

# Guide to Metal 3D Printers

How to find the right metal 3D printer for your business

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**"Two-thirds of manufacturers surveyed are currently implementing 3DP in some way. One in four said they plan to adopt 3DP some time in the future."**

PWC

[3D Printing and the New Shape of Industrial Manufacturing](#)

## Introduction

**Make your manufacturing and product development operations run more efficiently with metal 3D printing.**

Metal 3D printing introduces a unique and groundbreaking method to additively manufacture metal parts. Until recently, the technology was too immature to broadly utilize in manufacturing — however, advancement in the last five years has transformed metal 3D printing into a scalable, robust solution. Implementing this technology effectively can transform your business.

Due to its newness and the excitement surrounding it, metal 3D printing is a complex field with many misconceptions and a wide variety of technologies. In this guide, we'll help you cut through the noise by detailing why metal 3D printing is valuable, what technologies and materials are out there, and how you can take the first steps in adopting metal 3D printing in your own facility.

**In this guide, you'll learn about:**

- The business benefits and technical advantages of using metal 3D printers.
- Types of printers and groups of printable materials available today.
- The four key application spaces of metal 3D printing.
- How to calculate ROI for a metal 3D printer, both financially and through process improvement.
- Three ways to adapt your business to be successful with metal 3D printers.

# Benefits of Metal 3D Printing

There's a reason that you're here — 3D printing has changed the landscape of manufacturing. Let's explore why that's that's the case. 3D printing is a more agile process than other fabrication methods — allowing you to go from design to complex metal part faster, easier, and more affordably. Whether you're eliminating the need for detail drawings and machine programming or drastically shortening lead times that bog down your product development process, implementing metal 3D printing correctly can improve your business significantly.

"It's removed bureaucracy and it's added autonomy. It's **given our engineers the tools they need** to put their thoughts into parts."

Eric Mertz, CEO  
Caldwell Manufacturing

## Business Benefits

For a long time, tangible business benefits of investing in 3D printing were lost in the hype surrounding the technology. As the products have matured, here are three ways we've identified that metal 3D printing helps your bottom line.



### Get products to market faster

#### Why limit your ability to generate revenue with long product development cycles?

Iteration is the most important part of product development – more iterations make your product better, but too many cause you to miss deadlines and lose revenue. While a lot of work goes into each iteration, much of the time is spent on waiting. Waiting decreases the number of iterations that you can make and the risks that you can take.

Metal additive manufacturing is purpose built to accelerate product development. With a metal 3D printer, you can quickly and affordably prototype functional parts. Once your design is locked, this technology can help to produce tools, fixtures, and other parts that get you making production parts faster. In some cases, they can print low-volume end use parts, which eliminates manufacturing spin-up time altogether.



### Reduce manufacturing costs

#### Why spend extra money on inflexible manufacturing processes?

Manufacturing is expensive — it requires skilled labor, advanced machines, and custom tooling all working in tandem to effectively produce parts. Optimized manufacturing lines are efficient but often inflexible. In other cases, machines are stuck producing tooling and other non-revenue-generating parts, while skilled labor is triaging problems instead of making new parts.

Metal 3D printing increases your flexibility in manufacturing and allows you to spend more time producing revenue generating parts. Whether it's producing tooling and fixtures, mitigating unplanned downtime, or automating simple tasks, these machines will help you leverage your resources to produce parts more affordably.



## Replace inefficient manufacturing workflows

### Why commit time and labor to accomplish tasks that are poorly optimized?

Inefficient manufacturing workflows — like complex purchasing processes, unexpected downtime, third party manufacturers, and extended fabrication queues — create problems that extend through an entire organization. Simple logistical problems can wreak havoc.

Metal additive manufacturing will help you become a more dynamic, responsive organization. Utilizing a metal 3D printer enables you to compress product timelines and reduces the labor, time and money between a CAD design and a functional part. Parts can be digitally, stored, updated, and then printed on-demand in a seamless, intuitive workflow.

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## Technical Benefits

The technical benefits of metal additive manufacturing expand far beyond the capability to create ultra-complex parts. They come from manufacturing challenges that metal 3D printing is better suited to tackle than conventional fabrication methods. Companies that successfully adopt additive manufacturing apply its unique advantages to the challenges that they face.



### Design geometrically complex parts

#### Why let your designs be limited by traditional manufacturing constraints?

Unlike conventional manufacturing, additive manufacturing is cost-independent from part complexity. Compared to subtractive CNC machines, it's more adept at curved, natural shapes and intricate geometries. As a result, complex parts are cheaper, easier, and faster to produce with a metal 3D printer.

Metal 3D Printers are uniquely suited to fabricate complex parts. From the ultra-complex to process-optimized, they can print everything from generatively designed structures to custom cooling channels.



### Manufacture parts without tooling

#### Why manufacture tooling or fixturing if you don't have to?

Many traditionally manufactured parts require custom tooling and fixtures. These parts, while critical to the manufacturing process, occupy manufacturing bandwidth without generating revenue. For low volume production parts in particular, tooling costs can make fabrication cost-prohibitive.

No custom tooling or fixturing setups are needed to run a metal 3D printer, regardless of the parts you print. This reduces overhead costs associated with manufacturing and produces low-volume parts more quickly and affordably.



### Produce parts without detail drawings or CAM

#### Why spend time generating drawings and programming CAM if you don't have to?

Machined parts require drawings, CAM, or both — 3D printed parts do not. Metal 3D printing software automatically generates and executes the tool paths required to build your part. Instead of generating drawings and programming CAM, all you have to do is orient a part and select materials and basic print settings.





In addition to automatically generating toolpaths, most metal 3D printers require little-to-no supervision while fabricating parts. You can go from design to part with shorter lead times and less labor.

# Types of Metal 3D Printers

Did you know that most metal 3D printers use powder metal media? The key differences between printer types come down to the processes by which these machines transform powder into solid metal parts. From using high energy lasers to extruding bound metal powder filament, each printer type has a very unique process with its own set of advantages and weaknesses.

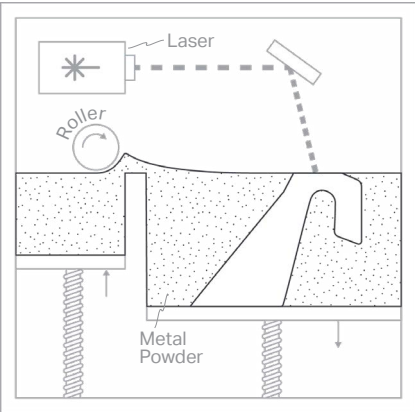
In this section, we'll be covering the four most common types of metal 3D printers.

- 1. Powder Bed Fusion
- 2. Direct Energy Deposition
- 3. Binder Jetting
- 4. Bound Powder Extrusion\*

Technology	Maturity	Cost (\$)	Facility Requirements	Part Size	Precision
<b>Powder Bed Fusion</b>	High ●●●	500k - 1M+ \$\$\$	Powder management, ventilation, post-processing equipment (CNC, EDM, HIP, heat treatment)	2mm - 350mm 	High ●●●
<b>Direct Energy Deposition</b>	High ●●●	400k - 2M+ \$\$\$	Powder management, ventilation, post-processing equipment (CNC, surface finishing, heat treatment)	50mm - 2000mm 	Low ●●●
<b>Binder Jetting</b>	Low ●●●	300k - 2M+ \$\$\$	Powder management, batch sintering solution, post-processing equipment (surface finishing, heat treatment)	1mm - 150mm 	High ●●●
<b>Bound Powder Extrusion*</b>	Medium ●●●	150 - 200k \$\$\$	Basic ventilation (not for metal powder), post-processing depending on use case (CNC, heat treatment, surface finishing)	10mm - 250mm 	Medium ●●●

\*Markforged produces machines that use Bound Powder Extrusion to 3D print parts.

# Powder Bed Fusion



Powder Bed Fusion is the most mature type of 3D printing, and the standard around which other technologies are benchmarked. These machines use a high power energy source (usually a laser) to selectively melt loose metal powder. They can create precise, intricate geometries, but often require time and iterations to properly calibrate each part for the process.

**Technologies:**  
Selective Laser Melting (SLM)  
Direct Metal Laser Sintering (DMLS)  
Electron Beam Melting (EBM)

**Technology Maturity:**  
High: Well proven with design standards and significant material variety available

**Acquisition Cost:**  
\$500k - \$1M+

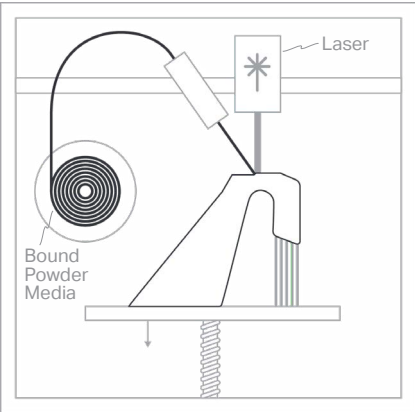
**Facility Requirements:**  
Powder management, ventilation, post-processing required (CNC, EDM, HIP, heat treatment)

**Recommended Part Size:**  
2mm - 350mm

- Pros:**
  - Diverse selection of machines and materials.
  - Process can fabricate intricate and complex geometries.
  - Once process is dialed in, can produce high-quality parts repeatably.
- Cons:**
  - Expensive to set up and labor-intensive to operate.
  - Parts **require** post treatment, and warping or cracking is common. It may take multiple iterations and significant post-processing to yield a successful part.
  - Parts are welded to the build plate and must be removed with EDM or bandsaw. Supports material also must be cut or milled off.
  - Loose metal powder can be dangerous and requires significant training to handle. Swapping materials requires hours of labor.

**Verdict:**  
While the printers are powerful and able to handle the most complex projects, their high cost to purchase and operate make them an option only for industrial users in markets where users demand high complexity or highly specialized materials.

# Direct Energy Deposition



Direct Energy Deposition (DED) machines use metal feedstock (powder or wire) and a laser to fabricate parts. Unlike powder bed fusion, the media is dispensed through a print head as while simultaneously being sintered by a laser. Powder DED is slightly faster and less accurate than powder bed fusion, but can be used in a variety of innovative ways. Wire DED is uncommon, but can be used to produce rough shapes of very large parts quickly. Both technologies are relatively niche when compared to Powder Bed Fusion.

**Technologies:**

Powder DED  
Wire DED

**Technology Maturity:**

High: Proven technology with a well-documented niche

**Acquisition Cost:**

\$400k - \$2M+

**Facility Requirements:**

Powder management, ventilation, post-processing required (CNC, surface finishing, heat treatment)

**Recommended Part Size:**

50mm - 2000mm

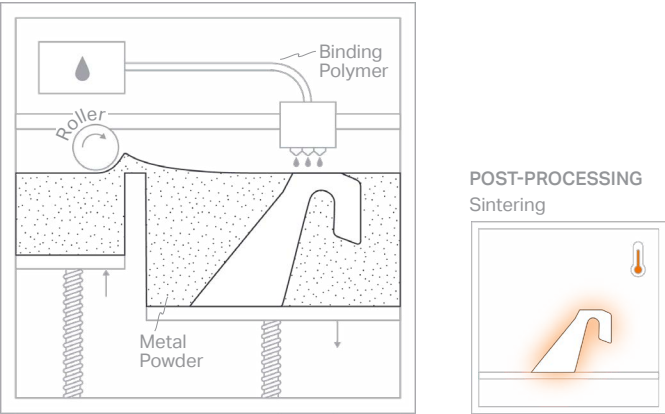
- Pros:**
- DED significantly faster than Powder Bed Fusion printers thanks to large nozzles and fast powder flow rates.
  - Wire DED systems are the largest, fastest printing types of 3D printers.
  - DED systems can be mounted on robotic arms and 5 axis gantries, allowing them to be used to dynamically add material on different planes.
  - In addition to fabricating parts from scratch, DED printers can also dynamically repair or "heal" broken parts.
- Cons:**
- Powder DED machines are less accurate than Powder Bed Fusion machines and Wire DED machines are extremely imprecise.
  - Loose metal powder can be dangerous and requires significant training to handle.
  - Expensive to set up and labor intensive to operate.

**Verdict:**

With many of the same pain points as the Powder Bed Fusion but less precision, it's still a largely industrial choice appropriate for those with specialized needs, like large parts, multi-planar printing, or dynamic part repair.



# Binder Jetting



This high throughput, high fidelity method of metal 3D printing fabricates parts very quickly and is capable of batch production. It uses specialized liquid polymer binders to adhere loose metal powder together, which creates lightly bound parts that can be sintered in batches. Though it has massive potential as a production 3D printing solution, Binder Jetting is still an immature technology — key questions remain about part accuracy, quality, and repeatability.

**Technologies:**  
  
Binder Jetting  
Metal Jetting

**Technology Maturity:**  
  
Low: Few systems in circulation and key technical questions unanswered

**Acquisition Cost:**  
  
\$300k - \$2M+

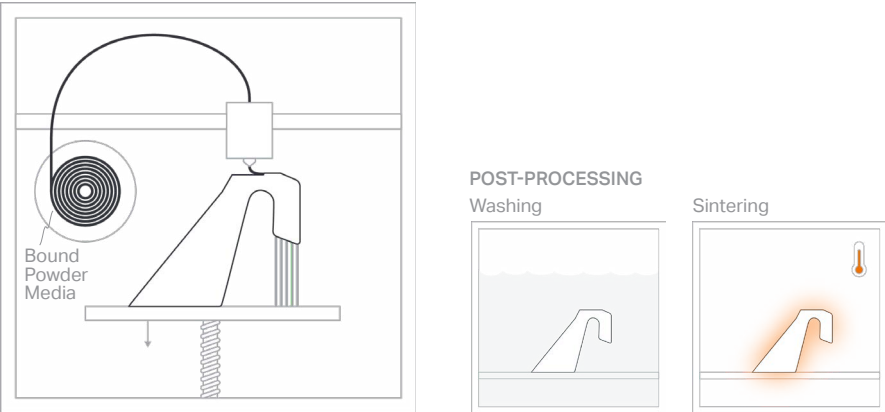
**Facility Requirements:**  
  
Powder management, batch sintering solution, post-processing recommended (surface finishing, heat treatment, etc.)

**Recommended Part Size:**  
  
1mm - 150mm

- Pros:**
  - The process uses no lasers, meaning it requires less energy and typically offers more affordable per unit build volume than Powder Bed Fusion.
  - By using an inkjet-style print head to quickly adhere layers together, Binder Jetting machines can achieve higher throughput than other methods.
  - Process can yield highly complex/intricate geometries, and does not require mechanical separation from build plates.
- Cons:**
  - Powder management requires significant resources.
  - Accuracy, density, and repeatability are still unproven.
  - As-printed parts are extremely fragile before sintering

**Verdict:**  
  
Binder Jetting has massive potential as a method of 3D printing mid- to high-volume metal parts, but is extremely unproven. It's cheaper than Powder Bed Fusion, but still uses loose powder. Expect to see significant development in the next 3-5 years.

# Bound Powder Extrusion



Also known as Atomic Diffusion Additive Manufacturing or ADAM\*, the Bound Powder Extrusion process uses no loose metal powder, but rather feedstock made from metal injection molding media (metal powder bound together in waxy polymers.) Bound Powder Extrusion systems use a debinding system and a sintering furnace to turn printed parts fully into metal. Due to their low cost and ease of use, Bound Powder Extrusion machines are a great fit for a wide variety of manufacturing applications.

**Technologies:**

Metal FFF  
Atomic Diffusion Additive Manufacturing (ADAM)\*

**Technology Maturity:**

Medium: Technology is proven for many applications and is still maturing

**Acquisition Cost:**

\$150k - \$250k

**Facility Requirements:**

Ventilation for wash and sinter, post-processing for some parts (heat treatment, CNC, surface finishing)

**Recommended Part Size:**

10mm - 250mm

- Pros:**
- Significantly more affordable to own and operate than other metal printers.
  - Can be used effectively with minimal training.
  - High yield — parts are usually successful on the first print.
  - Bound powder filament is safe — usage is similar to a standard FFF 3D printer.
  - Wide material availability with many more materials in development. Capable of printing pure copper, which isn't possible with powder based technologies.
  - Parts can be printed with open cell infill, reducing part weight.
- Cons:**
- Relatively low throughput relative to other systems.
  - Minimum part size and part intricacy are constrained by nozzle diameter.
  - Large, blocky parts can have extended debinding or "wash" times.

**Verdict:**

While they have limited throughput, Bound Powder Extrusion machines are far more affordable than any other major metal 3D printing system. Its low cost and ease of use makes it the most accessible option for a wide variety of industries.

\* Markforged produces machines that use Bound Powder Extrusion to 3D print parts. Atomic Diffusion Additive Manufacturing is a Markforged branded phrase.

# Metal 3D Printing Materials

As metal printing has matured, more and more materials have become available to print. Materials that are advantageous to print are typically difficult or expensive to otherwise fabricate, or hold unique material properties that are specialized for high-value operations. In this section, we take a look at the five most common material groups.

## Steel

Steel is the most common metal used in 3D printing. Its excellent material properties, versatility, and broad use in precision manufacturing make it an excellent option for printing high quality parts. Most types of steel can be printed, but the two types most commonly used are stainless steels and tool steels — metals that are more expensive and difficult to fabricate conventionally.

### Positive attributes:

- Excellent strength and stiffness
- Wide variety of material properties
- Heat treatable

3D printed stainless steel grippers are used to operate an automated bending cell. ►



- **Stainless steels** are strong, stiff steels that possess excellent corrosion resistance due to their significant chromium content (at least 12%, often up to 18%). Two types of stainless steels are commonly printed: austenitic and martensitic.
  - **Austenitic stainless steels**, the most common type of stainless steels, are corrosion resistant and can be both machined and welded, though they cannot be heat treated. **316L** is common 3D printed stainless steel known for its superior corrosion resistance.
  - **Martensitic stainless steels** are much harder than austenitic steels, but more brittle and less corrosion resistant. **17-4 PH** is a martensitic stainless steel that can be heat treated to fit a variety of material properties and is broadly used throughout manufacturing.
- **Tool steels** are named for their central application – tooling of all varieties. They contain carbide, an extremely hard compound that's critical to their ability to cut, grind, stamp, mold, or form. Generally, they're very hard, abrasion resistant, and many are usable at high temperatures. The three types most commonly metal 3D printed are A series, D series, and H series tool steels.
  - **A Series** tool steels are great general-use, machinable tool steels that balance wear resistance and toughness. There are eight varieties of A Series tool steels, the most common of which is **A2**. It's a versatile, cold-work tool steel often used to make punches and dies, as well as a wide variety of other applications.
  - **D Series** tool steels are optimized for wear resistance and hardness. They're not particularly tough and are only used for cold work applications. The most common variety of D Series tool steel is **D2**, a cold-work tool steel used for all kinds of cutting tools, from blades to industrial cutting tools and knives.
  - **H Series** tool steels cut and shape material at high (or cycling) temperatures. **H13** is the most common 3D printed hot-work tool steel. Its mix of excellent toughness, wear resistance, and heat resistance make it a good general use tool steel that's optimized for use in high temperatures.

## Superalloys

Metal 3D printing differentiates itself by being able to fabricate high-value alloys at relatively low costs. Often difficult and expensive to machine, 3D printing enables companies to produce high-performing parts more affordably than subtractive methods.

Superalloys thrive in adverse environments — places with high heat, corrosive chemicals, or both. Though there are many printable superalloys, the two most common groups are Inconel and Cobalt Chrome.

### Positive attributes:

- Excellent mechanical properties
- Heat resistant
- Good surface stability
- Corrosion resistant
- Biocompatible (Cobalt Chrome only)

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### ► Inconel

The most common proprietary nickel alloy group is Inconel. This extremely strong, tough, and corrosion-resistant material is used in turbines, engine seals, and rockets. The two formulations most used in 3D printing are the stronger, tougher **Inconel 718** and the more heat-resistant **Inconel 625**. Both are expensive to machine conventionally, making 3D printing a cost-effective alternative.

### ► Cobalt Chrome

This superalloy is known for its biocompatibility, high strength-to-weight ratio, and corrosion resistance; it's essentially a higher grade, denser, more expensive version of Titanium. Like Inconel, it's used in turbines and other hostile environments but can also be used in medical applications for which Inconel isn't suitable including orthopedic and dental implants.



*3D printed inconel parts are prized for their high temperature resistance.*

## Titanium

While not a common material used in conventional fabrication, titanium's strength to weight ratio and high cost (both material costs and machining costs) make it a great choice for 3D printing. Titanium is typically printed in two different varieties: Titanium alloys and pure Titanium (known as CP Ti).

### Positive attributes

- Strength-to-weight ratio
  - Heat resistant
  - Chemical resistant
  - Biocompatible (process and alloy dependent)
- 

#### ► Titanium Alloys

Titanium achieves its best mechanical qualities when alloyed with other metals. The most common titanium alloy is **Ti64 (Ti-6Al-4V)** — a material stronger and 40% less dense than 17-4 PH stainless steel. It excels in corrosive and high temperature environments. These traits make it a top choice in industries where high strength-to-weight ratio is valued, like aircraft and high performance vehicles.

#### ► Commercially Pure Titanium (CP Ti)

Pure titanium isn't as strong as most titanium alloys, but it's highly biocompatible. It's used for orthopedic inserts and similar medical applications.



*3D printed titanium parts are often used in aerospace and automotive applications where low weight and high strength are valued.*



## Copper

Copper presents a completely unique value among 3D printable metal materials — it's used for its thermal and electrical conductivity instead of its mechanical properties. Metal 3D printing allows engineers to create geometrically optimized copper parts like heat sinks, welding arms, and bus bars for a far lower cost.

There are only a few systems capable of printing any version of copper today. Copper can be printed in its pure form or more commonly in its alloyed form.

### Positive attributes:

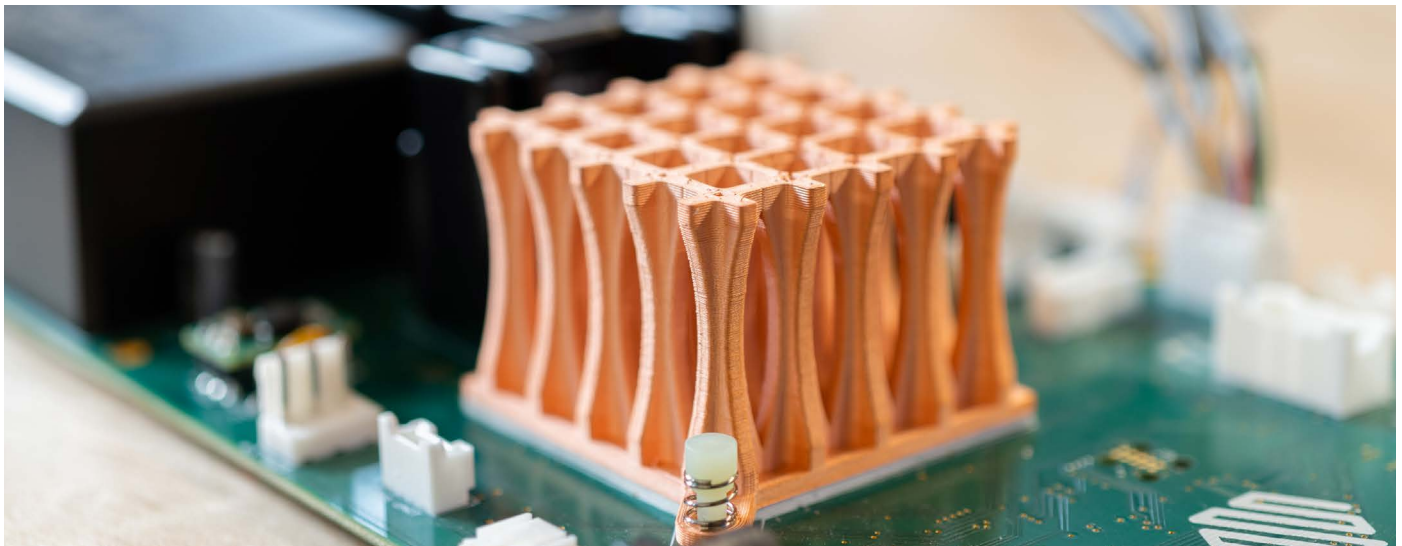
- Electrically conductive
  - Thermally conductive
  - Corrosion resistant
  - Ductile
- 

#### ► Pure Copper

Pure copper has the best thermal and electrical conductivity of any copper alloy, making it the preferred option. However, due its high conductivity and high laser reflectance, copper is incompatible with standard laser based systems. Pure copper is only available on Bound Powder Extrusion machines.

#### ► Alloyed Copper

Alloyed copper typically contains 1-2% of alloying elements, which make it printable on some Powder Bed Fusion machines. These alloys, while still relatively conductive, are inferior options to pure copper. An example of printable alloyed copper is **C18150**, an alloy with chromium and zirconium.



3D printed pure copper is prized for its heat and electrical conductivity, and is used for complex parts like heat sinks.

## Aluminum

Aluminum, while used in some metal 3D printers, is seen far less in 3D printing than in conventional manufacturing processes. Its scarcity in metal 3D printing is due to two factors: low printability and relatively low costs in conventional fabrication. As a result, the potential ROI for 3D printed aluminum parts is often not worth the trouble of printing them.

Most common Aluminum alloys – like 6061 and 7075 – are not printed. Instead, Powder Bed Fusion machines that print aluminum typically print softer, casting grade aluminums. These casting grade alloys contain up to 12% silicon by weight and have inferior mechanical properties.

### Positive attributes:

- Low weight
  - Durable
  - Ductile
- 

### When will aluminum become more widely available for 3D printing?

Because the value of printing is relatively low, it's not clear when it will become commonplace in 3D printing. Until then, titanium and steel provide similar strength-to-weight ratios when printed with open cell infill, while continuous composite 3D printers can produce near aluminum strength parts for a fraction of the cost.



*Aluminum is rarely printed due to its high machinability and low printability.*

# Applications

The most common question that people interested in metal 3D printing have is pretty simple “What should I print?” The answer isn’t simple — in truth, leveraging a system like a metal 3D printer is more about identifying your pain points and using its versatility to address them. However, there are four distinct groups that metal 3D printed parts tend to occupy:

- Functional metal prototypes
- Tooling and fixtures
- Low-volume production
- Legacy and replacement parts



## Functional Metal Prototypes

Prototyping is both a critical part of the R&D process and a giant resource sink. Prototypes are by nature low-volume and often complex — features that create high cost and long lead times for conventional manufacturing processes. This issue compounds if tooling is required or a specialized material is needed. As a result, engineers are often forced to decide between delivering a great product slowly or a mediocre product quickly.

Metal 3D printing offers a way to quickly produce metal prototypes without tooling. Engineers can have a wide variety of metal parts in hand in a matter of days, helping evaluate designs more quickly while avoiding expensive tooling development or rework. With metal additive manufacturing, engineers can accelerate their time-to-market by testing more designs in a shorter period of time.



## Tooling and Fixtures

While some tools are mass produced, many hit the sweet spot for metal printing — complex, low volume parts. Traditionally expensive to produce and carrying long lead times, a poorly run tool room can delay manufacturing while incurring massive costs against your bottom line.

Metal 3D printing allows manufacturers to bypass steep overhead costs and create custom tools at a low cost per part. Instead of waiting months for tools, you can have them in hand in days. In addition, metal 3D printing can be paired with carbon fiber 3D printing to create hybrid tools, which leverage the benefits of both processes to create higher-performing tools.



## Low-Volume Production

For some geometries, metal 3D printing is the most affordable (or only) way to fabricate low volume end-use parts. Determining what end-use parts are smart to produce with 3D printing usually depends on three factors:

- **Materials:** Some materials (superalloys, titanium, and tool steels particularly) carry high fabrication costs. Metal 3D printing material costs are more stable across materials, so printing parts can be hugely advantageous.
- **Complexity:** Complex geometries can be expensive or even impossible to fabricate. 3D printing opens up a new method to make these parts, and can be the best solution.
- **Volume:** For large-scale production, 3D printing is still not economically viable. However, depending on the process you’re using (binder jetting can produce at higher volume than other processes), low/medium-volume production can be cheaper using 3D printers than conventional processes.



## Legacy and Replacement parts

Legacy parts are components that are no longer in production. Replacement parts are low-volume parts kept in inventory. In both cases, the need to create low-volume parts affordably and quickly creates an opportunity for metal 3D printers. Additive manufacturing gives you the opportunity to print these legacy parts without tooling or machine programming costs, making it affordable to make an otherwise expensive one-off part.



# ROI for Metal 3D Printers

While metal 3D printers carry incredible hype, the most important factor in determining whether or not to purchase one is its potential value-add to **your business**. In this section, we'll show how to better understand ROI for metal 3D printers and calculate a time to financial ROI.

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## How to Calculate Financial ROI

Financial ROI will tell you approximately how long it will take for a new machine to create enough value to offset its acquisition costs.

**First, start with acquisition costs. These include:**

1. The purchase price of the machine.
2. Facility upgrades.
3. Cost of machine shipment and installation.
4. Cost to warranty and maintain the machine, plus replace parts, as needed.
5. Cost to train your workers, which is separate from fixed costs but important.

Depending on your unique facility needs and the type of printer you choose, acquiring a metal printer can cost anywhere from \$150,000 to more than \$1 million.

**Next, calculate an average operating cost savings per unit time.** This should be measured against your current process and adjusted/averaged over time. Use these steps to start.

6. Pick a part that represents what you would commonly print with the machine.
7. Determine cost per part by getting a part quote from a 3D printer OEM.
8. Estimate the cost to produce the same part with your traditional methods at your typical manufacturing volume.
9. Calculate cost savings per unit time by subtracting the printing cost from fabrication cost with a standard method. Divide that number by fabrication time.
10. Now, take the overall machine cost and divide it by the cost savings per unit time we found in step 4. The number you get will be the amount of time it takes to pay for the new metal 3D printing machine.

### ► EXAMPLE

#### Shukla Medical

Shukla Medical predicted that a Markforged Metal X would pay for itself in less than two years if they used it to in-source prototyping operations.

**Acquisition Costs:** All in, the Markforged Metal X system cost Shukla between \$150k and \$175k. This included the full system, installation, warranty, and small facility changes.

**Cost Savings:** By replacing their overseas prototyping operation with parts printed on their Markforged machine, they calculated they could save around \$1,000/prototype at a volume of about 10 per month. Based on this, they believed the monthly savings would be about \$10k/month.

**ROI:** Based on costs and savings accrued over the first year of owning their machine, Shukla is on track to achieve ROI in about 18 months. Their calculations have proven accurate, and they've found other ways to generate value with their printer.

"We either would send it out of house to a third-party vendor or Protolabs or just another machine shop, and that's fine, except it's usually pretty expensive — **high machine costs drove us to get a Metal X.**"

**Zach Sweitzer, Product Development Manager**

[Shukla Medical](#)

## Indirect ROI

Financial ROI will give you a bulletproof case for acquiring a metal 3D printer. However, ROI based on part costs only tells part of the story. Leveraging a metal 3D printer can benefit your organization in a wide variety of tangible ways.

### ROI can go beyond financial investments.

Additional benefits that extend beyond traditional cost- and time-value calculations include:

- Decreasing part lead times: In addition to decreasing part cost, 3D printing also delivers parts at much shorter lead times. This can speed iteration, get products to market faster, and increase uptime.
- Decreasing labor to make parts: Some 3D printers require much less labor than conventional machines. Save CAM programming time, operator time, and engineering drawing time (for parts that do not need drawings for tolerances) by printing parts.
- In-sourcing parts gives you more control: Outsourcing saves labor, but can introduce uncertainty into a fabrication process. Bringing fabrication in house gives you control.
- New fabrication capability: 3D printing parts can enable higher-performing designs and new parts that can't be made traditionally.

Brainstorm the ways you might use metal 3D printing to solve those problems that you can't easily assign a financial benefit. Then, add it to your demonstrated financial ROI from the previous page.

### ► EXAMPLE

#### Shukla Medical

In addition to building a strong financial case for their new metal 3D printer, Shukla found acquiring a machine allowed their R&D department to run more efficiently.

##### **Decreased Lead Times:**

Faster lead times allowed Shukla engineers get their products in the hands of surgeons faster, iterate more, and deliver products to market faster.

##### **In Sourcing:**

Bringing fabrication in-house allows Shukla greater control over what's getting made when, as well as greater freedom to explore new parts and make one-offs.

"Being able to prototype more efficiently and **get finished products to market more quickly** will keep us on the forefront of the industry."

**Zach Sweitzer, Product Development Manager**

**Shukla Medical**

# Maximizing Your Investment

Metal 3D printers fabricate parts in a fundamentally unique way. To maximize their value, you must learn how to use your 3D printer to replace traditional fabrication methods. We've identified three things that are critical to learn when adopting metal 3D printing.

- Parameters and capabilities of the printer
- Design for additive manufacturing (DFAM)
- Digital inventory and file management

Learn these, and you'll be on your way to leveraging additive manufacturing to improve your organization.

**"I was afraid that 3D printing would make my job harder** and I was going to have to learn a lot more and different things. **But in reality, it's changed things for the better** because now I can create a lot of things I couldn't create before."

Pat Milligan, Senior Model Maker, [Caldwell Manufacturing](#)



## Machine Parameters and Capabilities

Each printer type uses a different technology, but at a high level, the 3D printing process is the same: slicing a CAD file into discrete layers and then building that part layer by layer.

The specifics of the format of the printer — its construction, what it's made of, and the quality of its components — factor in the quality and scale of the parts it can produce. Becoming familiar with these parameters from the onset will guide you in developing a plan for how you'll produce parts and what changes will be made to your process.

Even understanding how long a part will take to make is important. Is it best to produce a part in the morning? Or over the weekend? A solid knowledge of your printer will help you answer these questions, too.



## Digital Inventory and File Management

A distinct advantage that metal 3D printing has over other methods is that parts can be economically printed on-demand. Instead of amassing inventory costs storing parts in a warehouse environment, digital inventory allows for the part design and specifications to be held in the cloud, only utilized when they're needed to fabricate a part.

Those using a digital inventory enjoy lower overhead costs and a more flexible manufacturing workflow, free of warehousing and conventional inventory management. Those looking to add metal 3D printing to their process can begin thinking about how digitization of their components should happen, even before the part in question fails or needs to be manufactured.



## Design for Additive Manufacturing

Manufacturing process is the second largest influence on how a part is designed (after functional requirements). As a result, changing the process by which a part is manufactured can significantly influence the optimal design. What happens when we move from subtractive methods to additive methods? The optimized part design changes. Not all parts require design alterations, but approaching designing parts in a way that takes into account the metal 3D printing process will give you a distinct advantage.

Can the part be balanced differently? Can a subassembly be consolidated into fewer parts? How will the assembly differ? 3D printing changes how parts are made, and optimizing around its process opens up a new field of possibilities.

# The Markforged Advantage

## Range of industrial-grade materials

From stainless steels and tool steels to superalloys like Inconel to copper, the Metal X platform supports a wide variety of easy-to-change materials. Our materials are optimized to support many applications and verticals. Stainless steels are great general-use materials, whether they be stronger (17-4 PH) or more ductile and corrosion resistant (316L). Tool steels provide hardness (D2), extreme durability (A2), and stability in high and cycling temperatures (H13). Inconel 625 is strong, stable in high temperatures, and extremely corrosion resistant. Titanium 64 has best-in-class strength-to-weight ratio, while Pure Copper conducts heat and electricity better than any 3D printable alternative.

These materials are all useful individually, and together they form a toolbox to innovate with. All Markforged customers benefit from our continuous development of metal materials.

## Designed for great part quality

Markforged's Metal X Bound Powder Extrusion additive manufacturing solution is comprised of three machines purpose built to industrial grade standards.

Every design decision made for the Metal X system had two goals in mind: producing the highest quality part and enabling the best customer experience. A systems level approach is required to truly deliver great part outcomes. Due to this, Markforged combines best-in-class software, materials research, and a 4th-generation motion system to deliver industrial-grade parts. Key parameters that impact part outcomes include: print pathing and accuracy, input material composition and particle size, sintering process temperature and hold time, and sintering atmosphere in the furnace.

## Affordable, safe, and easy to use

The Metal X has significantly lower acquisition and operation costs than all other types of metal 3D printers. All in, a Markforged Metal X system will cost you between \$150,000 and \$200,000 to acquire — between 5 and 10 times more affordable than other systems. They require minimal facility upgrades, no powder management system, and no dedicated operator.

All metal 3D printers have a learning curve, but the Metal X is purposefully designed to be easy to use. Paired with our cloud-based software, you can upload, slice, print, and post process parts in an integrated workflow. Markforged provides material cost estimates through our software and incorporates fail safes and redundancy throughout the process.



MARKFORGED METAL X SYSTEM  
Wash-1, Metal X, Sinter-2

“The **Metal X** system allows us to make parts faster, reduce lead time, know exactly when we can deliver, go further with the design. And cost-wise, **it was very much a no-brainer.**”

Louis Croisetiere, Ph.D, Founder

[Nieka Systems](#)

## Take the first step in acquiring a metal 3D printer today.

The Metal X system is a safe and affordable metal additive manufacturing solution that is up to 90% less expensive than alternative metal additive manufacturing technologies, and 95% faster and cheaper than traditional fabrication techniques like machining or casting. By printing metal powder bound in a plastic matrix, Markforged has eliminated the safety risks associated with traditional metal 3D printers, while enabling new features like closed-cell infill for reduced part weight and cost. The Metal X comes equipped with powerful cloud-based software that manages printers, active jobs, materials, and error detection to make it the simplest way to manufacture metal parts.

Visit [markforged.com/metal-x](https://markforged.com/metal-x) to learn more about how the Metal X can support your business today.