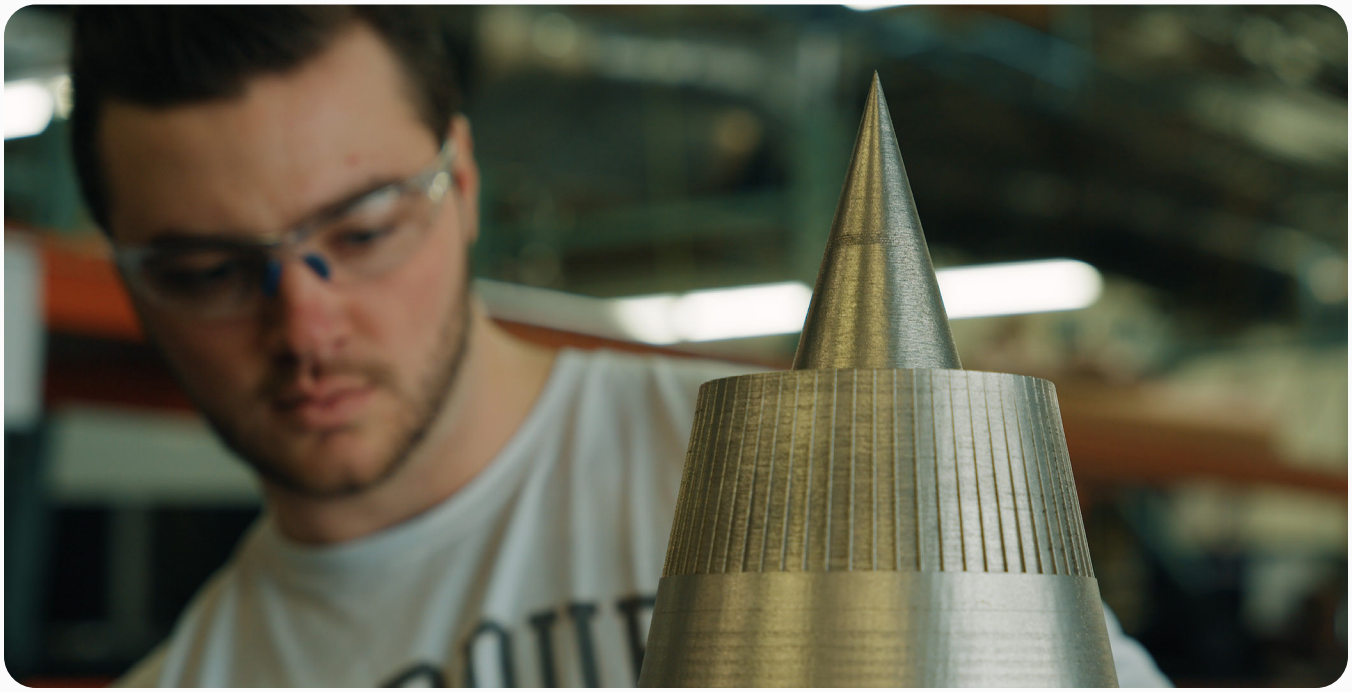
RAMJET CASE STUDY

Advancing Supersonic Technologies: The Velo3D and Lockheed Martin Collaboration

Introduction

In the field of metal additive manufacturing (AM), Velo3D is pushing the boundaries of innovation and design. A standout achievement demonstrating this approach is the advanced ramjet engine engineered by Velo3D's Applications Development Engineer, Jay Blake. This engine is the result of a fruitful collaboration with aerospace leader Lockheed Martin, highlighting the real-world application and industrial readiness of the latest in-situ process monitoring capabilities found in state-of-the-art laser powder-bed fusion (LPBF) AM systems.

Designed to propel small, either reusable or expendable, unmanned aircraft at breathtaking supersonic speeds, this ramjet engine is not just a piece of machinery; it's a testament to the potential of metal AM in pushing the envelope of aerospace engineering. Manufactured as a singular, support-free structure using a Sapphire 1MZ printer in high-grade Inconel® 718, the project was brought to fruition with funding from LIFT, a Detroit-based national manufacturing innovation institute, in partnership with the Department of Defense.



Jay Blake, Application Development Engineer - Velo3D

Overcoming Traditional Manufacturing Hurdles

Traditional manufacturing methods often struggle to achieve the delicate balance between intricate design features and operational efficiency, particularly for high aspect ratio structures critical in aerospace applications. The ramjet design embarked on an exploratory path, considering the innovative use of fuel as a heat sink to manage the aerodynamic heating, thereby delivering hotter fuel to the combustor for enhanced performance. The design's ingenuity extended to integrating bleed air injection into the wake of the flame holder, aiming to reduce parasitic drag without compromising combustion efficiency.

The Velo3D Advantage

Velo3D's advanced metal AM technology was pivotal in actualizing these intricate design features with exceptional dimensional accuracy. The ramjet part is a showcase of AM's transformative potential, highlighting benefits such as component consolidation, rapid prototyping capabilities, and the realization of complex internal architectures unattainable with conventional manufacturing methods.

Critical Feature: Part Consolidation

The uniqueness of the design lies in how much functionality just one part serves. Building a system like this with traditional manufacturing methods can take months to years of development along with hundreds of individual components that would require brazing or welding. This component consolidates an inlet spike, heat exchanger, flame holder, struts, and fuel injectors into one-piece. It was printed in just eight days without supports.

Critical Feature: Perforated Boundary Layer Bleed

Velo3D technology made it possible for overall engine efficiency with a consistent perforated array of 500 µm holes. With this consistency and remarkable circularity, it minimizes the thermoacoustic instabilities and diffuses supersonic flow regimes caused in the inlet spike.

Critical Feature: Flow Channels

Velo3D's ability to produce parts with thin walls, lattice structures, and complex internal channels such as the flow channels of this ramjet. This can prove exceptionally valuable in supersonic and hypersonic systems.

Critical Feature: Bleed Air-Injected Flame Holder

Due to Velo3D's non-contact recoater, the flame holder of this ramjet was printed completely without supports. As air flows inside, it is then ejected out of the wake of the flame holder, helping to maintain combustion and reduce some of the parasitic drag on the engine.

Embracing Part Consolidation

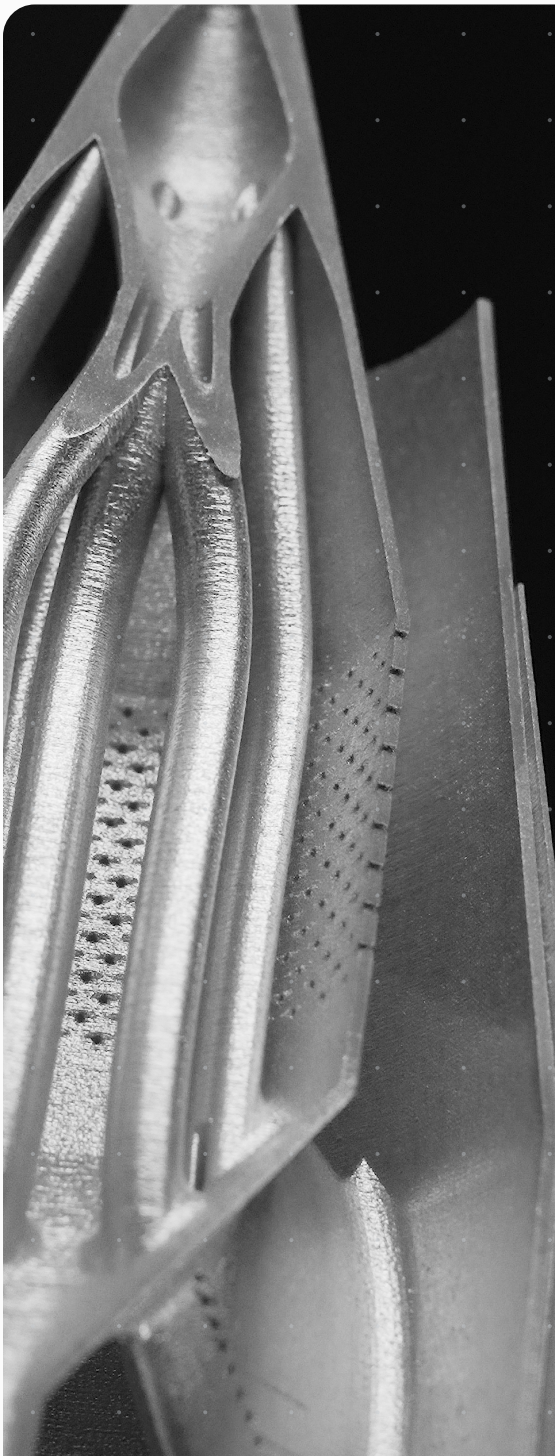
The design's ingenuity lies in its multifunctionality, consolidating critical components such as the inlet spike, heat exchanger, flame holder, struts, and fuel injectors into a single cohesive unit. Traditionally, such a system would require extensive development time and a multitude of individual parts requiring complex assembly. The Velo3D solution, however, facilitated the printing of this intricate assembly in just eight days, highlighting the profound impact of part consolidation on reducing interfaces, simplifying manufacturing flows, and significantly reducing production times.

Innovations in Performance Features

The ramjet engine benefits from several of Velo3D's technological innovations, including a perforated boundary layer bleed system featuring a consistent array of ultra-fine holes, and advanced flow channels allowing for the construction of parts with incredibly thin walls and complex internal structures. Furthermore, the non-contact recoater technology employed in the printing process ensured the flame holder was produced without supports, enhancing airflow efficiency and reducing drag.

Velo3D's non-contact recoater technology marks a significant leap in metal 3D printing, enhancing both print reliability and design flexibility. Here are the key advancements:

1. **Geometric Flexibility:** This technology enables the creation of complex geometries with low-angle overhangs, achieving angles as shallow as 0° relative to the build platform under specific conditions, broadening design possibilities.
2. **Stability for High Aspect Ratio Features:** High aspect ratio structures, often delicate in nature, are better preserved with the non-contact recoater. By minimizing shearing forces during the recoating phase, it ensures these intricate features remain undistorted, regardless of their orientation.
3. **Expanded Processing Windows:** The recoater extends beyond traditional LPBF processing limits, accommodating new scanning strategies for low-angle overhangs and potentially enhancing surface quality for these challenging features.
4. **Automated Calibration and Monitoring:** Incorporating an automatic calibration routine, the recoater verifies the precision of essential processes, contributing to a consistent build environment. This rigorous evaluation extends to every layer of the build, ensuring steadfast adherence to specifications.



A Comprehensive Metal AM Solution

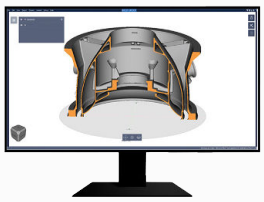
Velo3D's leadership in metal AM is encapsulated in its comprehensive solution, merging pre-print design sophistication with state-of-the-art printing hardware and in-situ quality assurance. This integrated approach ensures reproducible, predictable outcomes, enabling scalability without compromising on design complexity or functionality.

For defense organizations and engineering teams, Velo3D's technology opens new horizons for efficient, high-performance component designs, driving future military advancements and fostering more agile supply chains.

The collaboration between Velo3D and Lockheed Martin on the ramjet engine project not only underscores the transformative potential of metal AM in aerospace applications but also exemplifies how innovative engineering, when paired with advanced manufacturing technologies, can lead to breakthroughs in design, efficiency, and performance.

The Velo3D Manufacturing Process

Our fully integrated manufacturing solution is comprised of software, hardware and an intelligent underlying manufacturing process allowing engineers to build and scale mission-critical parts.



FLOW
Input CAD designs into our industry-leading print preparation software

SAPPHIRE
Metal AM Family of Printers

ASSURE
Quality validation software with a robust build report

A Secure, US-Based Solution

- Velo3D is a US-based solution – both developed and produced in the US – that's compliant with Buy American Act requirements
- Tap into a secure, trusted network of contract manufacturers in the US and abroad
- Trusted by leaders in military and defense
- Capable of working with export-controlled data and operating in classified environments with data segregation routes to different servers based on need

ADDMAN ENGINEERING · AEROJET ROCKETDYNE · HERMEUS · Honeywell · KNUST-GODWIN · LOCKHEED MARTIN · PRATT & WHITNEY GO BEYOND

VELO 3D

WITHOUT COMPROMISE

Headquarters
2710 Lakeview Court
Fremont, CA 94538

Get in Touch:
velo3d.com
info@velo3d.com