Markforged

3D Printing A More Efficient Factory Floor

In a new era of uncertainty, don't let supply chains bottleneck efficiency

Are you responsible for keeping your manufacturing operations running smoothly? If so, you're aware that unlocking factory floor efficiency while keeping costs down isn't so simple.

In modern factory environments, optimizing efficiency in the long run — for production line throughput, inventory costs, manufacturing line uptime, and worker safety — requires resources. However, for these resources to be effective, they must be available right when and where you need them.

In an ideal world your team can quickly and painlessly obtain all resources needed to increase productivity and keep costs low. But with disruptive events cascading across entire supplier ecosystems, procuring resources today isn't as simple as executing traditional just-in-time (JIT) supply chain tactics and contingency plans. Without large stocks of inventory to fall back on — or a fast and versatile production capability at the point of need — factory floors are susceptible to extended periods of costly downtime.

Today's additive manufacturing platforms make it simple to print reliable, functional parts for industrial uses right where you need them— unlocking your factory floor's potential for operational efficiency and agility. Powerful industrial 3D printers make specialized parts accessible in many high-performance materials, while digital software tools make additive processes fast, easy, and flexible.

Read this white paper to learn:

- What types of problems in-house additive manufacturing can solve for your factory floor
- How additive manufacturing solves widespread problems on factory floors, and ultimately boosts productivity
- 3D printing applications for the factory floor
- Exploration of 3D printing technologies powering factory floor applications

Do you experience any of these pain points on your factory floor?

1. Difficulty getting parts you need, when you need them
2. Overpaying for parts while waiting forever for them to arrive
3. Large amounts of capital tied up in physical inventory and storage space
4. Unplanned downtime due to lengthy procurement processes for replacement parts
5. Reliance on third party suppliers, lack of internal self-sufficiency
6. Labor shortage and a need to allocate expensive specialized labor towards fixtures, tooling, and other activities that don't directly generate revenue
7. Continuous process improvements blocked by sourcing costs
8. Processes that could be made safer and more efficient with custom tools
9. Slow development speeds for new products or processes
10. Large quantities of waste caused by excess inventory

Here's how leading manufacturers use additive to boost productivity and lower costs

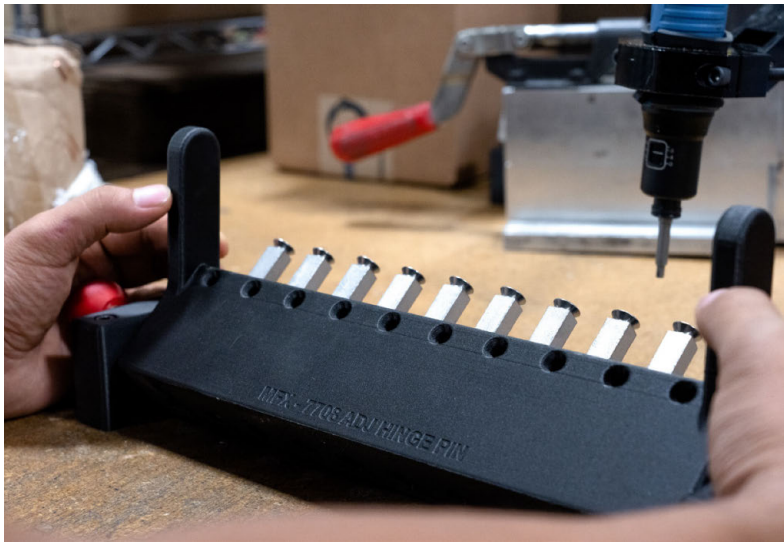
Bring quick, cost-effective parts to the point of need: 3D printing is a cost-effective way to overcome logistical hurdles— and get you the part you need in just hours, or days. Printing any part for your manufacturing operation — like custom tooling and fixtures, spares, jigs, guides, ergonomic tools and grips — has never been easier.

Caldwell Manufacturing, a global door and window hardware manufacturer, 3D prints everything from assembly fixtures, shop floor tooling, R&D, and robotic parts for testing, all the way to post-processed parts for customers. The same parts that would cost anywhere between $300-$5,000 through traditional methods — and take eight weeks to receive — now cost only $30 and take three days to produce.

Significant savings can be realized by replacing machined metal parts with continuous fiber-reinforced composites. Additive also inherently produces far less material waste compared to traditional manufacturing processes, leading to reduced material costs.

Move your inventory to the cloud and reduce holding costs:
Securely storing parts in the cloud as print files frees capital tied up in inventory and prevents it from wasting valuable warehouse space. The option to get a part on-demand precludes a need for physical inventory. When the part is needed, it can be obtained in just hours or days.

Vestas, a leading manufacturer of wind turbines, uses Markforged 3D printing software to store over 2000+ Vestas parts digitally in a secure, cloud-based repository. Not only does this free up physical space and capital—employees at any location can quickly search for and print any number of fiber-reinforced composite parts at the point of need.

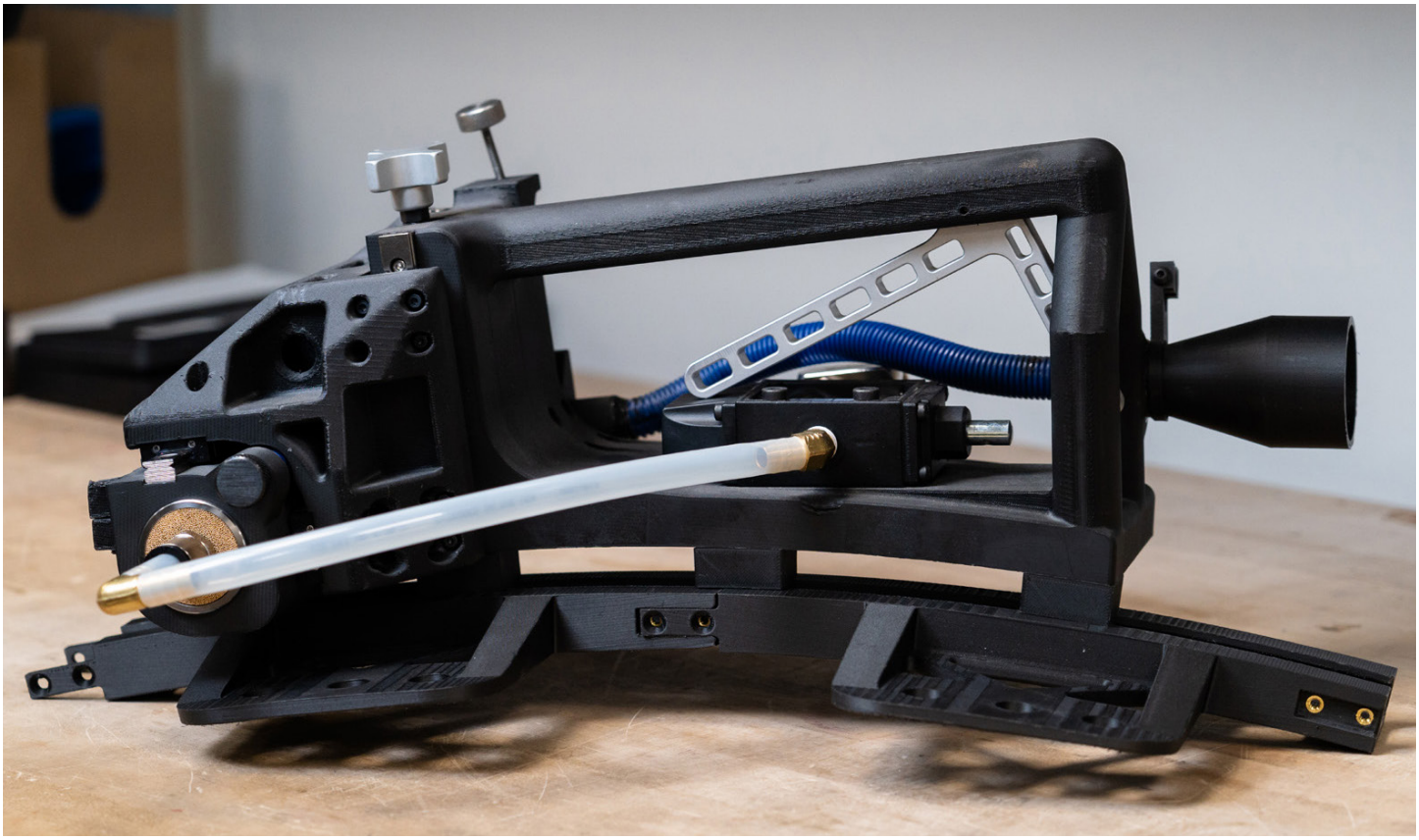


Supply chain flexibility and autonomy:
Don't let production lines get held up by parts with long lead times: skip lengthy procurement processes and get replacement parts on-demand. Saint Gobain Research North America — which aims to optimize plant operations across over 100 locations with new technologies — replaced metal fixtures with strong, 3D-printed composite fixtures needed to make important production components. If Saint Gobain turned to internal machining resources, their production line would have needed to wait 90 days to start. Instead, they were able to quickly 3D print a solution and begin production far sooner.

Design, produce custom tools to boost efficiency and safety:
Using ergonomic grips and tools not only improves operator comfort and safety, but can also decrease cycle times and boost efficiency.

3D print tooling and fixtures to reduce expensive specialized labor:
This frees specialized labor, such as busy in-house machinists, to stay focused on revenue-generating jobs. Cashco, a global industrial control manufacturer, used Markforged carbon fiber 3D printers to produce strong tooling for their factory floor: reducing the need for metal tooling work by 90%. Applications include custom end effector gripping pads for collaborative robots, custom grids for pre-machined parts that reduce changeover times, and unique subplate setups for lathes and mills. Bringing a carbon fiber composite 3D printer in-house also reduced time to manufacture tooling by 75%. In just three months, the savings from these process improvements paid for the entire printer cost.

Empower employees to solve more problems in-house, accelerate innovation:
The ability to produce more parts in-house builds a culture of continuous improvement, where engineers and operators can creatively build solutions to boost efficiency. Eric Mertz, CEO of Caldwell Manufacturing, credits his decision to bring additive manufacturing in-house for building a culture of continuous improvement on his factory floor: removing bureaucracy and adding autonomy. “It’s given them the tools they need to put their thoughts into parts,” says Mertz. “And ultimately, I think it’s bigger than that. I think that those things create more engagement from our employees. It’s part of our culture now.” This also allows Caldwell to **accelerate innovation**, as the freedom to quickly iterate and get a working end-use part means new processes can be developed and implemented faster.



This printed MRO tool from the Siemens Energy Innovation Center mitigates 3-4 weeks of downtime per instance. Both prototypes and final end-use parts can be printed, leading to significant time and cost savings.

What types of composites can replace metal?

Continuous Fiber Reinforcement (CFR), a patented technology from Markforged, produces strong polymer composites reinforced with continuous fibers to boost strength, stiffness, heat resistance, and other material properties. These parts are capable of replacing machined aluminum faster, cheaper, and at a fraction of the weight.

CFR alone improves the strength of a plastic part to hold up to **2.5x** the load. Combining CFR with design optimizations demonstrated strength improvements of up to **6.4x**.[1]

Wärtsilä used to machine solid steel lifting tools for moving 240-kg engine pistons, but found the resulting tools to be too expensive, too time-intensive to manufacture, and too heavy for people to use and transport. Now, Wärtsilä 3D prints lifting tools out of Onyx reinforced with continuous carbon fibers that are capable of lifting up to 960kg with a safety factor of four. 3D printing this tool has saved over €100,000 in tooling alone in just eight months.

> “This will enable Wärtsilä to speed up the introduction of new products with faster, cheaper, and safer tool creation.”

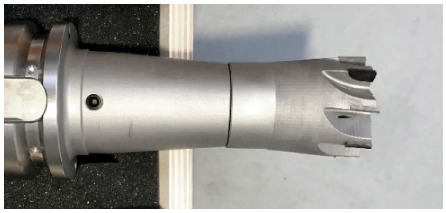
— Giuseppe Saragò, Director, Manufacturing Excellence, Wärtsilä.

[1]Kelly, P.G., Gallup, B.H. and Roy-Mayhew, J.D. (2023), “Multiplanar continuous fiber reinforcement in additively manufactured parts via co-part assembly”, Rapid Prototyping Journal, Vol. 29 No. 11, pp. 64-73. https://doi.org/10.1108/RPJ-12-2022-0415

Factory floor applications for industrial 3D printing

Assembly tools and fixtures
If a customer requests slight modifications to an existing part, you may be waiting on a new tool to start that production run. The option to print high-strength, customized tooling and fixtures allows your floor to move faster with requests.

Additionally, many parts historically made from metal can be printed with continuous fiber-reinforced composites and save time, cost, and weight.



Milling Cutter Body

Welding Fixtures

CNC Part Catcher

Stanchion Adapter

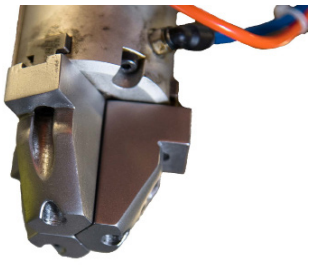
Press Brake Punch and Die

Composite Gripper Jaws

Thermoset Mold

Vise and Soft Jaws

Grippers



Metal Gripper Jaws

CMM Fixtures

Workholding Gears

Spindle Adapters

Application	Materials	Lead Time Reduction	Cost Reduction
Milling Cutter Body	H13 Tool Steel	66% reduction	75% cost savings
Welding Fixtures	Onyx	6.5 days to 12 hrs (92% decrease)	$800 to $10 (99% decrease)
CNC Part Catcher	Onyx, CFR-reinforced with Carbon Fiber	144 hrs to 6 hrs (96% decrease)	$400 to $25 (94% decrease)
Stanchion Adapter	Onyx, CFR-reinforced with Fiberglass	3 weeks to 12 hrs (98% decrease)	$115 - $28 (76% decrease)
Press Brake Punch and Die	Onyx	10 days to 1.5 days (85% decrease)	$1,400 to $200 (86% decrease)
Composite Gripper Jaws	Onyx	144 hrs to 9 hrs (94% decrease)	$290 to $9 (97% decrease)
Thermoset Mold	Onyx, CFR-reinforced with HSHT Fiberglass	144 hrs to 60 hrs (58% decrease)	$1,000 to $240 (76% decrease)
Vise and Soft Jaws	Onyx, CFR-reinforced with Carbon Fiber	3 weeks to 1 week (67% decrease)	$6,000 to $1,500 (75% decrease)
Grippers	Onyx, CFR-reinforced with Carbon Fiber	75% reduction	90% reduction in need for metal tooling work
Metal Gripper Jaws	17-4PH Stainless Steel	14 days to 1.25 days (91% decrease)	$355 to $7 (98% decrease)
CMM Fixtures	Onyx, CFR-reinforced with Carbon Fiber	10 days to 3 days (70% decrease)	$1,590 to $330 (79.2% decrease)
Workholding Gears	Onyx	90% reduction	70% cost savings
Spindle Adapters	Onyx	90 day lead time reduction	86% cost savings

On-demand replacement parts

Many critical parts are no longer supported by their original manufacturers, or would take too long to obtain due to supply chain restrictions. A single replacement part, which can take months to get, can shut down an entire production line until it's received.

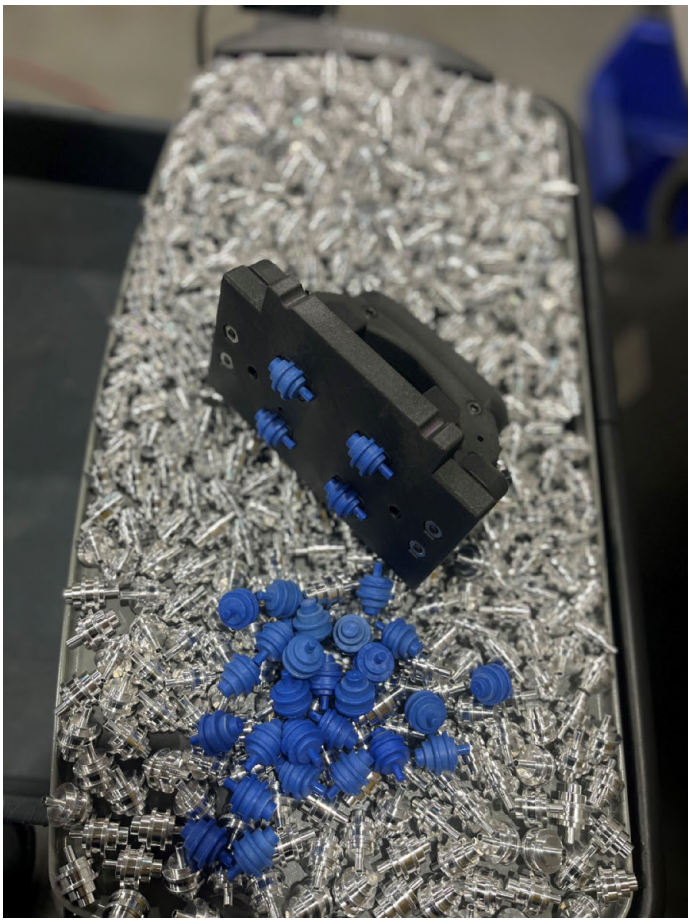
Additive manufacturing makes it possible to quickly design and print many legacy part replacements that are otherwise difficult to procure. Replacement parts are not bound to any specific application categories — they can take the form of tooling, fixturing, or end use parts.

Ergonomic tools and grips

Working as an operator for any manufacturing process comes with inherent risks and hazards, many of which can be mitigated by 3D printing custom equipment. Along with improving the safety and comfort of workers, 3D printed tools and grips can substantially increase operator efficiency.

This custom tool was designed and 3D printed for loading brass inserts into a 275-degree mold in a plastic injection mold machine.

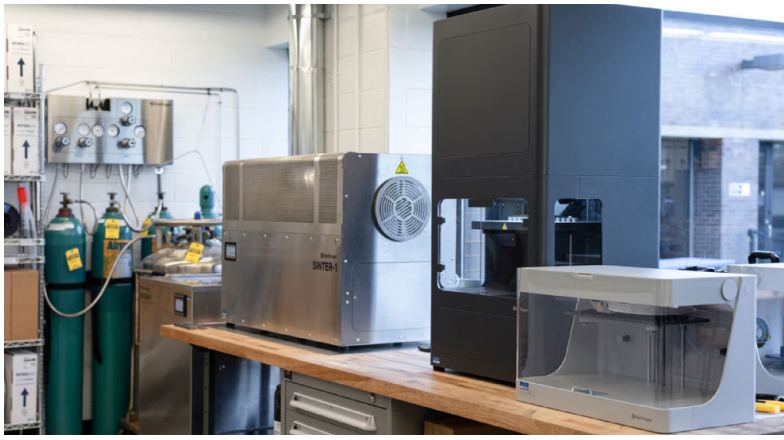
Not only did this tool make it easier for the operator to load the machine but it also reduced cycle times (previously 45 seconds on average) by 19-20 seconds — increasing production by 50%. The faster cycle times allow the shop to finish orders more quickly— providing an opportunity to run other jobs in the press and cut back on employee hours needed to run those parts, while eliminating the burn hazard.



Custom tool used for manually loading brass inserts into injection molding machine.

What technologies power 3D printing on the manufacturing floor?

The Digital Forge isn't just another prototyping machine – it's the first additive manufacturing platform designed specifically for factory floors. We made it easy to use and reliable.. There are no more layers of red tape or long tool room queues to get the part you need. Instead focus on designing the right part to increase your uptime, reduce cycle time, or increase your throughput. Capable of printing in both metal and advanced composites, you get strong, accurate parts every time. It's the first tool you will want to pick up when a problem pops up on the factory floor.



Carbon fiber-reinforced composites for unparalleled strength

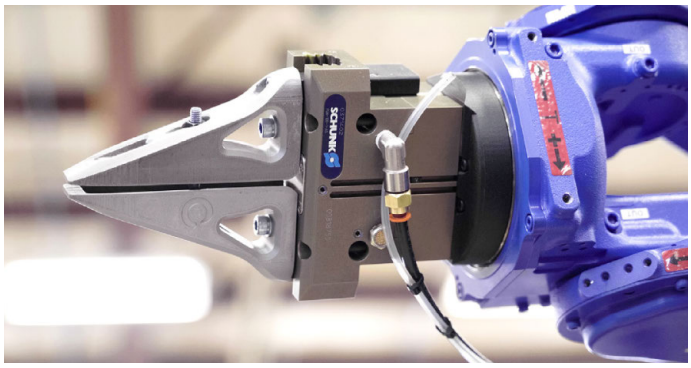
Markforged is the first company to make 3D printers capable of **Continuous Fiber Reinforcement (CFR)** in parts. What does this mean? You can print composite parts strong enough to replace machined metal. Fabricate metal-strength composites with our small but mighty Desktop series, or scale up throughput with the FX20.

While chopped carbon fibers are able to improve the mechanical properties and print quality of 3D printed thermoplastics, continuous fibers can further increase part strength by an order of magnitude. Print metal-strength composite parts with the confidence that they will perform.

The most accessible metal 3D printing with Metal FFF

While expensive and complicated is considered the reality of any metal fabrication process, one metal printing process defies this status quo. Metal fused filament fabrication (metal FFF) is the first additive manufacturing process that makes metal fabrication fast, cost-effective, and user-friendly.

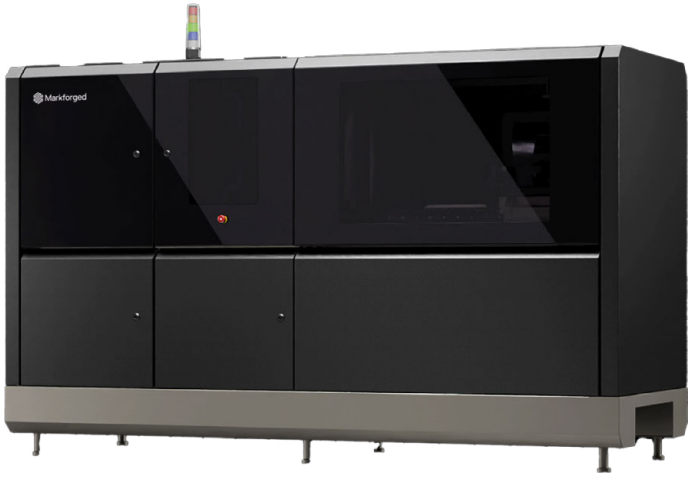
Print a wide range of industrial metals — stainless steel, tool steels, pure copper, and Inconel — without the need for highly trained operators or extensive PPE. Use of bound powder feedstock creates a more simple user experience.



Precise, scalable binder jetting. High-throughput metal with no tooling

In the summer of 2022, Markforged acquired Digital Metal: adding a leading binder jetting solution to the Digital Forge. The PX100 is a precise, reliable platform capable of fabricating thousands of small, complex end-use parts. It lets companies bring products to market faster and cheaper while fully controlling their own means of production.

Traditional mass production technologies take months to set up, can introduce 3rd party supplier risk, and suffer from poor unit economics during ramp up and in lower volumes. PX100 from Markforged unlocks high-volume metal production at the point of need, giving manufacturers a reliable, direct solution they can control.

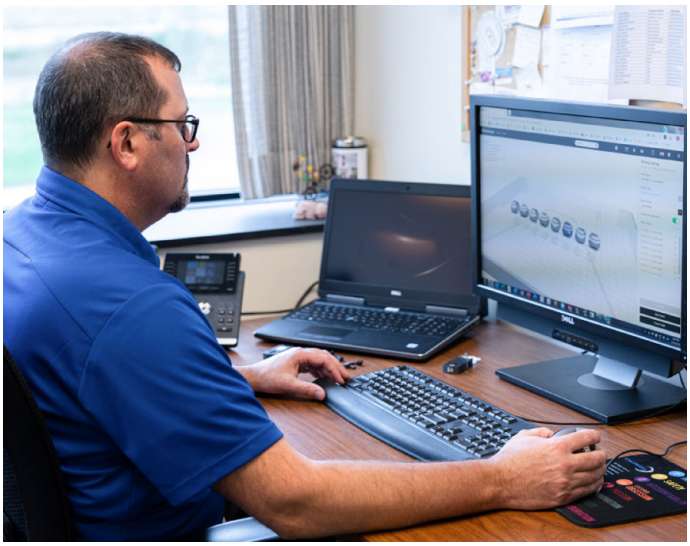


Secure, user-friendly software platform for slicing and digital inventory

Eiger software makes it quick and simple to configure print settings and fiber reinforcement patterns for your parts. Store parts as digital inventory, print to anywhere in your organization's network of connected 3D printers.

Eiger features robust authentication processes, enterprise-grade user management, API integrations with factory systems, and on-app dashboards for easy fleet performance tracking.

The Digital Forge is the first ISO/IEC:27001-certified additive manufacturing platform.



Smart software tools for maximum process efficiency

Software tools available on The Digital Forge let you deliver trusted parts faster without additional labor or hardware resources.

The **Simulation** smart feature in Eiger virtually tests part strength and stiffness, so users can validate how their part will perform before they print it. Simulation dramatically reduces the need for print-break test cycles, which typically consume significant amounts of time and material. Simulation can also optimize prints to reduce material costs and/or print times, while still meeting defined performance requirements.

Inspection software scans parts for quality assurance inspection during the printing process. Once printing is finished, the inspection software automatically generates a report that shows you if your part is within spec via clear pass/fail analysis. Automated inspection of parts boosts manufacturing productivity by reducing manpower and time required for manual quality assurance.

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Markforged

Partner with Markforged, an innovator in 3D Printing Technology

“Markforged (NYSE:MKFG) is a leading additive manufacturing provider bringing industrial production to the point of need. The Digital Forge — the world’s most reliable, intelligent, and easy-to-use additive manufacturing platform — makes manufacturing flexible and resilient through today’s ever-changing supply chains. With powerful cloud-based software, the strongest composite parts available, and the most accessible metal 3D printing, Markforged makes it simple to solve the most complex manufacturing challenges. Over 10,000+ companies in 70+ countries use Markforged to print tooling and fixtures, functional prototypes, and strong end-use production parts for specialized applications.”

To learn more, visit
markforged.com