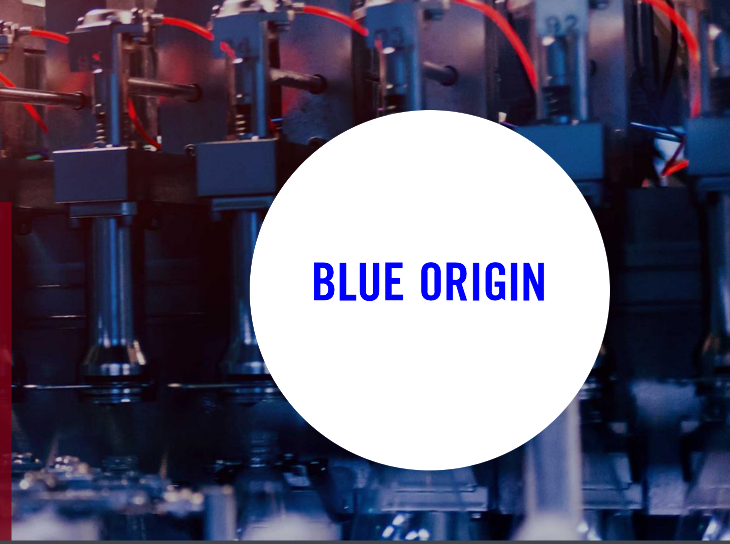

Geometry, Learning, & Optimization for Raw Material Planning

BLUE ORIGIN

BUSINESS PROBLEM

In aerospace manufacturing, engineering artifacts define part geometry, but procurement decisions require discrete commitments in standard stock forms. At Blue Origin, procurement managers lack direct visibility into how much raw material is consumed per vehicle or production cycle. This opacity stems from a structural gap: bills of materials specify what parts are needed, but not how much stock is removed to produce them. Blank sizing is performed manually by machinists, recorded inconsistently in free-text work orders, and never systematically linked back to planning systems.

The result is imprecise demand forecasting, limited advance visibility into part-level material needs, missed opportunities for supplier consolidation, and higher raw material procurement costs that directly translate into increased vehicle costs.

DATA SOURCES

The framework ingests part master data from Databricks (metadata, BOM hierarchies, material specs), STEP CAD files downloaded at scale via Windchill REST API for ~4,000 released parts, and blank dimension records extracted from free-text work orders using an AI-based parsing agent.

APPROACH

A three-stage methodology was developed in Python to translate engineering geometry into procurement-ready raw material demand. Stage 1: CAD-based geometric estimation computes oriented bounding boxes from STEP files to derive baseline blank dimensions for machined parts and flat-pattern unfolding via face adjacency graphs for sheet metal. Stage 2: An OLS regression model calibrates geometry-derived estimates against historical shop-floor records, learning systematic machining allowances (R^2 = 0.98 for length, 0.93 for width). Stage 3: A MILP nesting optimizer allocates estimated blanks to standard plate/sheet stock sizes, minimizing material waste. Top-level vehicle demand from the Master Production Schedule is propagated through BOM hierarchies using a DAG-based cascading formulation, translating system-level build plans into part-level material requirements.

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IMPACT

The framework creates a structured, scalable layer of procurement-ready attributes attachable to the entire part catalog. Once propagated through bills of material, it enables visibility into material consumption per vehicle, time-phased procurement signals aligned with build schedules, supplier consolidation through accurate demand aggregation, and disciplined waste quantification via nesting optimization. This replaces manual, experience dependent blank estimation with a reproducible, geometry-grounded methodology – converting weeks of ad-hoc analysis into automated, auditable output.

DRIVERS	Aerospace cost reduction requires upstream visibility. Raw material procurement is a foundational yet opaque cost driver – blank sizing is manual, inconsistent, and disconnected from planning systems across the industry.
INNOVATION	Combines oriented bounding box estimation, face-adjacency-graph unfolding for sheet metal, regression-based allowance learning, and MILP nesting into a single end-to-end pipeline from CAD to procurement signal.
IMPROVEMENT	Geometry alone is necessary but not sufficient – width is systematically underestimated by ~1.7" due to machining allowances invisible in CAD. The learning layer closes this gap with a calibration mapping trained on historical practice.
OTHER APPLICATIONS	Framework applies to any discrete manufacturer with subtractive processes and standard stock: aerospace, defense, shipbuilding, heavy equipment – anywhere BOM-to-stock translation is opaque.