

Process Optimization and Proactive Quality Control to Increase Investment Casting Throughput

The Blue Origin logo, consisting of the words "BLUE ORIGIN" in blue capital letters inside a white circle, is positioned in the upper right quadrant of the slide. The background of the entire slide is a close-up photograph of a large industrial turbine engine, showing various components like compressor blades and casings in shades of blue, orange, and yellow.

BLUE ORIGIN

BUSINESS PROBLEM

Blue Castings is Blue Origin's investment casting plant located in the greater Seattle metroplex. The plant wants to increase throughput of the BE-4 engine components which it produces. Increasing throughput at Blue Castings is challenging as investment casting is a complex process that involves long rework times, high natural defect rates, and significant process variability. Inability to increase throughput can lead to schedule delays and inefficiencies that will impede Blue Origin's ability to meet its ambitious production goals to support growth in the commercial space industry.

DATA SOURCES

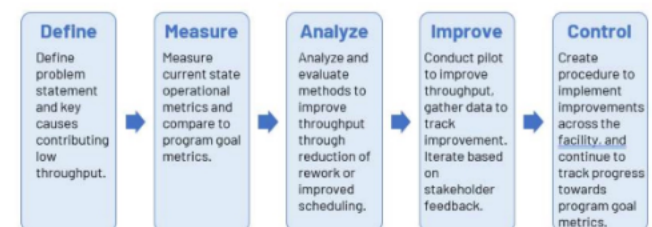
Data was collected via on-site qualitative interviews, sampling of defect data documented in weld maps, and querying of Blue Origin's manufacturing execution systems and quality management databases. Additionally, manufacturing process data relating to the slurry was collected from Blue Castings' production testing logs – this includes measurements such as viscosity, pH, and conductivity.

Data Types and Format

Spreadsheets, PDF files of weld maps, Output files from manufacturing execution system, transcripts/notes from interviews

APPROACH

The researcher analyzed gaps between goal and actual throughput, identified root causes of the gaps, and investigated solutions. Solutions explored include process improvement to reduce unnecessary rework, cross-functional collaboration to increase design producibility, and use of machine learning to generate insights and aid in decision-making to better prevent and manage defects.



IMPACT

Reducing unnecessary rework on machined surfaces can increase the capacity of the rework work center by up to 70%. This improvement alone could potentially increase overall system throughput by up to 15%. The reduction in rework leads to direct and support labor cost savings. Additionally, improved producibility and defect prevention mechanisms will save money by reducing non-conformances. Additionally, digitizing defect tracking and integrating machine learning for predictive analytics improves data quality and enables better root cause analysis. If implemented, this will facilitate more accurate predictions of rework severity, allowing for better planning and resource allocation. Finally, establishing a producibility working group to formalize design best practices enables better communication between design, manufacturing, and quality teams. This leads to more "castable" designs, reduces defects, and improves overall production efficiency.

DRIVERS



The demand for cost-effective, high-throughput production of rockets, combined with pressure to reduce schedule delays and improve manufacturing efficiency, drives the need for innovative defect management and prevention. In response to this rapid growth in commercial space exploration and the resulting pressure on the aerospace industry, Blue Origin has set ambitious goals for BE-4 production.

BARRIERS



Limited historical data and inconsistent data capture made it challenging to perform data analysis and modeling. The lengthy casting process (4-6+ months/part) made it difficult to evaluate the impact of improvements within the project timeline. Equipment failures, urgent business needs, and personnel changes caused delays in piloting solutions. Finally, concurrent initiatives made it difficult to isolate the impact of specific interventions.

ENABLERS



High willingness to establish cross-functional collaboration between design, manufacturing, quality, and process engineers to improve design producibility. Commitment from Blue Origin and Blue Castings leadership to provide guidance and resources. Engineers with 20+ years' experience who provided valuable insights into investment casting processes. Blue Origin's leadership principles of bias for action, customer focus, and operational excellence.

ACTIONS



Created, piloted, and evaluated a process improvement to reduce rework. Created cross-functional group to analyze trends in casting quality issues and create chapter for Blue Origin's design handbook to improve producibility. Conducted cost-benefit analysis of defect tracking methods, piloted digital defect tracking approach, and evaluated potential return on investment of select methods and use of machine learning for predictive analytics.

INNOVATION



Use machine learning to predict rework severity at this facility, identify root causes of defects, and enhance Blue Castings' quality control. Evaluate importance of factory modernization to automate defect documentation, improve data accuracy, and enable trend analysis. Apply line-balancing strategies commonly used in the emergency medicine industry to optimize throughput and reduce bottlenecks.

IMPROVEMENT



Roadmap for Blue Castings to increase throughput via a mixed-method approach. Casting producibility best practice guide released company-wide. Business case and results to encourage Blue Castings to fully implement machine surface rework reduction to increase overall throughput by up to 15%. Business case and estimated timeline to onboard digital defect tracking software and build enough data to enable machine learning for predictive analytics.

BEST PRACTICES



Engage members from design, manufacturing, and quality early to discuss production challenges and possible solutions. Consider the impact and level of effort of more robust data collection than the status quo, and evaluate the return on investment of data improvements. Small-scale pilots and subsequent iteration can validate solutions and build consensus prior to implementation. Create mechanisms for regular review and refinement of processes.

OTHER APPLICATIONS



Predictive analytics and digital defect tracking can be applied across many of Blue Origin's commodities beyond investment casting, such as additive manufacturing or machining. Improved design producibility to reduce non-conformances can be implemented across manufacturing, sub-assembly, and inspection work centers. These principles can be useful across industries such as automotive manufacturing to optimize throughput and improve quality.