CASE STUDY

DESIGN EXPLORATION: CHOOSING THE BEST MANUFACTURING METHOD FOR AN AIRCRAFT BRACKET

When developing breakthrough products, aerospace companies seek to expand possibilities in materials, part shapes, and manufacturing methods while ensuring cost control and viability. Therefore, they must constantly seek the optimal balance between performance (weight and structural integrity), cost, and production scalability to determine the best approach for part development.

Additionally, before production, designs undergo industrial feasibility validation, often leading to iterative exchanges between design and manufacturing/industrial teams, causing delays and inefficiencies. Streamlining this process from the earliest design stage is essential for faster decision-making and optimized workflows.

This case study, in collaboration with Potez Aéronautique, demonstrates how Cognitive Design facilitated design exploration for optimization for an aircraft structural bracket comparing Additive Manufacturing (AM) and CNC Machining. By leveraging Topology Optimization, Simulation-Driven Design (SDD), and Manufacturing-Driven Design (MDD), we automated design adaptation while integrating cost estimation.

Consolidating these metrics in a single environment allowed Potez Aeronautique's engineers to make data-driven trade-offs, optimizing performance and cost while accelerating the transition from concept to production.

COGNITIVE DESIGN SYSTEMS

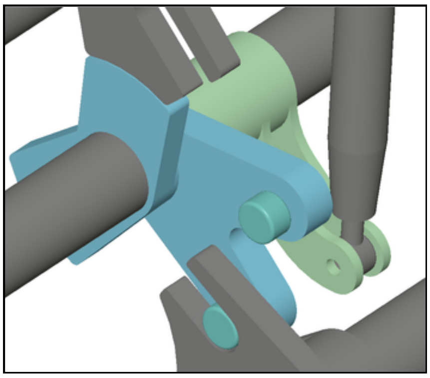
DESIGN EXPLORATION FOR PERFORMANCE: POTENTIAL COST SAVINGS

When discussing component efficiency, minimizing weight is essential to achieving optimal performance as reducing weight is crucial for fuel efficiency, lower operational costs in aerospace. Brackets alone, which number in the **thousands per aircraft**, present a major opportunity for weight reduction and savings on the long run.

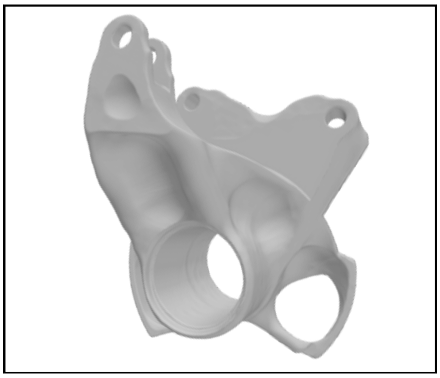
In fact, eliminating bracket weight by 50% could reduce an aircraft's total weight by 1,000 to 10,000 kg[(1)]. For context, this equates to saving up to 23.4% of an Airbus A320's empty weight[(2)]. Given that shedding 100 kg of plane material saves 8 to 17 kg of fuel per flight[(3)], a lighter Airbus A320neo could save 300 tons of fuel over its lifetime, translating to **$1.8 million in cost savings per aircraft**[(4)].

DESIGNING LIGHTWEIGHT AIRCRAFT BRACKETS

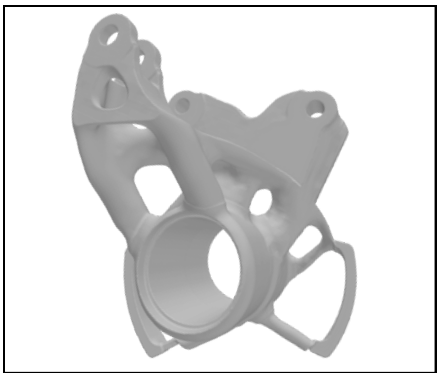
The study focused on an aircraft structural bracket, developed with Potez Aeronautique. The initial concept parts were designed with the 3-axis machining process in mind, resulting in heavier components that required two separate pieces and an additional assembly step. To optimize efficiency and reduce weight, the Potez Aéronautique team sought to explore new viable opportunities.



2-part assembly of 3-axis CNC parts



Optimized bracket for 5-axis CNC Machining



Optimized bracket for Additive Manufacturing

WHY TRADITIONAL CAD TOOLS ARE LIMITED FOR INTRICATE DESIGN EXPLORATION?

RESTRICTED DESIGN FLEXIBILITY

Unable to handle complex geometries from intricate topology optimization.

DEPENDENCE ON MULTIPLE TOOLS

Engineers must use separate software (CAD, FEA, TopOpt...), increasing errors.

TIME-CONSUMING ADJUSTMENTS

Optimized designs often require manual rework for manufacturing.

CHALLENGES WITH TOPOLOGY OPTIMIZATION

Generated shapes don't always fit constraints, needing extra validation.

ENGINEERING LEAD TIME COMPARISON

As we can observe on the next page, the design method with Cognitive Design provides a significant advantage over both traditional CAD and CAD with Topology Optimization (TopOpt) methods by drastically reducing engineering lead time, increasing automation, and integrating key performance metrics like cost.

Engineering Time Efficiency

One of the most striking advantages of Cognitive Design is its ability to **reduce design exploration time by up to 85%** compared to traditional CAD methods and **over 77%** compared to the TopOpt method.

Manufacturing Readiness & Flexibility

A critical limitation of both Traditional CAD and TopOpt methods is the lack of early-stage manufacturability considerations. Traditional CAD involves a 48-hour iterative FEA simulation loop repeated three times (one design per manufacturing method), while TopOpt requires multiple steps, including 16 hours for topology optimization, 8 hours for geometry reconstruction, and an additional 24 hours for FEA simulation. These approaches focus primarily on design and simulation, leaving manufacturing feasibility checks until the later stages.

By incorporating Manufacturing-Driven Design (MDD) and simulation-driven design (SDD) early in the process, the Cognitive Design method ensures that the generated designs are not only structurally optimized but also practical for the given manufacturing methods. With a total “MDD-FEA-SDD” time of just 6 hours, this eliminates unnecessary redesign cycles and reduces additional rework time required in traditional methods.

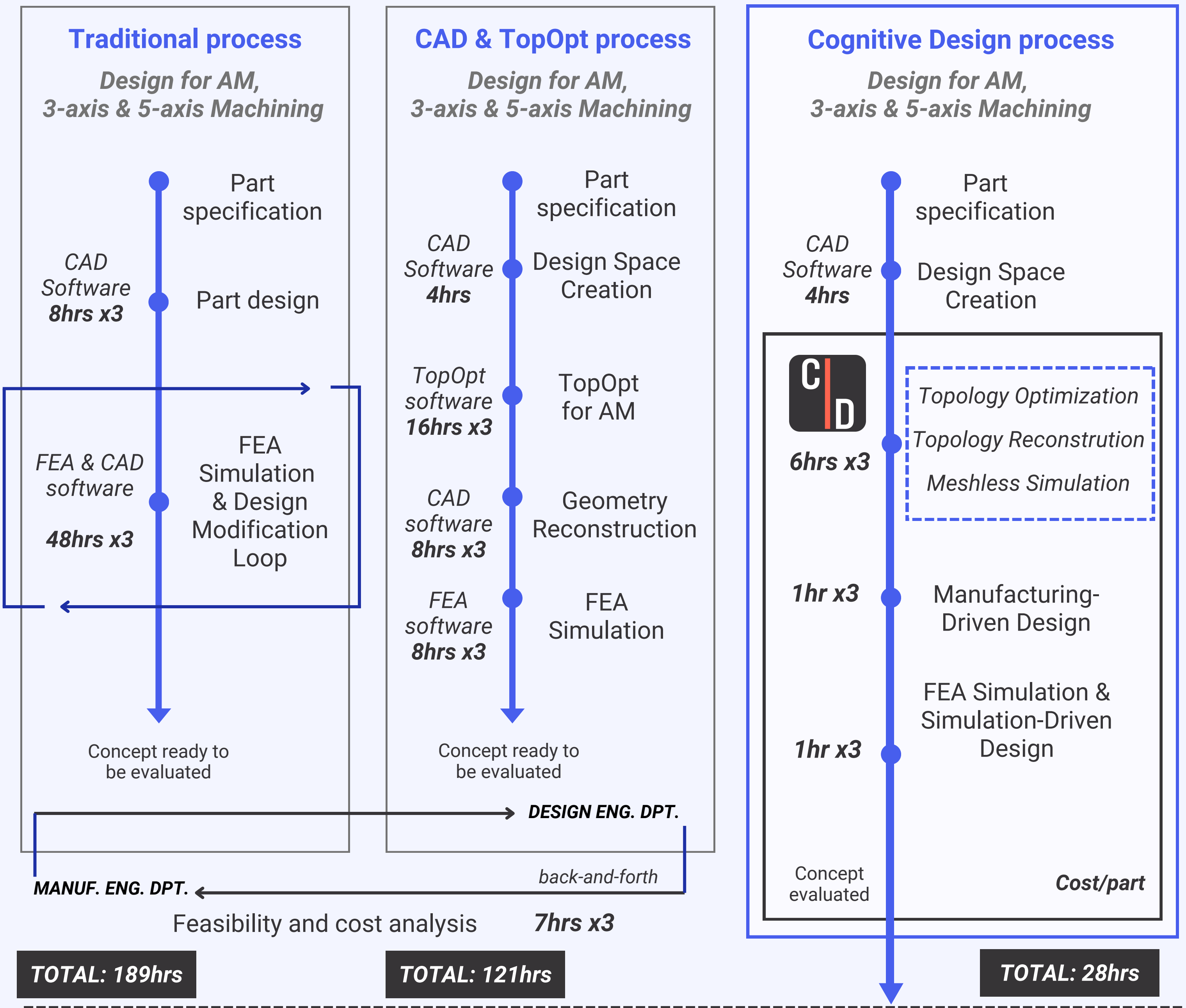
Integration of Cost Metrics

Neither traditional CAD nor TopOpt provides direct insight into manufacturing costs and environmental impact during the design phase. These assessments must be conducted separately, adding extra time and effort. In contrast, Cognitive Design integrates cost-per-part assessment directly into the workflow, eliminating the need for an additional 7-hour feasibility analysis required in other methods.

With a total design exploration time of just **28 hours**, Cognitive Design emerges as the most holistic and efficient approach, providing superior automation and manufacturability integration.

CASE STUDY

COMPARISON: TRADITIONAL DESIGN EXPLORATION METHODS VS. COGNITIVE DESIGN



Manufacturing method chosen to pursue product development

28 HOURS

to find the right design, ready for production

85%

reduction of design exploration time compared to the traditional CAD method

COST ANALYSIS

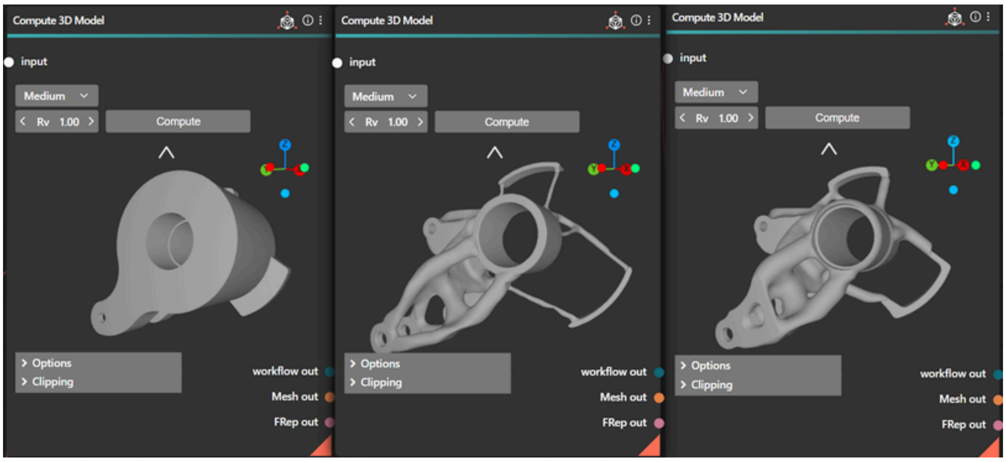
integrated from the first design iteration

THE WORKFLOW WITH COGNITIVE DESIGN

1. TOPOLOGY OPTIMIZATION WORKFLOW AND RECONSTRUCTION

From the design space, we first optimized the bracket for mechanical performance with:

- **Topology optimization**, integrating load cases to ensure stiffness while reducing weight.
- Then, we used **Topology Optimization Post-Process (TOPP) app** to reconstruct the raw topology, seamlessly connecting functional regions, smoothing fillets, and fixing disconnected areas, resulting in a refined, manufacturable design.



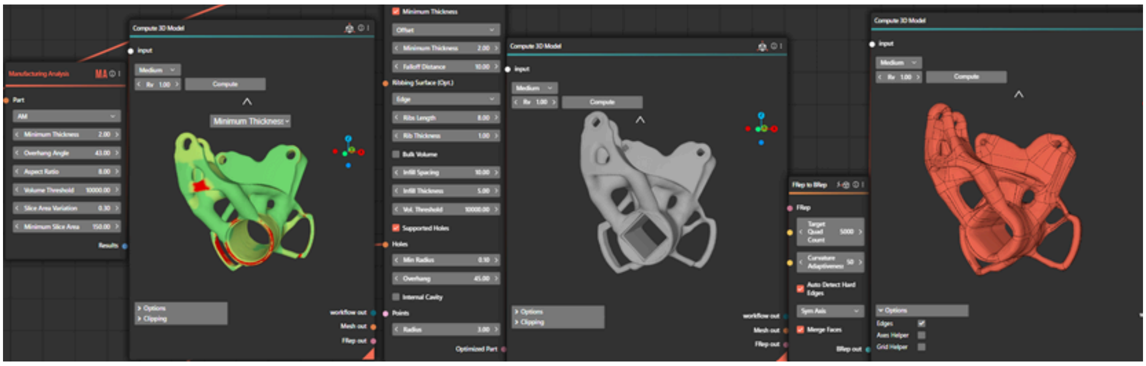
On the left: Bracket Design space
In the middle: TopOpt results before post-processing
On the right: TopOpt results after post-processing

2.DESIGN FOR ADDITIVE MANUFACTURING

2.1. Ensure design feasibility for Additive Manufacturing

After finalizing the optimal design for mechanical performance, we needed to adapt its shape for the AM process while maintaining identical mechanical properties to the original model. To achieve this, we first utilized the **MDD app** to ensure the part's manufacturability for AM by:

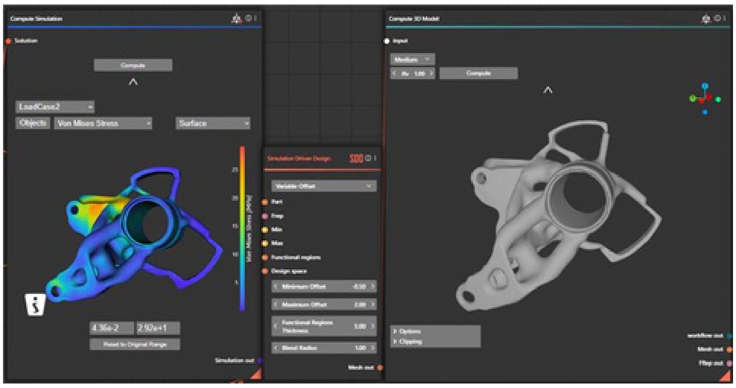
- **Optimizing part orientation** to reduce material waste, print time, and production risks while maintaining quality.
- **Enforcing minimum thickness** to prevent weak points and ensure structural integrity.
- **Generating self-supporting features**: we allowed machining of critical interfaces and holes without excessive supports.
- **Integration with CAD**: we transformed the optimized geometry into a CAD-compatible format for seamless integration.



Workflow of the Manufacturing-Driven Design for Additive Manufacturing

2.2 Maintain structural integrity for Additive Manufacturing with SDD

Then, we used the **Simulation-Driven Design (SDD) app** in Cognitive Design to validate and refine the design. The SDD app ensured the geometry met safety standards, handled expected stresses, and avoided weak points.



Overview of the iterative loop between FEA checks and automated design modifications for AM

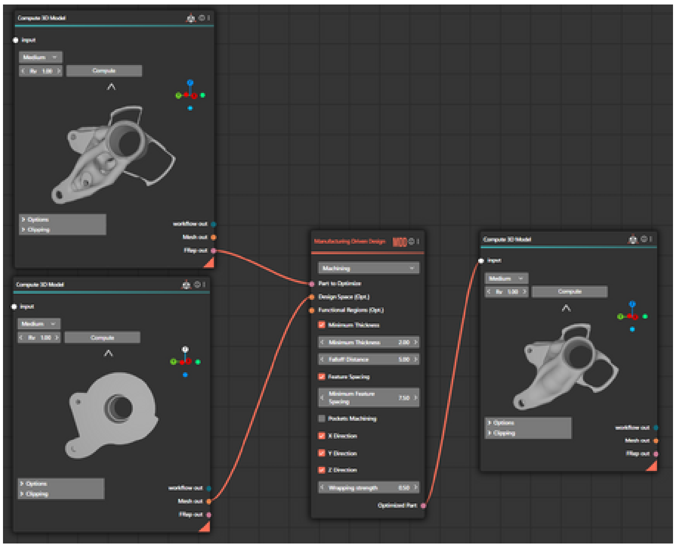
With SDD, we kept reducing the bracket's weight by 8% after topology optimization and MDD and increased the Safety factor above 2.

This was achieved by automatically removing material from low-stress areas while reinforcing high-stress regions, ensuring both weight reduction and structural strength.

3. DESIGN FOR 5-AXIS MACHINING

3.1. Ensure design feasibility for 5-axis Machining

As for AM, we started the optimization for 5-axis machining from the topology-optimized design, following the same process. As a reminder, the initial part was produced with a 3-axis machining method so we will only focus on 5-axis optimization. To do so, we first used the **MDD app** to ensure part's manufacturability for 5-axis machining by:

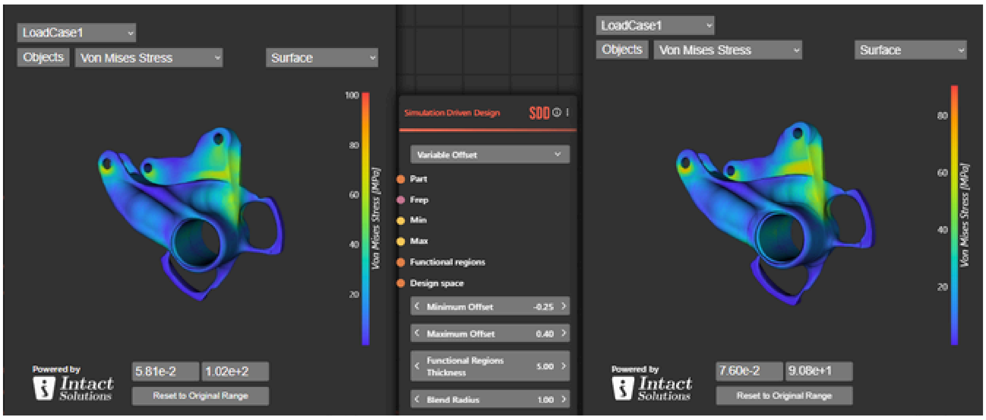


Workflow of the Manufacturing-Driven Design for 5-axis Machining

- **Enforcing minimum thickness** to prevent weak points and ensure structural integrity.
- **Eliminating intricate undercuts**.
- **Closing all gaps** smaller than the minimum feature spacing.
- **Integration with CAD**: we transformed the optimized geometry into a CAD-compatible format for seamless integration.

3.2 Maintain structural integrity for Machining with SDD

Next, we used the SDD app in Cognitive Design to validate and refine the geometry for 5-axis machining. By strategically reinforcing critical areas and minimizing excess material, we achieved a balance between maintained structural performance and ensured manufacturability.



Overview of the iterative loop between FEA checks and automated design modifications

With SDD, we maintained the same bracket's weight as after topology optimization and MDD and increased the Safety factor above 2.

4. DESIGN EXPLORATION RESULTS: PERFORMANCE & COST

Now that we have a comprehensive understanding of the design workflow in Cognitive Design for both AM and Machining, we can evaluate the best scenario balancing manufacturing costs, weight reduction and safety factor. The following table presents a comparative analysis to determine the optimal manufacturing approach based on three scenarios: 3-axis Machining, 5-axis Machining, and AM.

Metrics per part	3-axis Machining	5-axis Machining	AM
Weight	0,214 kg	0,203 kg	0,165 kg
Safety factor	1.5	>2	>2
Manuf. Cost	172€	251€	913€

CONCLUSION

This case study, conducted in collaboration with Potez Aéronautique, demonstrates how Cognitive Design enabled to significantly accelerate the design exploration workflow.

By integrating performance, manufacturability, cost, and environmental impact into a single workflow, we allowed engineers to explore multiple design scenarios faster and more efficiently.

Through this approach, we optimized an aircraft structural bracket by comparing AM and CNC Machining, primarily identified to be the most relevant manufacturing methods for the part. Thanks to Cognitive Design, we eliminated inefficiencies by embedding Topology Optimization, SDD and MDD into a unified framework. This ensured that designs were structurally optimized, manufacturable, and cost-efficient from the earliest stages.

For Potez Aeronautique, the benefits are:

- **Design exploration time was reduced by up to 85%** (from 189 hours to 28 hours) compared to traditional CAD methods.
- Potez Aéronautique engineers were able to **quickly assess trade-offs** between weight, performance, cost, and, accelerating decision-making.
- **Manufacturing feasibility was ensured** early in the design process, preventing costly design iterations and rework.
- **Costs were integrated** into the design workflow, allowing engineers to prioritize both economic and environmental impact in their optimization choices.

Cognitive Design helped Potez Aéronautique engineers make faster, data-driven decisions, eliminating the delays of traditional design methods. This study paves the way for a more agile and efficient design process, contributing to the development of lightweight, fuel-efficient, and cost-effective aerospace structures.

Aircraft bracket optimized for 5-axis Machining

Aircraft bracket optimized for Additive Manufacturing

RELATED CASE STUDY

Lightweighting Aircraft Bracket Design: How Potez Aéronautique Achieved Major Weight Savings

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COGNITIVE DESIGN SYSTEMS

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