

TECHNICAL EXPLORATION

How Velo3D's Height Mapper Enhances the Landscape of Modern AM Metrology

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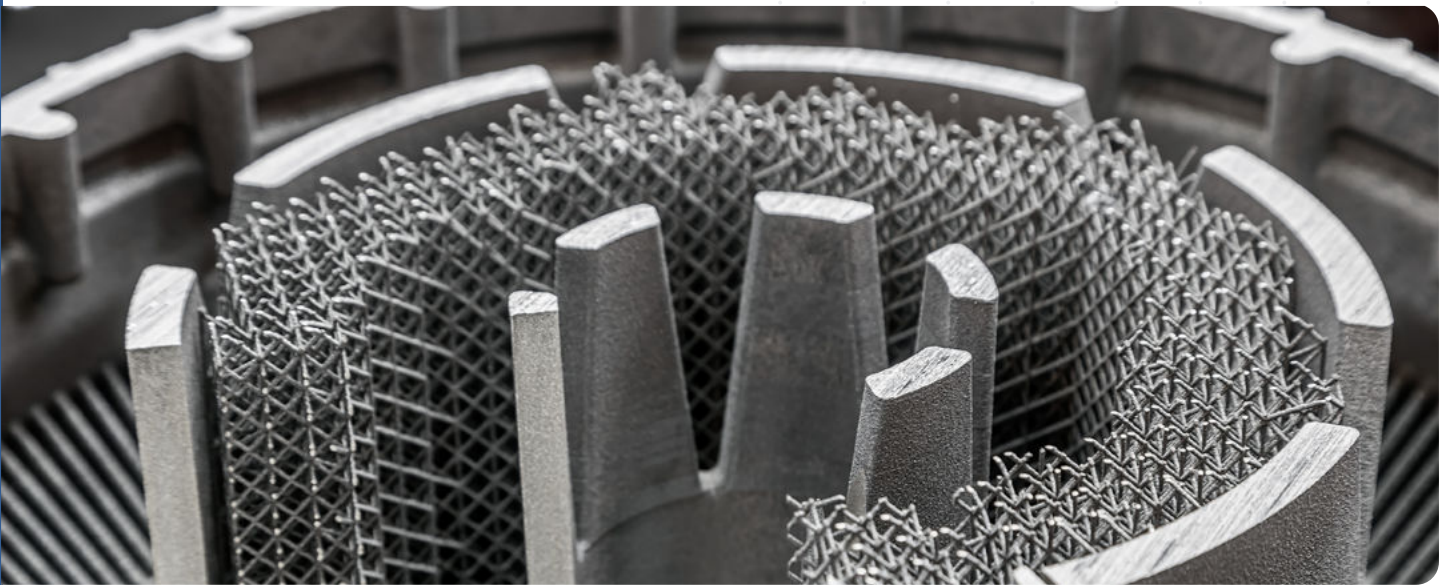
Introduction

3D printing technology has continued to evolve, promising high levels of precision and quality in manufactured parts. However, a fundamental challenge remains in ensuring the quality of the powder bed and recoating process during the printing cycle. This paper aims to present an in-depth look into Velo3D's Height Mapper technology, an essential metrology tool for monitoring and improving the quality and accuracy of the powder bed in metal 3D printing.

With the advent of metal 3D printing technologies, the emphasis on ensuring print quality and precision has never been more critical. One of the primary factors affecting the quality of 3D printed parts is the integrity of the powder bed, ideally monitored real-time and documented throughout the printing process.

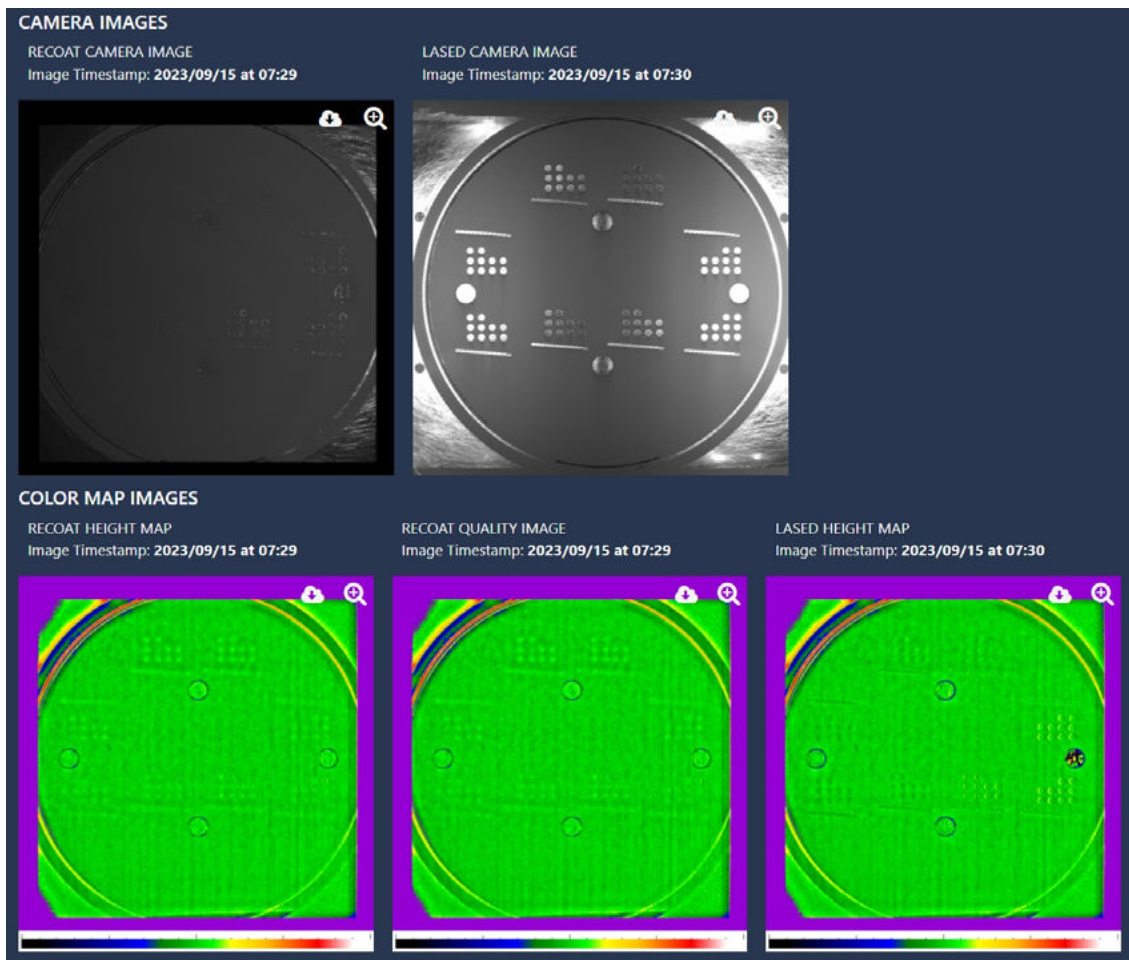
The dynamic nature of the laser powder bed fusion (LPBF) process, combined with the intricacies of working with metal powders, makes ensuring the quality of the powder bed and recoating process during the printing cycle a complex task. Advances in metrology and printer design are helping to address these challenges, but achieving consistency remains a complex endeavor.

Velo3D's Height Mapper technology provides a comprehensive solution to this problem, leveraging advanced metrology techniques to ensure optimal powder bed and recoater setup.



What is Height Mapper?

Height Mapper is an integrated metrology tool within Velo3D's Sapphire metal 3D printers. Situated at the top of the build chamber, the system consists of a structured light projector and a high-resolution camera. The structured light projector casts a pattern across the powder bed. Multiple pictures of the pattern are then captured and processed. Through these images, a topographical map of the powder bed is generated, allowing for the assessment of the quality of the powder bed in terms of peaks and troughs.



Camera and Color Map Images captured by Height Mapper displaying the full range of image data provided.

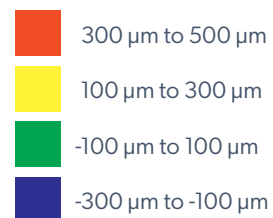
Key Features

- 1. Layer-by-Layer Monitoring:** Continuously assesses powder bed and part quality throughout the build, enabling optimization and early detection of potential issues.
- 2. Powder Bed Qualification:** Takes approximately 20 minutes to complete and is unique to Velo3D's approach.
- 3. Gas Flow Setup:** Assists in setting up the optimal inert gas flow rate during machine maintenance.

Layer-by-Layer Monitoring

The primary function of Height Mapper is to continuously validate the quality of the powder bed during the printing process. The technology can detect inconsistencies like Y-streaks in the powder bed or changes in powder bed roughness, which could be indicative of problems like nozzle blockage or changes in the flowability of the powder.

Additionally, Height Mapper is also used to capture images of the powder bed after the laser-emission has been concluded to identify the roughness and protrusion-tendency of the solidified part.



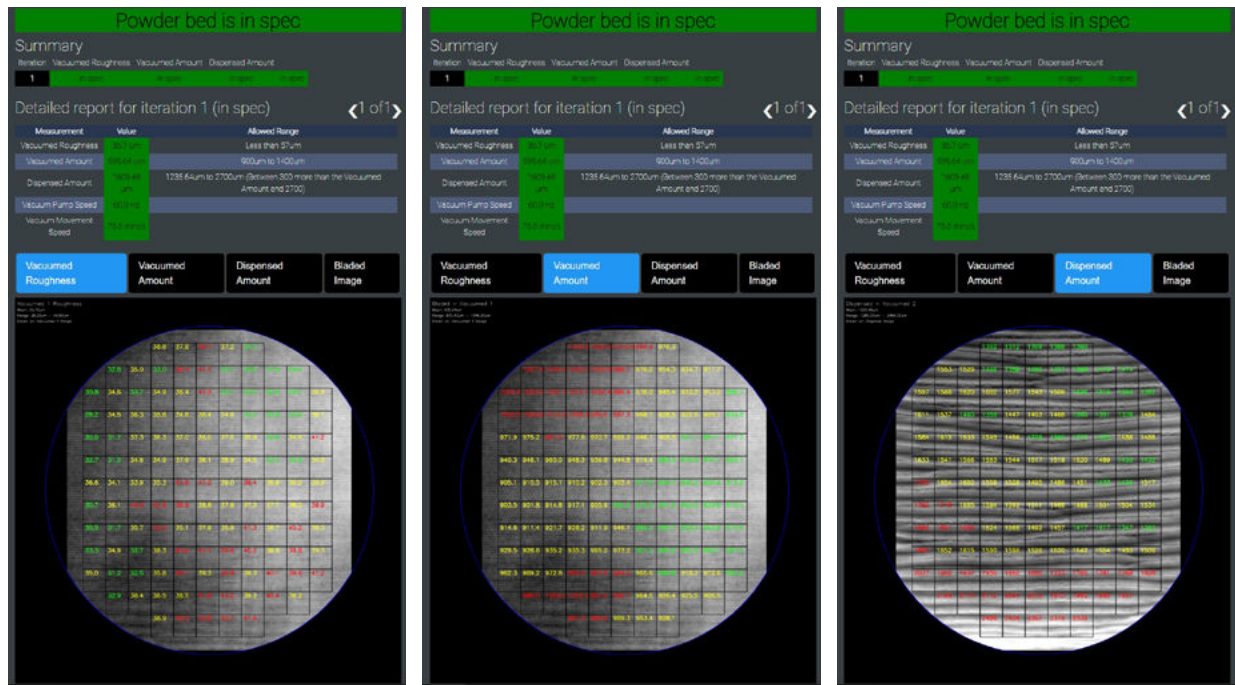
Gray and green scale height mapper image showing a stable part without protrusions.

Powder Bed Qualification

A secondary function of Height Mapper is to assist in setting up the recoating system, a critical subsystem in metal 3D printing that involves three key elements:

1. **Dispenser:** Lays down a thick layer of powder.
2. **Blade:** Normalizes or homogenizes the powder bed.
3. **Vacuum:** Vacuums excess powder to achieve the working layer thickness.

Height Mapper verifies the correct setup of Velo3D's unique non-contact recoater. It measures the specific amounts of powder used in each step of the recoating process—dispensing, blading, and vacuuming. This ensures the powder bed stays within the defined upper and lower limits for each process.



The above image displays the validation of the recoater setup and powder bed quality by measuring the amounts dispensed, bladed, and vacuumed with Height Mapper.

Gas Flow Setup

Height Mapper is also involved in setting up the optimal inert gas flow rate during machine maintenance. By conducting an erosion test, it enables the calibration of the maximum possible inert gas flow rate, thereby indirectly ensuring that the flow rate does not adversely affect the integrity of the powder bed. This is done by comparing changes in powder bed roughness after being exposed to the inert-gas-flow over a designated period.

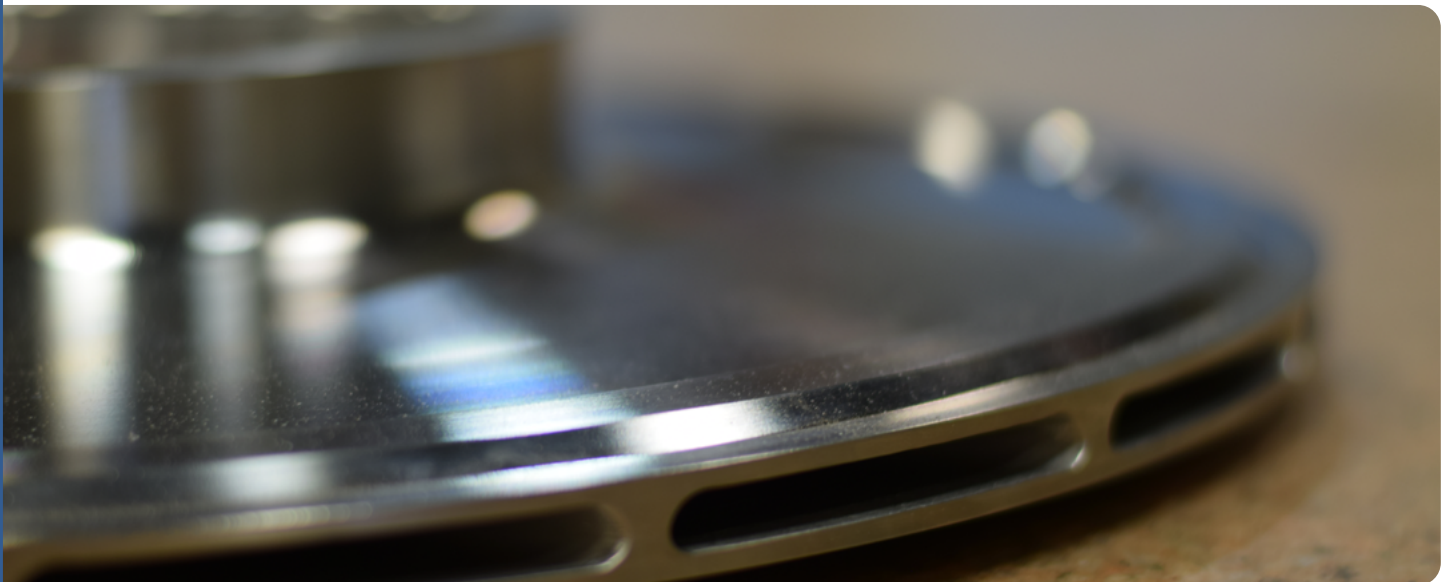
Quality Control and Problem-Solving Capabilities

Real-time Quality Assurance

Height mapper monitors the quality of the powder bed in real-time. By doing so, it allows for early detection of issues like agglomerates blocking the nozzle, changes in powder flowability, or tendencies for part protrusions. This data-driven approach enhances both the efficiency and reliability of the printing process.

Reduction in Test Prints

Height Mapper's precise metrology reduces the number of test prints needed to reach an optimized build file, saving material costs and machine time. Additionally, the system improves the acceptance for finished parts, offering conclusive layer-by-layer proof of process-quality to customers, thereby minimizing grounds for part rejection.



483 mm shrouded impeller printed on a Sapphire XC in Inconel 718.

Support Strategy Validation

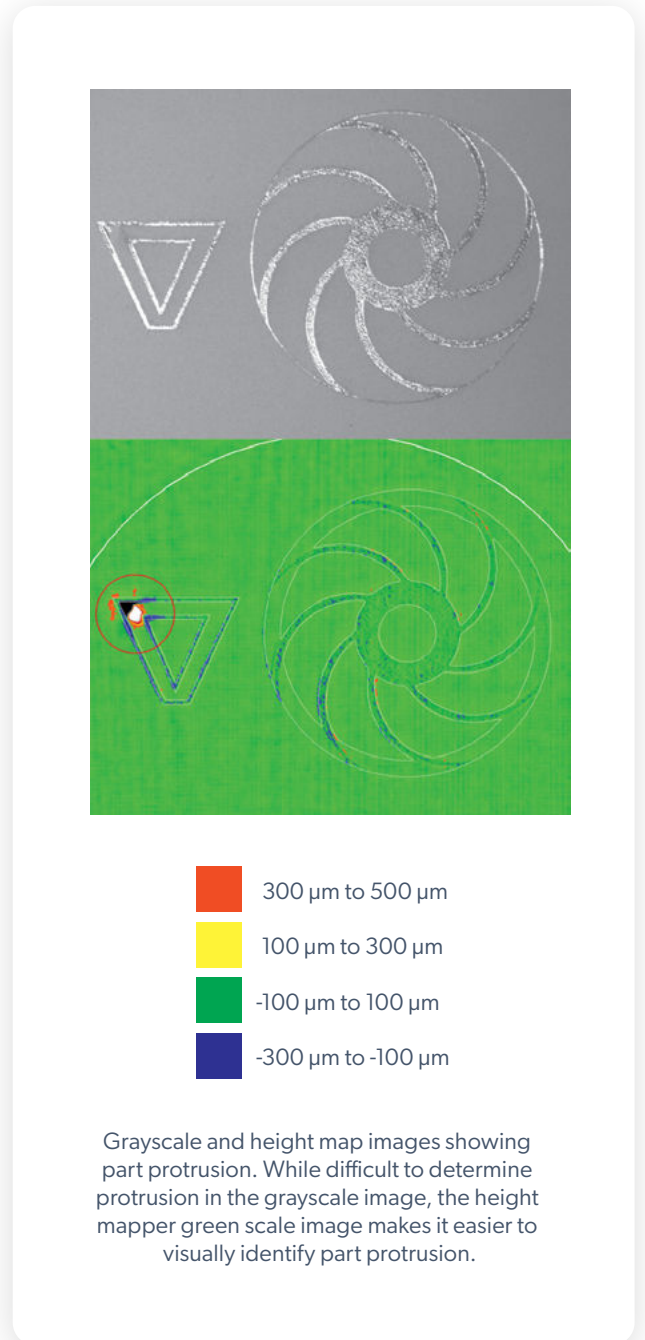
Height Mapper is a primary tool for applications teams in validating their support strategies and checking powder quality. It offers invaluable data for iterative development, aiding in achieving a 'Golden Print file'—Velo3D's proprietary single print file approach. The system also allows for monitoring areas that have tendencies to protrude, helping to refine support strategies and minimizing iterations.

High Precision Measurements

Velo3D's Height Mapper utilizes proprietary techniques in structured light projection, allowing for a higher resolution and accuracy than competing technologies. These proprietary methods enable the system to define upper and lower limits for what is termed as 'powder bed roughness'—the maximum distance between the highest and lowest points on the powder bed. These precise measurements ensure that the process remains within specified tolerances, preventing issues like under-melting or over-melting.

Risk Mitigation

The technology also helps to prevent catastrophic failures, such as recoater crashes, by stopping the machine automatically if significant protrusions are detected. This feature reduces machine downtime, further safeguarding ROI.



Operational Advantages

Streamlined Installation and Maintenance

One of Height Mapper's significant operational benefits is its role in rapidly determining the optimal inert gas flow during machine installation and maintenance, without interfering with the print process. This feature enhances the machine's operational stability, aiding in soot removal and preventing soot interference. This in turn enables high throughput lasing parameters without risking beam-soot interference and soiling/contamination of the laser path.

Recoater Validation and Calibration

By facilitating and validating the recoater setup process, Height Mapper solves a critical problem in ensuring the correct layer thickness and quality for each recoating cycle. A qualified powder bed is essential for successful metal 3D printing, and Height Mapper provides an automated, efficient way to qualify the powder bed before printing.

Impact on Speed and Reliability

Height Mapper's layer-by-layer measurements ensure that process robustness and powder bed quality are maintained throughout the build. Furthermore, the technology significantly expedites machine setup, contributing to faster production times without compromising quality or reliability.

Real-time Measurements

Height Mapper's measurements occur in parallel to other operations, ensuring no additional time is consumed for layer-by-layer metrology. This feature sets it apart from traditional methods, which often necessitate halting the printing process for assessments, thereby lengthening the build time.



Assure (Velo3D's quality assurance software) plot of peak height measurements for a portion of a build showing a measurement over warning threshold.

Please note that while measurements over warning thresholds should be monitored, they do not necessarily indicate an issue with the build.

Gas Flow Monitoring

Height Mapper is also involved in setting up the optimal inert gas flow rate during machine maintenance. By conducting an erosion test, it enables the calibration of the maximum possible inert gas flow rate, thereby indirectly ensuring that the flow rate does not adversely affect the integrity of the powder bed. This is done by comparing changes in powder bed roughness after being exposed to the inert-gas-flow over a designated period.

Approachable for Any Skill-level

Height Mapper's detailed layer-by-layer reporting lowers the barrier to hiring, reducing the need for highly specialized personnel to interpret build failures, thereby leading to cost savings in training and personnel.

Customer Support

The service is backed by Velo3D's annual service contract and a robust support infrastructure. Customers can send their build reports to Velo3D's team for troubleshooting, which facilitates a deeper level of problem-solving and offers solutions in the event of an issue. Additional data can be accessed for in-depth analysis of each layer through the Assure-quality validation server linked within the integrated system's build report.



Key Takeaways

1. **Maintaining Quality throughout the Build:** The technology continuously monitors and ensures the quality and robustness of the powder bed and the lasing process throughout the printing cycle.
2. **Rapid and Semi-Automatic Recoater Setup:** Height Mapper provides a fast and semi-automated method for ensuring optimal recoater and powder bed setup, thereby significantly improving operational efficiency.

Velo3D's Height Mapper technology represents an essential cornerstone in the field of metal 3D printing metrology. Its high-precision, real-time monitoring capabilities not only improve the efficiency and reliability of the printing process but also have profound financial implications in terms of ROI. By automating quality assurance and reducing the need for manual oversight, Height Mapper sets a new standard for what can be achieved in metal 3D printing, positioning Velo3D at the forefront of innovation in the industry.

Height Mapper's technical and operational aspects reveals it to be an invaluable tool for modern metal 3D printing applications. Its unique capabilities ensure that metal 3D printing is faster, more reliable, and economically feasible, heralding a new era of quality and efficiency in additive manufacturing.

Ready to Learn More About Velo3D?

Let us help you with your most challenging and innovative projects.

Contact us today to schedule a consultation or to learn more about our fully integrated metal AM solution.



Without Compromise

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