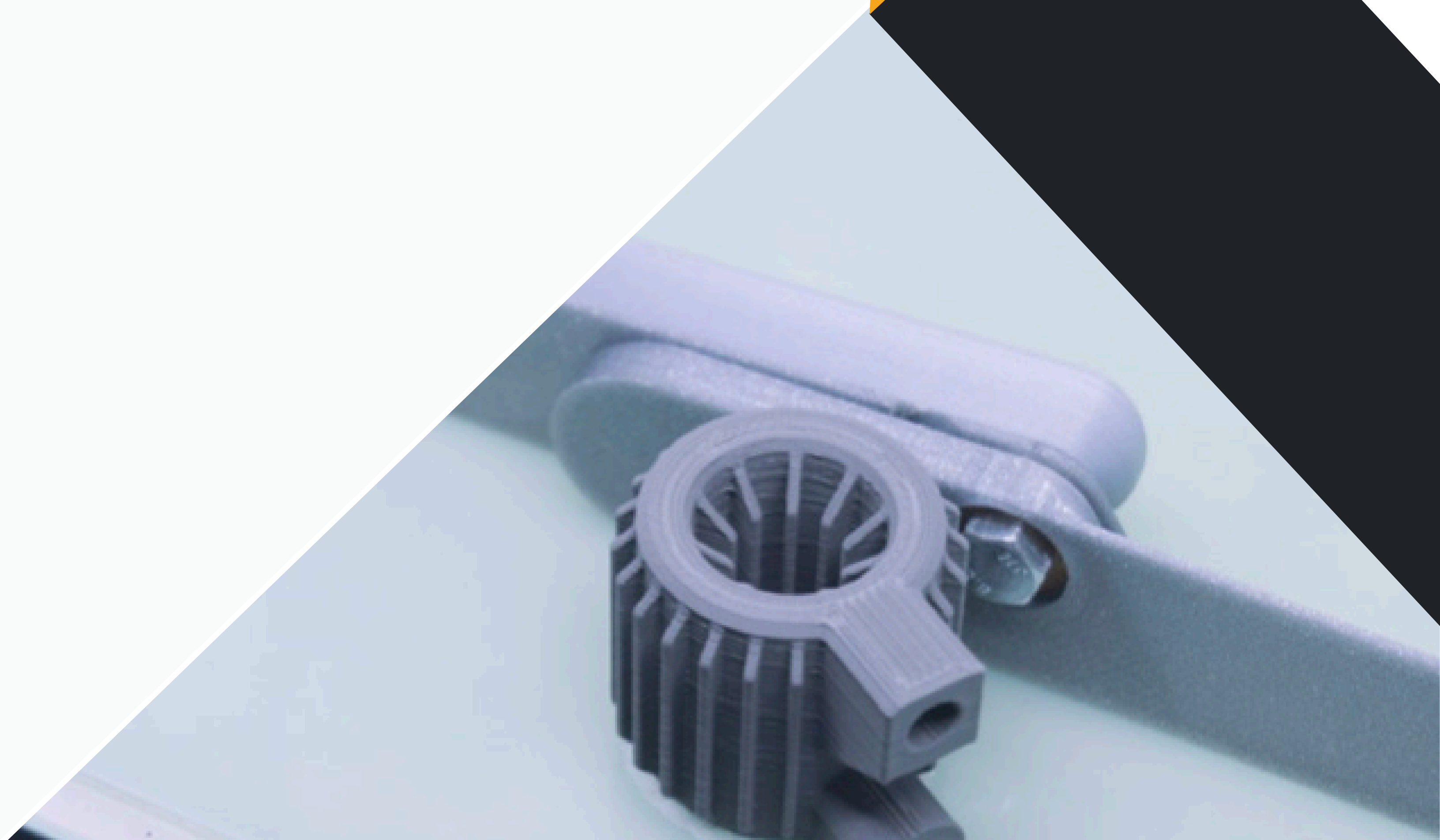
3DQue

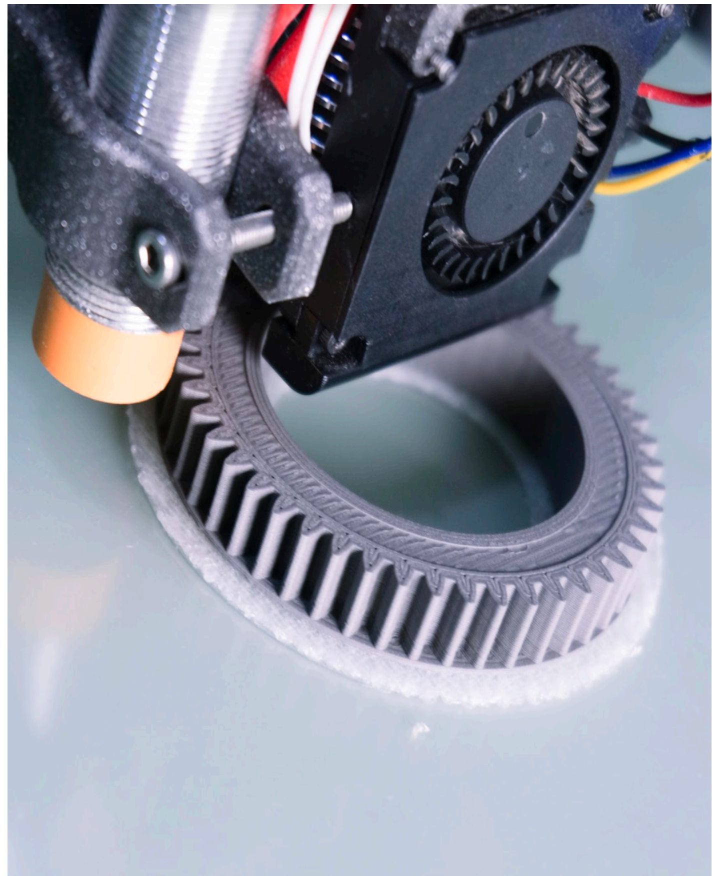
Automating Metal 3D Printing at Scale

How the Quinly automation system can accelerate the adoption of metal 3D printing for cost-effective high-volume production



OVERVIEW:

Though metal 3D printing has proven to be viable for production of certain end-use metal parts, a lack of scalability and high capital costs limit it from being adopted as a primary mode of production. Adoption of the technology is limited to industries such as automotive and aerospace, where a premium is paid for the unique benefits of additive metals [1].



Metal 3D printing allows for the creation and optimization of lightweight components, geometric complexity with little added cost, assembly consolidation, and shorter supply chains [2]. Additive manufacturing allows components to be produced onsite, on-demand, and without physical molds. This reduces lead times and minimizes material waste. Metal 3D printing at scale has the potential to redefine how the world manufactures metal parts.

Global Adoption of Metal 3D Printing is Blocked

Metal 3D printing is currently limited due to the complex nature of the manufacturing processes, which require many points of human interaction, expensive equipment [2], and skilled operators to maintain the machines [3]. Existing systems cannot provide high-volume production without large additional investments into machines and trained operators. This results in low adoption rates amongst manufacturers.

3DQue Systems overcomes these limitations by automating dual-extrusion FFF/FDM printers [4]. This paper discusses how the Quinly automation system makes metal 3D printing scalable and cost-effective for manufacturers to bring in-house.

THE CHALLENGE:
Inefficiencies in Additive Metals

Metal 3D printing can be a very slow and expensive manufacturing process. According to 63% of industry professionals in 3D printing, high equipment costs are the largest factor holding additive metals back from widespread adoption [5]. There are also several points of human interaction, which leads to high labour costs. In order for operators to remove parts from the print bed, clean them off for post-processing, remove supports, and start the next print, they must be physically with the printers. The table below outlines the annual operating costs of the most commonly used metal 3D printing processes.

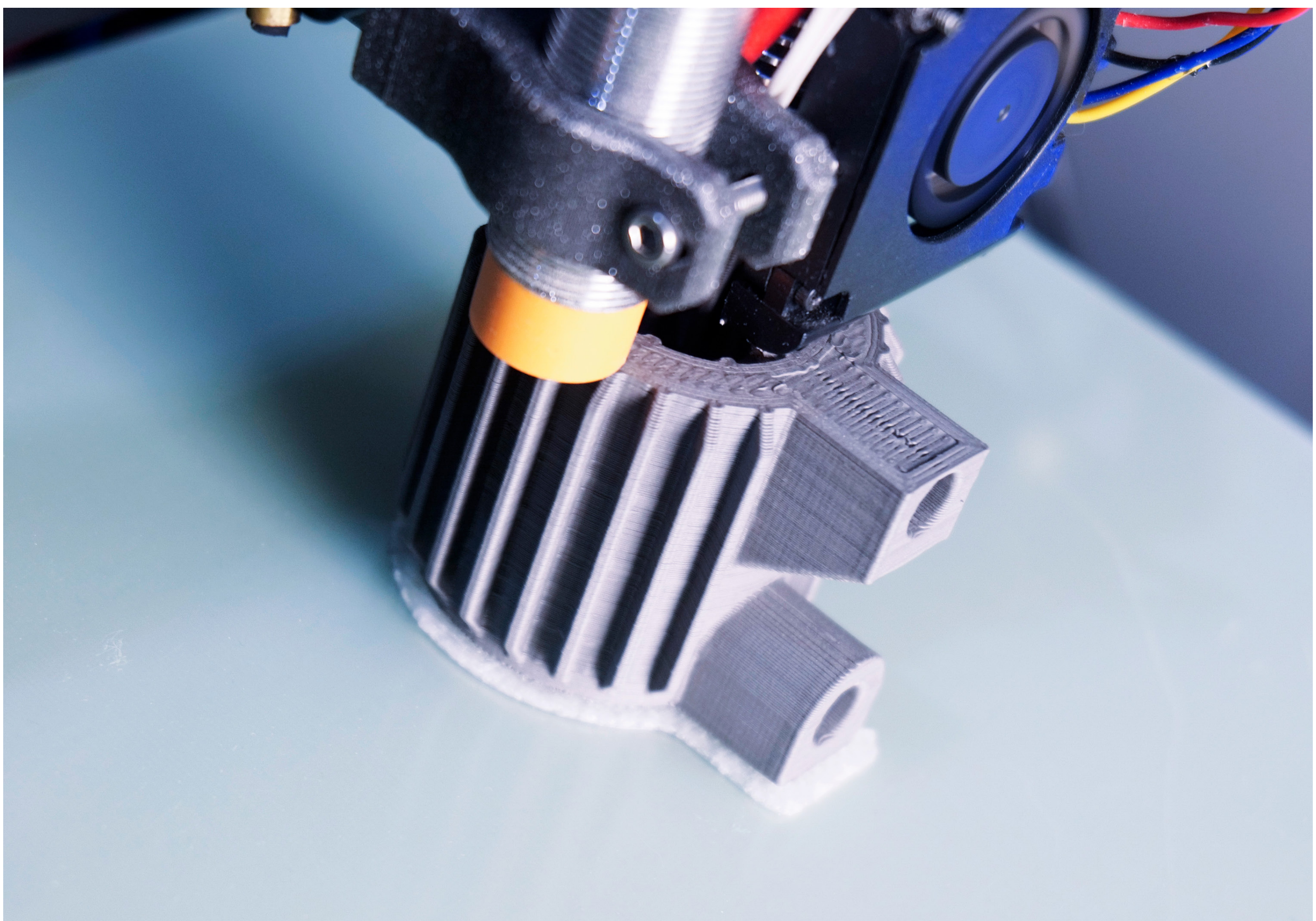
Annual Operating Costs of Current Metal 3D Printing Processes [6]

Metal 3D Printing	Per-Unit Annual Operating Costs (USD/yr)
Laser Powder Bed Fusion	$300k - $500k
E-Beam Powder Bed	$300k - $400k
Powder DED	$150k - $200k
Wire DED	$300k - $500k
Binder Jetting	$150k - $250k
Joule Printing	$300k - $500k

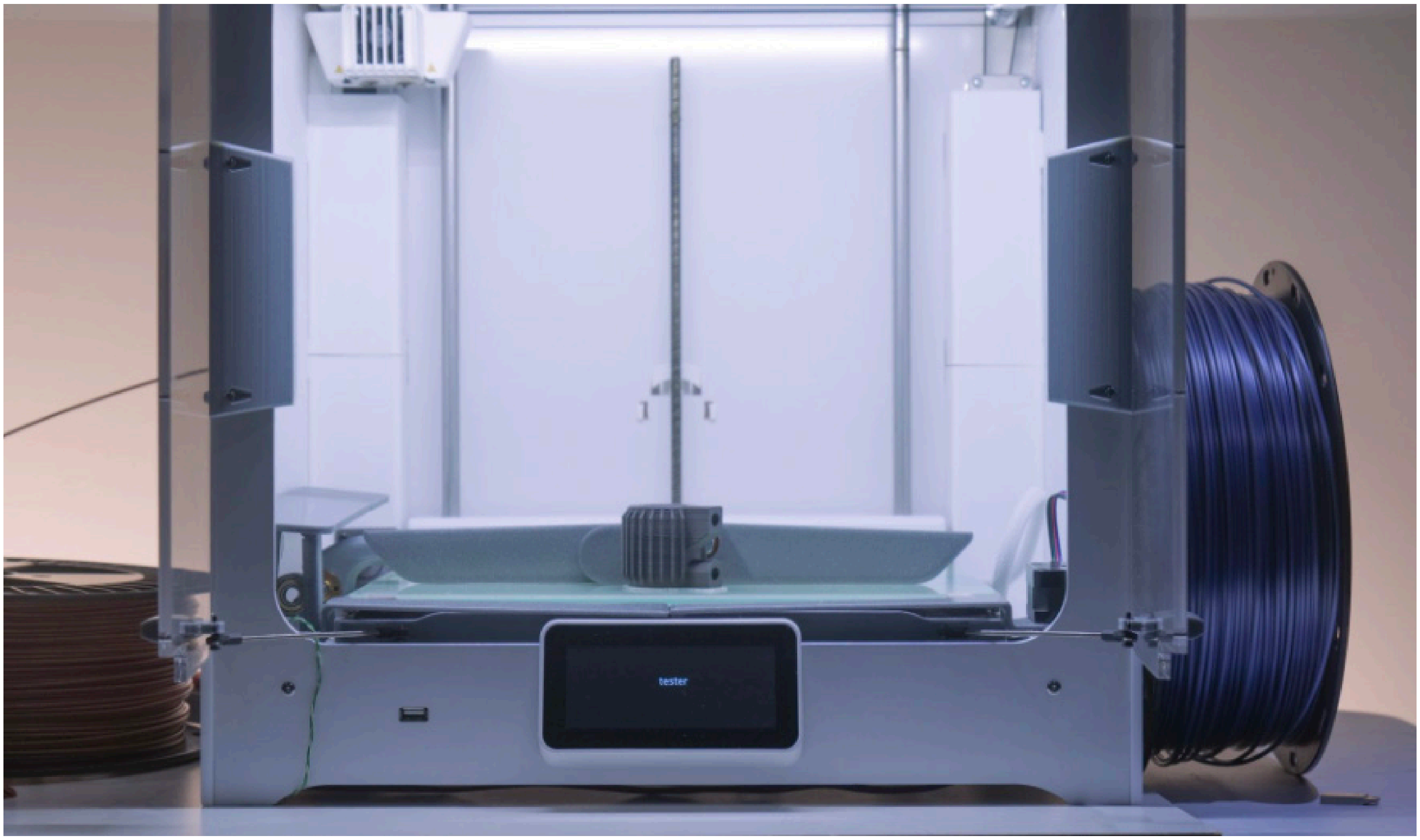
Annual Operating Costs = Annual Cost of Printer + Maintenance + Operator Salary

Such high operating costs limit the use of metal 3D printing to only those manufacturers that can invest in a large number of units to produce high volumes of valuable parts. This is about to change with the introduction of tabletop metal 3D printers that enable in-house metal parts production using bound metal deposition (BMD).

BMD printers are a slower, more economical additive metal production method [2]. These printers heat filament composed of metal powder and a binder, which is extruded layer-by-layer to form a part. Once complete, parts are sintered and supports are removed. Metal components can be produced with BMD at a lower cost than other metal 3D printing processes [7]. These printers do not have significant health and safety requirements and are easier to use; such factors make BMD printers good for in-house low-volume manufacturing. However, these printers still require a large outlay of capital. The industry standard BMD printer is Desktop Metal's Studio System 2, which starts at $60,000 USD [8].



THE SOLUTION:
Automating Metal 3D Printing

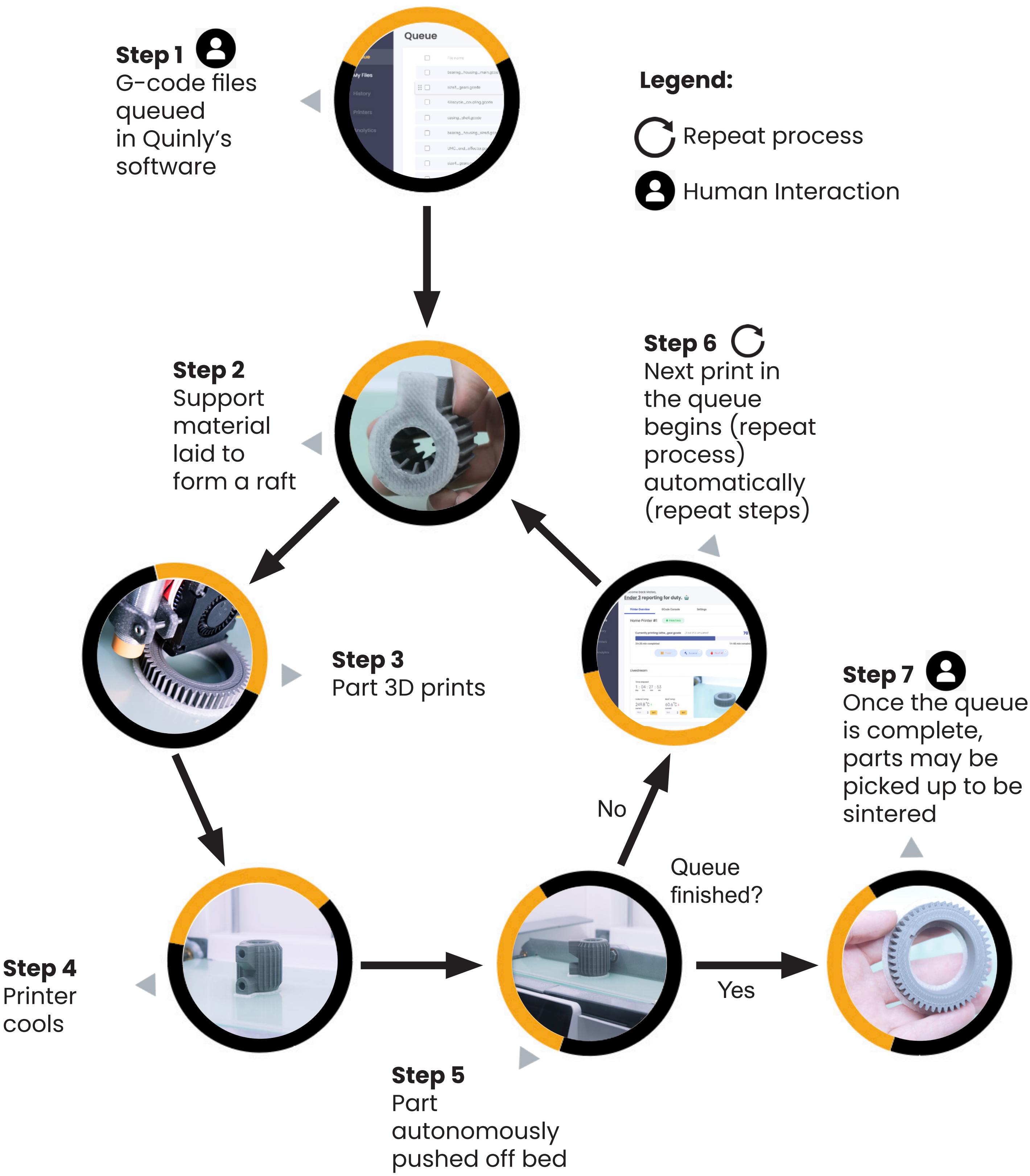


Since the BMD process is very similar to the FDM process, and FDM systems can be leveraged for the production of metal parts by automating them. FDM printers can print with metal-filled filament as long as
they are able to perform dual extrusion (the ability to print with 2 different materials in parallel) as metal filament and support filament are both required for metal 3D printing.

When metal-capable FDM systems are automated, labour is minimized,
printer downtime is reduced, and production throughput increases [9] allowing for the creation of cost-effective metal parts.

3DQue Systems is currently developing the Quinly automation system for the Ultimaker S5 [10], which has dual nozzle extrusion and has already been used to print metal parts [6]. Quinly software combined with the VAAPR™ print bed enables users to queue any number of varying prints for continuous production and autonomous part removal which eliminates printer downtime and the dependency on operators to clear beds and start prints. Quinly is fully capable of metal 3D printing on the Ultimaker S5 and any metal filament may be used alongside a support polymer that burns clean. Maximum throughput may be achieved through continuous printing and simplified post-processing.

THE SOLUTION:
Production Method



ADDITIVE METALS COSTING: Quinly Automation in Practice

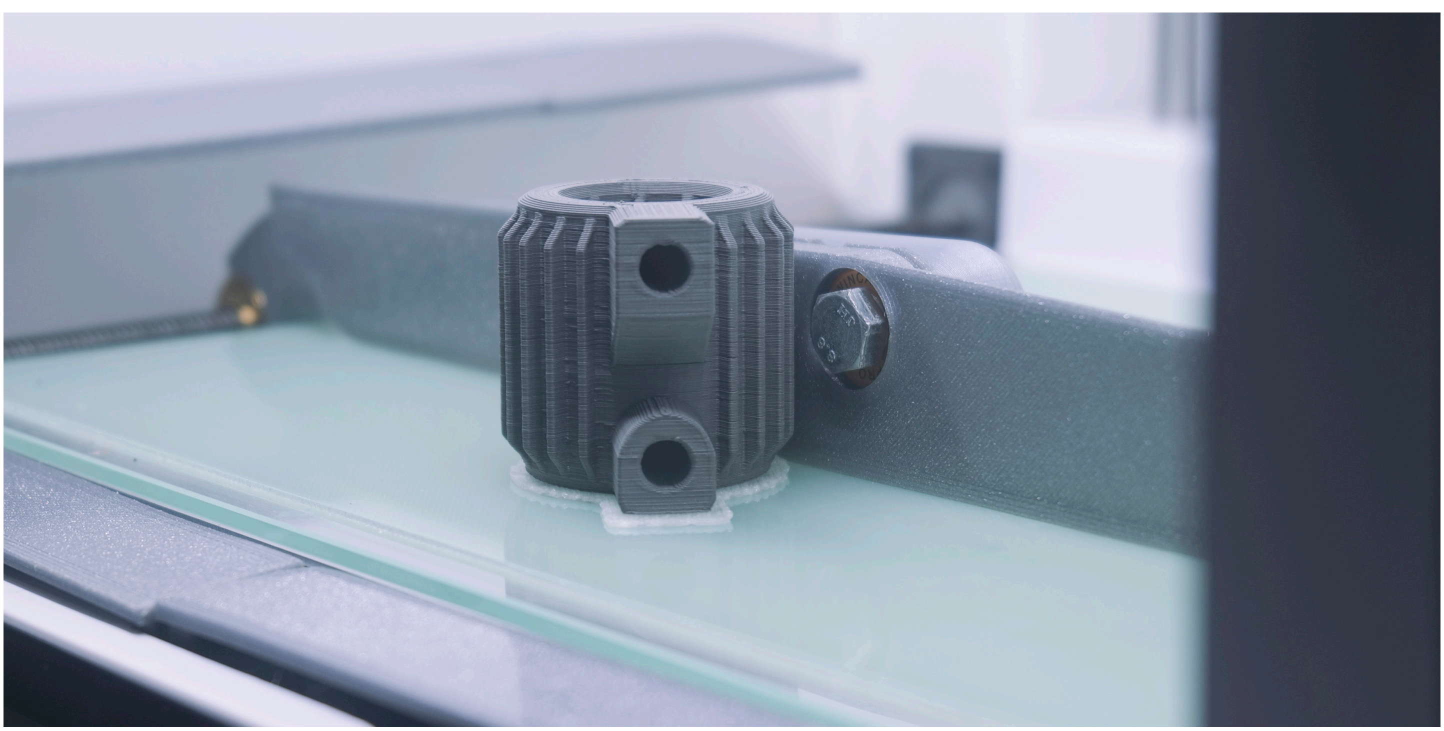
To verify the efficacy of metal 3D printing using a Quinly-automated Ultimaker S5, parts designed by Desktop Metal were replicated (using the information available on their website) [12] [13] and produced. Parts were printed using BASF Ultrafuse 316L metal filament [14] and Polymaker PolyCast filament for rafts and supports [15]. Since Desktop Metal is an industry standard in metal additive, their production data was used as a benchmark.

Key objectives:

- Test Polymaker PolyCast for bed release once cool
- Ensure Quinly is able to successfully clear metal parts from the bed
- Observe support residue left once parts are sintered

During printing, PolyCast filament served as an effective raft material and was fully compatible with Quinly's VAAPR™ surface. Rafts had excellent bed adhesion at 60°C and fully released at 35°C. This allowed all parts to be autonomously removed successfully from the printer via the wiper arm mechanism included in the Quinly for Ultimaker S5 automation system. The printer required only 10 minutes to cool and clear the print bed between print jobs.

Printed parts were sintered with the rafts and supports in place. The PolyCast filament was burnt away, leaving only 0.003% residue [15]. Sintering without a raft was tested as well; the PolyCast rafts were easily removable by hand after printing was complete and did not fuse to the metal filament.

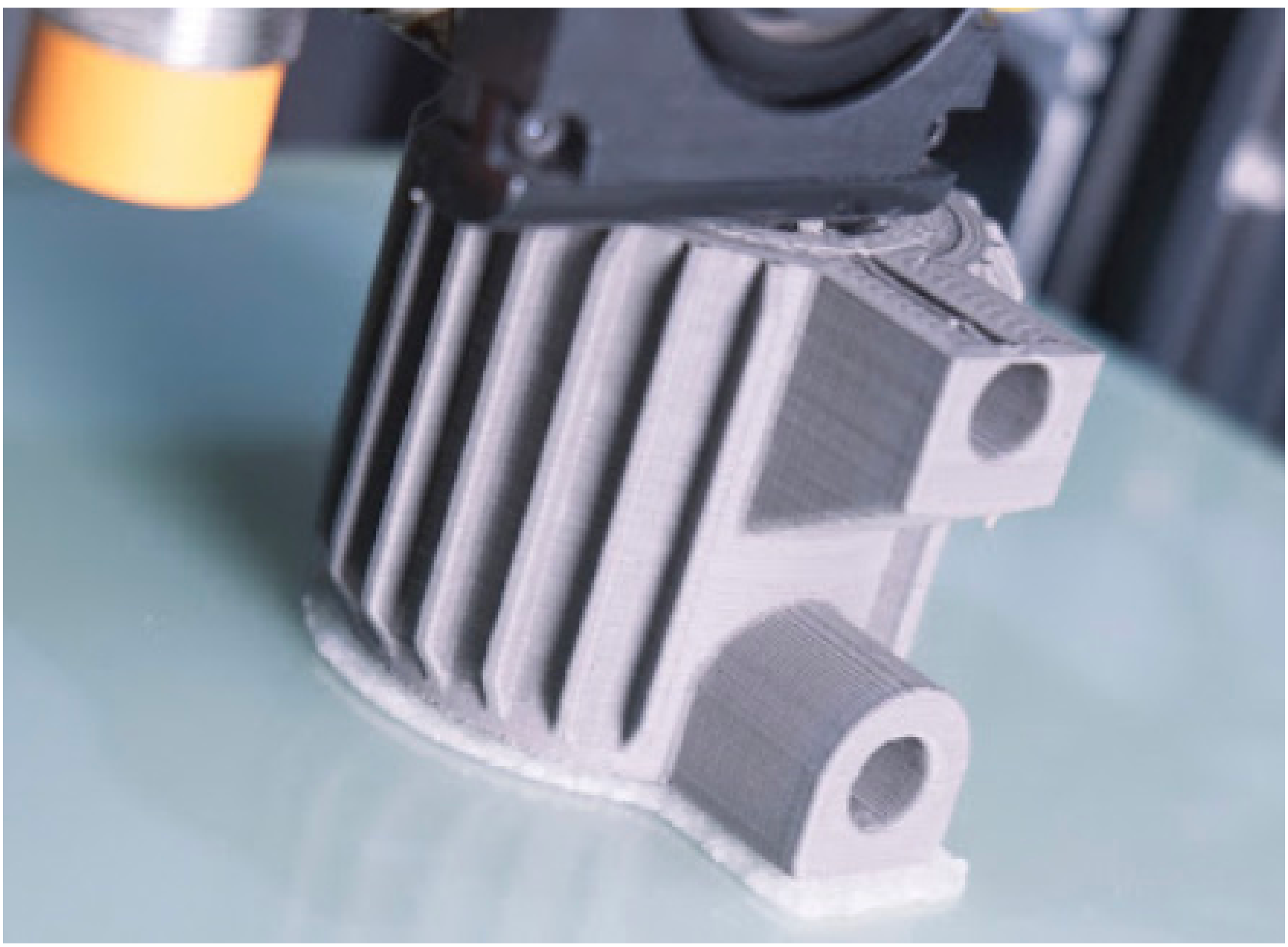


ADDITIVE METALS COSTING:
Metal Parts Production made Accessible with Quinly

Consider a production fitting of 4 Quinly-automated Ultimaker S5 Pro printers, with equipment costs listed in the table below.

Equipment Costs of a Quinly-Automated Ultimaker S5

Equipment	Cost (USD)
Ultimaker S5 Pro Complete System [9]	$9,688
Quinly for Ultimaker S5 [9]	$2,500
Quinly Pro Software (monthly subscription)[9]	$25/ month



With such low capital setup costs for a continuous production system, a high volume of cost-effective parts may be produced. Production of some of Desktop Metal's Studio System 2 parts were compared with production using Quinly-automated Ultimaker S5 printers. See the tables below for the savings achieved when using a more affordable, automated system.

Quinly Production Cost Comparison to a BMD Printer

Production Details	UMC End Effector	Lathe Gear
Desktop Metal Figures - Studio System 2		
Cost Per Part [12]	$23	$58
Quinly Automation System Figures		
Number of Systems	4	4
Total Weekly Throughput	597	168
Inputs Cost Per Part (Material and Labour)	$8.52	$31.20
Amortized Equipment Cost Per Part (5-Year Depreciation)	$0.23	$0.87
Cost Per Part	$8.75	$32.06
Savings (%)	**62%**	**45%**

These preliminary tests showed promising results indicating that automated metal 3D printing can be an affordable alternative to traditional metal 3D printing.

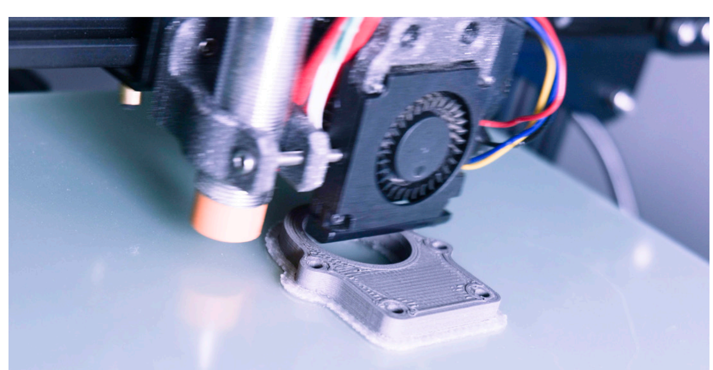
Lathe Gear

To test the feasibility of using Quinly-automated Ultimaker S5 printers for volume production was assessed by comparing parts produced by the Desktop Metal Shop System, a binder jetting printer that starts at $150,000 USD [16] to the Quinly-enabled Ultimaker. Cost savings using Quinly are presented for each part in tables below.

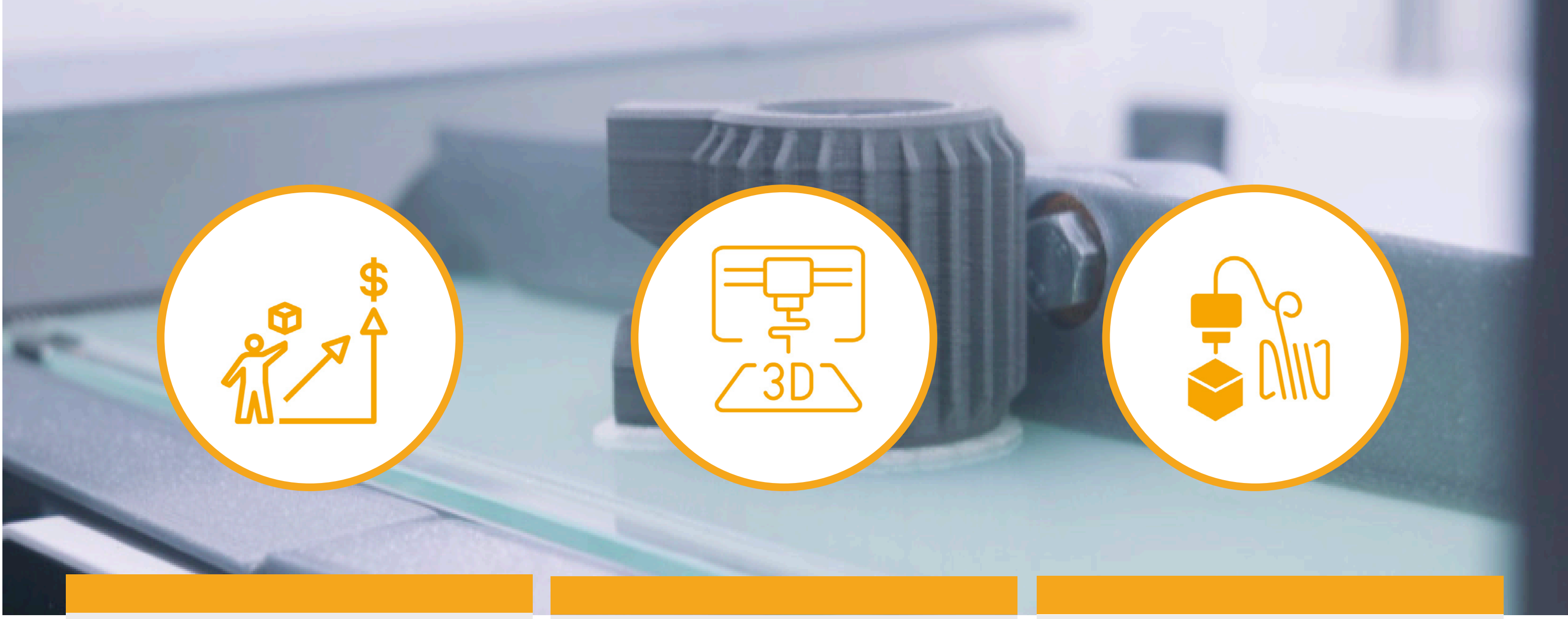
Quinly Production Cost Comparison to a Binder Jetting Printer

Production Details	Killacycle Coupling	Bearing Housing
Desktop Metal Figures - Shop System		
Cost Per Part [13]	$86.94	$72.89
Total Weekly Throughput [13]	137	192
Quinly Automation System Figures		
Number of Systems	4	4
Total Weekly Throughput	192	208
Inputs Cost Per Part (Material and Labour)	$25.28	$25.79
Amortized Equipment Cost Per Part(5-Year Depreciation)	$0.76	$0.69
Cost Per Part	$26.04	$26.49
Savings (%)	**70%**	**64%**

To generate production throughputs comparable to that of binder jetting using a cost-effective platform like the Ultimaker S5 opens the door for metal 3D printing to be broadly adopted for production without the need for high capital spending. By automating Ultimakers with Quinly, companies can avoid large capital outlays, making metal 3D printing more accessible to a broader range of companies.



ADDITIONAL BENEFITS OF AUTOMATION FOR METALS:
Metal Parts Production made Accessible with Quinly



01. Expand Production, not Work Hours

The Ultimaker S5 and similar industry-grade dual extrusion printers are already well established, having already been used to prototype and produce end-use metal parts. These systems are simple to use and have a small footprint. Dual extrusion FDM printers are more affordable, allowing manufacturers to engage in metal 3D printing with a lower capital outlay than existing additive metals systems.

02. Print with Metal on Widely Used Systems

With Quinly, production throughput can be multiplied without increasing manual labor, transforming 3D printing from a batch to continuous-flow process . Technicians can focus their time on dialing in gcode files for better quality prints instead of spending time on menial tasks like scraping and applying adhesives. Quinly's automation removes a major barrier to scaling 3D printing - the shortage of skilled operators - by allowing operators to run more printers in less time.

03. Unrestricted Filament Options

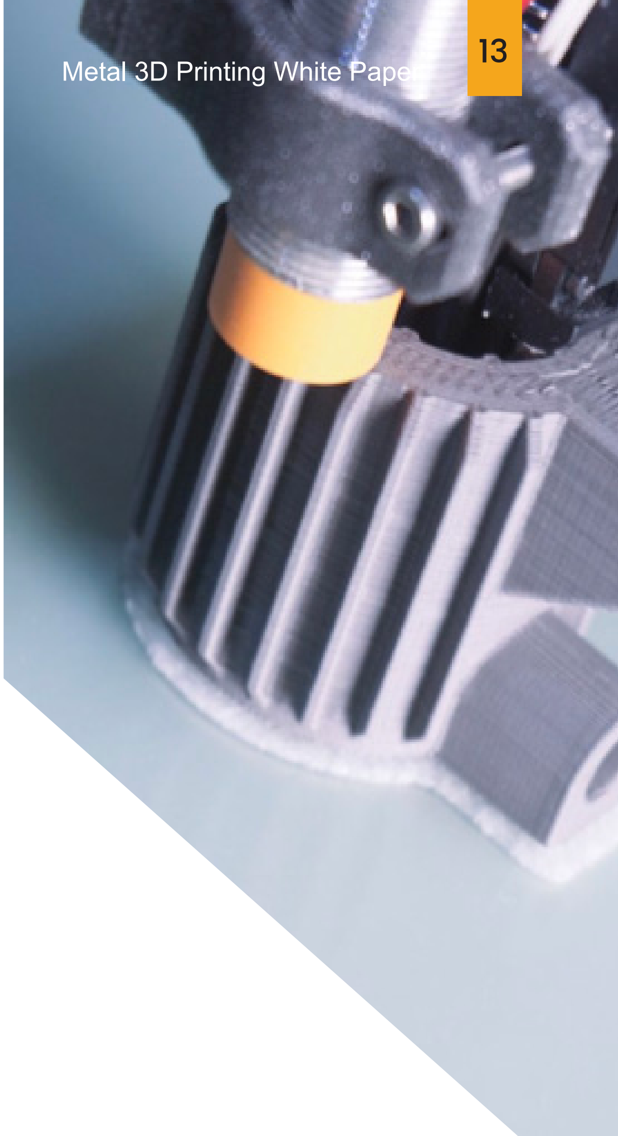
Metal 3D printers are limited to printing with metal filaments only. Leveraging the dual-extrusion and multi-material handling capabilities of Ultimaker printers allows Quinly to mass produce parts using any filament material. By using their existing plastic printing systems for metal parts production, organizations do not need to invest in multiple systems.
PolyCast rafts make Quinly-fitted Ultimakers compatible with any metal filament on the market. The raft easily slides off the bed once cooled, making metal filament bed adhesion issues a thing of the past.

04. Reduced Inventory, Increased Flexibility

Automating the metal 3D printing process allows manufacturers to produce high volumes of any part on-demand. Systems are not limited to producing a single part for long periods of time as Quinly's software queues parts for continuous production.

05. A Focus on Sustainability

Quinly enables efficient in-house production at low costs using existing printers. The metal manufacturing supply chain can be very long, which causes harsh environmental impacts as parts are shipped to and from companies before they reach the assembly line or end-user. Quinly shortens the supply chain, digitizing everything from tooling to shipping to production, enabling companies to deliver parts into customer's hands faster while minimizing the production footprint.



CONCLUSION:

By taking advantage of automation, Quinly outfits dual extrusion FDM printers like the Ultimaker S5 for cost-effective high-volume additive metals manufacturing. Automation is the next step in metal 3D printing, because labor is minimized, part-cost is reduced by 40-70%, and the barrier to entry is much lower by using a much more affordable Ultimaker S5. Automation allows this technology to beaffordable and accessible by all levels of the manufacturing industry, and we expect this will increase adoption rates of metal 3D printing and accelerate its development.

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