design Exploration Results to Identify the Most Suitable Iteration

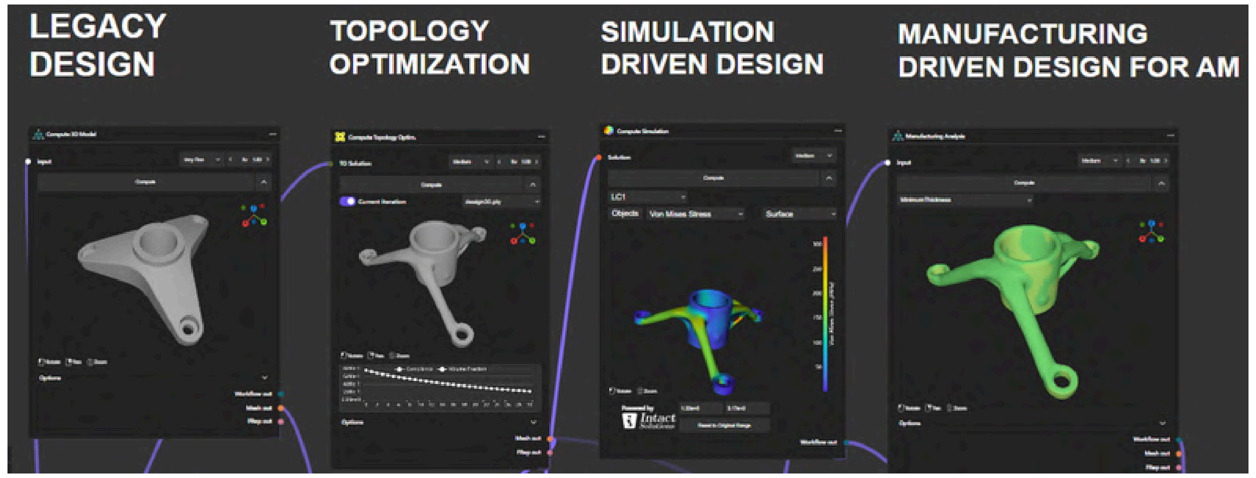
Once multiple generative and refined bracket candidates were produced, the focus shifted to structured evaluation across all relevant engineering criteria. The Design Explorer provided the analytical framework for this phase, enabling the team to **assess every iteration** consistently and objectively through three core activities:

- **Quantitative KPIs** including mass, peak stress, safety factor, displacement, manufacturability scores, cost, and carbon footprint were automatically recorded and made available for direct comparison across the full candidate set.
- **Performance tradeoffs** were visualized through graph-based interfaces and comparative charts, giving the team a clear picture of which designs simultaneously satisfied weight, stiffness, and structural safety targets.
- **Threshold filters and ranking tools** were applied to narrow the field, retaining only candidates that met the defined structural and manufacturing requirements.

This structured review replaced subjective design judgment with a repeatable, data-driven selection process grounded in quantified engineering outcomes.

Extract the Workflow Capturing All Design Intents Leading to the Best-Performing Model

Once the best-performing structural bracket iteration is identified, Cognitive Design allows engineers to access the complete workflow that generated it. All modeling operations, transformations, constraints, and parameter relationships are already **encapsulated** within that design iteration. Because the workflow is natively captured by Cognitive Design as part of the design iteration, TAS engineers can immediately leverage it to generate new structural bracket variants, ensuring full traceability and consistency without re-creating any modeling steps.

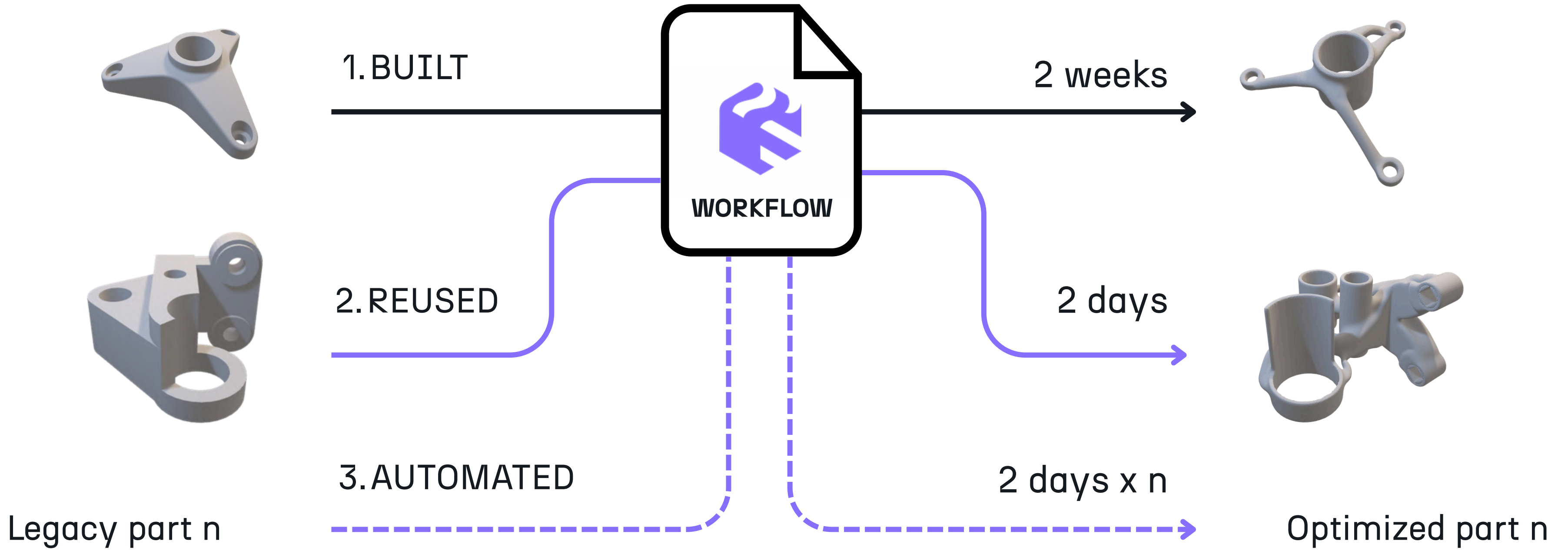


Workflow of the best-performing iteration

Design Workflow with Cognitive Design: Workflow Automation

Once the optimal workflow is extracted from the selected bracket iteration, it can be directly **reused across the entire bracket family**. By duplicating the workflow via a save-as operation and **swapping only the input geometry and simulation** macro block, the complete chain, from generative synthesis through simulation-driven refinement and manufacturing-driven design, rebuilds automatically for each new variant without additional configuration. This transforms what would conventionally require a full redesign cycle into a straightforward parameter update, **freeing engineering time for higher-value decisions** such as synthesis tuning or process selection strategy.

The selected candidate is then **exported as a clean STEP file** using the mesh-to-BREP conversion block, which preserves clean, clickable surfaces on all functional regions while maintaining the organic character of the optimized geometry elsewhere. This ensures the exported model is immediately usable for final validation in the engineering team's standard CAD or FEA environment, with no manual surface cleanup required.



Project in Numbers

15+ variants — The number of structural bracket variants that can be designed and optimized by reusing a single Cognitive Design workflow.

2 hours — The time required to generate the second bracket variant in full, using the same workflow built for the first bracket, with only the input geometry and simulation setup updated.

4x faster — The acceleration in engineering time achieved across the full bracket family through direct workflow reuse, compressing what would have taken months to just days.

40% lighter — The average mass reduction achieved across generated bracket candidates, while remaining within all structural requirements.

Conclusion

This project demonstrated a concrete shift in how structural brackets can be conceived, optimized, and scaled across a part family.

By replacing a linear, bracket-by-bracket workflow with a unified generative and parametric approach, the team was able to produce significantly lighter designs without sacrificing structural integrity, manufacturability, or process flexibility. Generated candidates delivered up to 40% mass reduction compared to the legacy machined part, while meeting all defined safety factor and displacement requirements across three distinct manufacturing processes.

Beyond structural performance, the project illustrated how Cognitive Design compresses the full engineering cycle. Design exploration across multiple synthesis methods and process variants was completed within a single workflow, with the Design Explorer providing immediate, data-driven visibility into the tradeoffs. The transition to the second bracket required no workflow rebuild, reducing what would conventionally take weeks of repeated modeling, simulation, and manufacturability iteration down to a configuration update completed in hours.

The approach is not specific to this bracket geometry or application. Any engineering team managing recurring part families across aerospace, defense, automotive, or industrial machinery faces the same compounding cost of repetitive redesign work. A parametric, reusable workflow architecture addresses this directly, shifting engineering effort away from non-innovative tasks and toward the decisions that actually drive design quality and program performance.