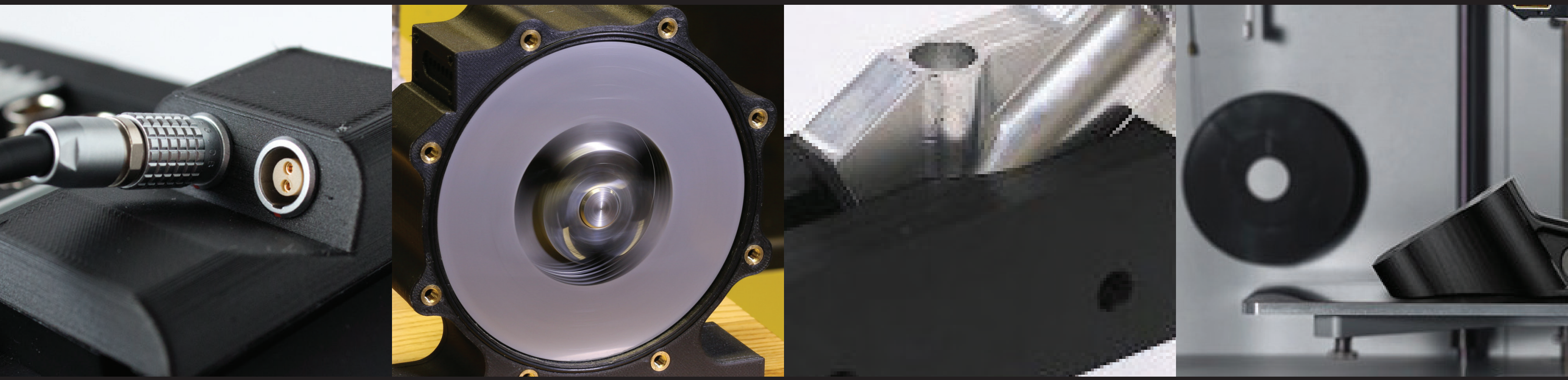
Markforged

The Economics of 3D Printing

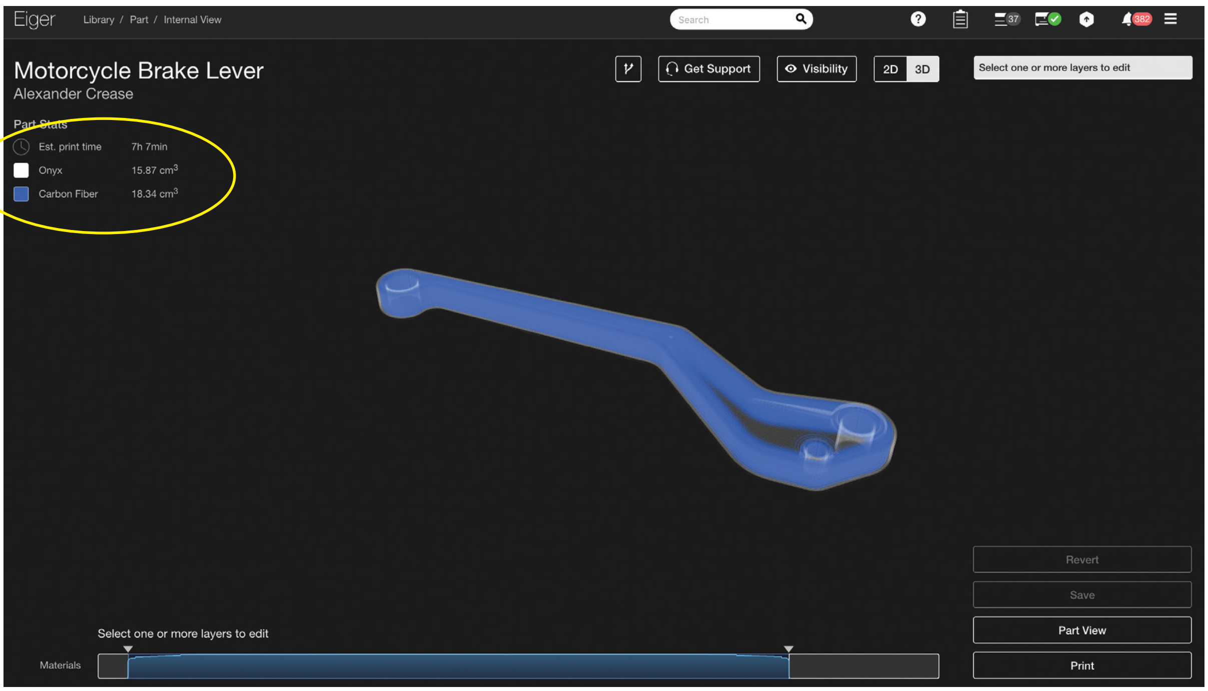


3D printing is advancing into the realm of production, both in terms of work-holding to assist in machining operations and custom end-use parts. While the value of a printer may not seem apparent at first, executing the calculations will tell a different story. In production and manufacturing, productivity is directly tied to revenue and performance. By offloading manufacturing and therefore costs from production machines or services to on-site rapid manufacturing machines, you can save money as calculated by a Return On Investment (ROI). The Return On Investment is an evaluation tool used to calculate the return you have achieved on an investment by percentage. This can apply to manufacturing technologies to help determine how much you can save by using something like a 3D printer. While the price of a production quality 3D printer may sound steep, it is the money you are saving by eliminating "routine" product manufacturing costs like work-holding, prototyping, and tooling costs that can make the printer worth the investment. Below, we outline the steps you can take to calculate the ROI for a 3D printer. The Markforged Mark Two, a high-strength 3D printer that reinforces plastics with continuous fibers. A similar procedure can be used for other 3D printing platforms.

Finding your ROI

1 Calculating the Cost of Your Printed Part

The first step to determining the ROI of your 3D printer is calculating the cost of materials per part. Markforged's Eiger software provides material estimates to simplify this process. In this paper, a carbon fiber reinforced brake lever printed on the Mark Two 3D Printer is analyzed. As shown, it uses 13.16 cubic centimeters of Onyx and 17.30 cubic centimeters of carbon fiber.



The internal view of our motorcycle brake lever sample part.

The cost and volume per spool of each material can be found on our [materials page](), and with this information we can find the price per cubic centimeter:

For Onyx, spools currently cost \$190 for 800 cc, or \$0.24/cc.

For Carbon Fiber, spools currently cost \$150 for 50 cc, or \$3.00/cc.

With the following equation the material cost can be determined.

(cost per cc of plastic) X (volume of plastic)
+ (cost per cc of fiber) X (volume of fiber) = Total Cost
(\$0.24 /cc)(15.87 cc) + (\$3/cc)(18.34cc) = \$3.81 + \$55.02 = \$58.83

The total cost of this brake lever is $58.83. Much of that expense comes from continuous carbon fiber, which reinforces this brake lever to be just as strong as metal — an affordable price for something this strong. However, not all parts need to be packed with carbon fiber just to achieve that strength. Efficient fiber routing can reduce costs and print time, and different material combinations will achieve different results.

One of the valuable advantages of a Markforged printer is its versatility. With different fibers, you can achieve different material properties. For example, fiberglass, one of our other continuous fiber options, is still a strong and robust material but ends up being heavier and less stiff. Fiberglass is a more cost effective option at $1.50/cc if a high strength-to-weight ratio is not necessary. With the same file and fiber routing optimized for fiberglass, the numbers change a bit:

($0.24 /cc)(14.07 cc) + ($1.50/cc)(13.61 cc) = $3.38 + $20.42 = $23.80*

$35.03 is saved with continuous fiberglass reinforcement and similar strength. By understanding the strength properties your part needs, you can use the continuous fibers efficiently to cut down on costs. Parts don't have to be packed with carbon fiber to meet the necessary strength needs of your product. You can use the geometry and loading conditions to optimize fiber routing throughout your part. For example, if you only need to resist bending in one plane, use a sandwich panel instead of filling every layer with fiber, as explained here. These techniques allow further cost reduction for getting robust, beautiful, and precise parts.

*The material consumption for a part reinforced with fiberglass differs from that of carbon fiber because selecting a different fiber affects print settings and material usage

2 Determining Costs of Alternate Production

Now that the final cost of $55.06 is determined, it's time to compare that cost to those of other manufacturing methods. This brake lever is normally CNC milled. For quantities under 100, the per unit cost is $195.95. For quantities over 100, the per unit cost is $117.11 and further decreases in bulk quantities. These costs may vary depending upon the machining service or method you use. For example, if this part were cast, the initial cost would be extremely high to produce the mold, but the cost per part once the mold is produced would be minimal. If this part were to be machined in house, the cost would not only include material costs but also your company's own manufacturing bandwidth and time devoted to the part.

By comparing the two processes, it is immediately clear that 3D printing is the less expensive option. The difference in price (CNC machining cost per part minus the printing cost per part) is $137.12. However, there is a bit more to it than that. The 3D printer has an initial overhead cost, and the CNC machining service operates only on a per-part basis. This is where many engineers and designers get stuck justifying the cost of a 3D printer. The initial price of our Mark Two is $13,499, while CNC machining a part is only a few hundred dollars each time.

3 Finding Your Break Even Point

The $137.12 you could be saving with each prototype, tool, or product you send to an external machine shop builds up, and you can speculate how many parts it will take to "break even", which means calculating how many parts it will take to make up for the cost of the machine. Assuming you only print this one part, an Enterprise Kit will pay for itself in 98 parts:

$13,499/$137.12 = 98.45

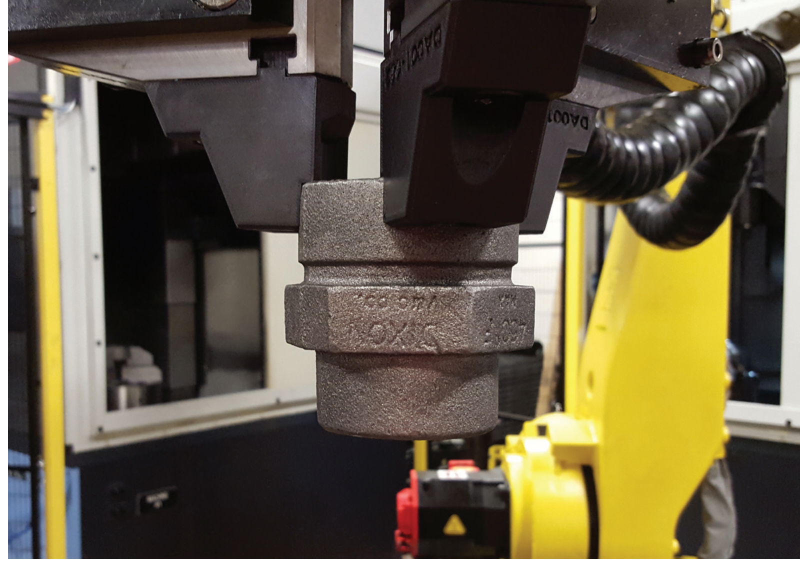
4 Return on Investment: The Value of 3D Printing

3D printing eliminates the overhead manufacturing costs required for every part and every design change. The same brake lever used earlier has a tooling cost of $2,865 for an injection mold prototype. If any modifications are made to that design, that cost must be included with each design change. The price of a 3D printer you only need to pay once, while tooling and prototyping costs are required for every design otherwise. Those overhead costs combined with manufacturing lead time delay the product development cycle make the investment worth it, as some of our customers can attest:

"We're able to take a part that would have cost $400, with two and a half week lead time of machining from one of our local vendors, we printed it over the weekend and the manufacturing floor likes it just as much, if not a little better...and they're using it to this day," says Joe Walters, New Product Design Engineer at Arow Global. "I would estimate that we have seen a full return from printing 5 parts each of 3 different plastic injection molded prototype components, specifically from not having to invest in the soft tooling traditionally used to create injection molded parts."

	Cost	Time
Machine ShopóAluminum	$400.00	420 hours
Printed on Markforged	1.59	1.92 hours

Arow Global was able to save time and money with a Markforged printer



Strength, Beauty, and Precision at a low cost.

5

Calculating Your ROI

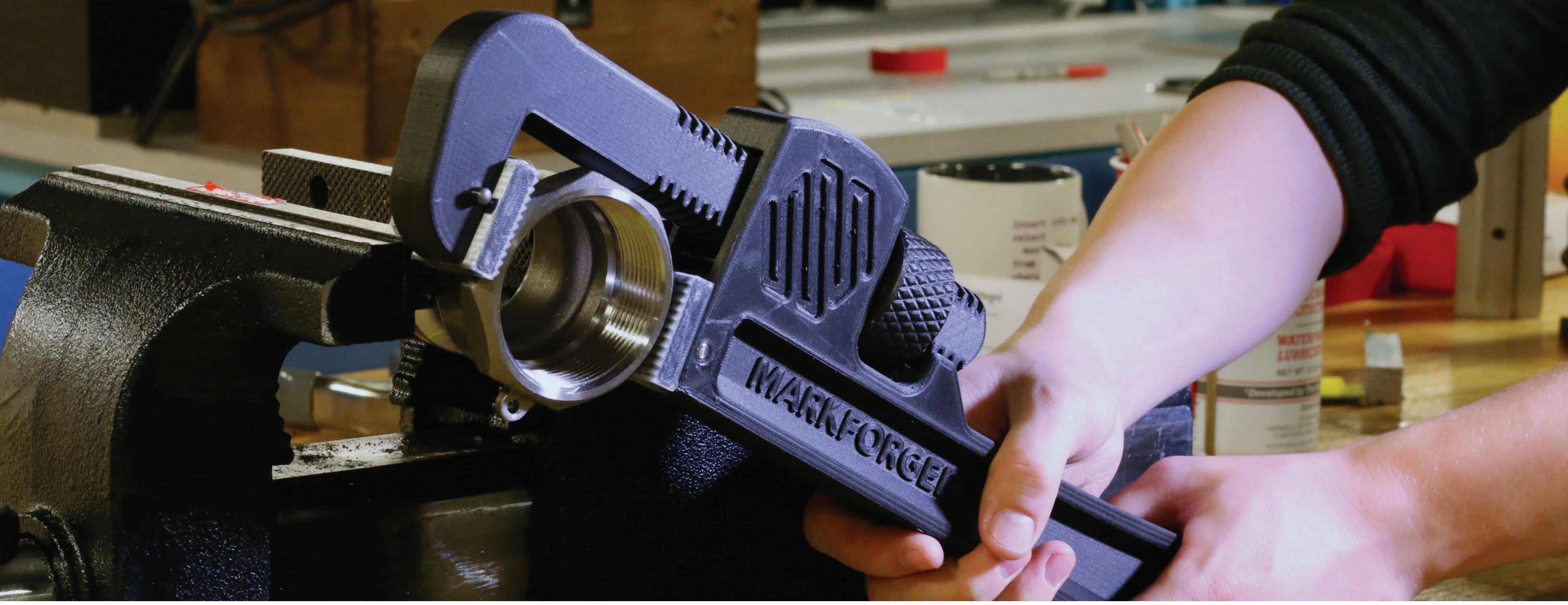
Your ROI can be calculated with information about overhead tooling costs from other fabrication methods and the cost of products your printer may produce. This is a function of the number of prints you actually produce — if you buy a printer only to print one part, it won't be worth the investment. But the more parts you print, with each new design, each iteration, your Markforged 3D printer can push product development to be more time efficient and cost effective.

Let's say you are designing a part to be injection molded using the quote above as an example. With an overhead cost of $2,865 and an individual part cost of $3.46, each design iteration of the part effectively costs $2869.46 to prototype without a professional 3D printer. Knowing this, your ROI can be calculated with the following equation:

ROI = 100% x (Gain From Investment – Cost of Investment)/Cost of Investment

The Gain from Investment in this case is how much money you saved using additive manufacturing over injection molding. If you am working on three different products to fine tune for production, and each product will go through three iterations, that is nine parts each with their own unique mold or machining process. As an abstraction the injection mold quote provided above will be used to calculate the gain from investment. The Cost of Investment is the cost of the 3D printer — in this case, a Mark Two.

Gain from Investment = 9*($2,869.46) – 9*($58.83) = $25,295.67
The ROI can now be calculated:
100%*($25295.67 – $13,499)/$13,499 = 87.3%



This number is the net return achieved from the investment of the printer. From 9 product prototypes, not only has the Mark Two paid for itself and broken even, but also it has returned 87.6% of the cost on top of that as well. This is where the power of additive manufacturing really shines — as 3D printers are mainly used for prototyping and iteration, the cost and time without a rapid prototyping solution adds up, even if the initial investment of a 3D printer sounds steep. With rapid turnaround time and a hands-off process, additive manufacturing can streamline product development cycles by expediting prototyping cost effectively. This gives engineers bandwidth to iterate on the products they are designing, making their workflows more productive and getting products out to market quickly.

With a Markforged 3D printer you achieve an even greater benefit: break past prototyping and 3D print parts strong enough for functional use. Continuous composite fiber reinforcement gives you the agency to manufacture professional, high strength parts. This could mean anything from functional prototypes to validate design geometries and loading conditions to end use parts that can be shipped out to customers. The printer gives the added benefit of eliminating many overhead manufacturing costs and time-sinks by printing parts that can hold up in a machine shop environment: tooling, fixtures, and work-holding jaws can be easily designed and manufactured without consuming machine bandwidth. Its speed and quality improve the product development cycle, allowing you to produce presentable, high-performance parts in less than a day. The offer of adaptability no matter what the part allows you to produce parts with the strength and quality needed to succeed at a speed and cost unmatched in industry.

Don't have a Markforged 3D printer yet?
Try out our software so you can calculate your own ROI.

Markforged