Transforming Design and Manufacturing

Technology introduction

3D Printing transformation

Until the introduction of the Industrial Revolution, hand-crafted one-off design and manufacturing was the norm. Blacksmiths were both designer and manufacturer; each pair of horseshoes they crafted was unique, even when made for the same horse! Production was slow and products were made to order. Save for a few high value items like coffee, tea, and spices, products were rarely, if ever, made in advance, inventoried, and ready for sale. Supply chains for manufactured goods were nonexistent.

But this changed in the 18th century with the rise of the machine and the first Industrial Revolution. Textiles went from handspun wool to cotton woven with a spinning wheel and loom, leading to faster production time with lower material costs. The introductions of the weaving loom, cotton gin, steam engine, and factories for assembling products changed the very nature of how things were made.

Over a period of roughly 75 years—late 1700s to the mid-1800s—production became increasingly standardized, and each task from design to manufacturing and assembly was broken down into discrete functions. Henry Ford's Model T took things to a new level at the start of the 20th century, gaining speed and efficiency with the introduction of mass production and factories. New materials and methodologies from metal casting to Injection Molding have helped to produce most of the products in the world today. With refined workforce and manufacturing practices and the computer automation of previously manual labor-intensive tasks throughout the last century, production rates have accelerated, resulting in the ability to produce in larger quantities. Those who failed to adopt were left behind.

Despite all of this forward movement, the basic design and manufacturing process hasn't fundamentally changed over the past 100+ years. In fact, not only have the processes not improved but they've also put a substantial strain on our natural resources, pushed production farther and farther from the consumer, and constrained design flexibility and customization.

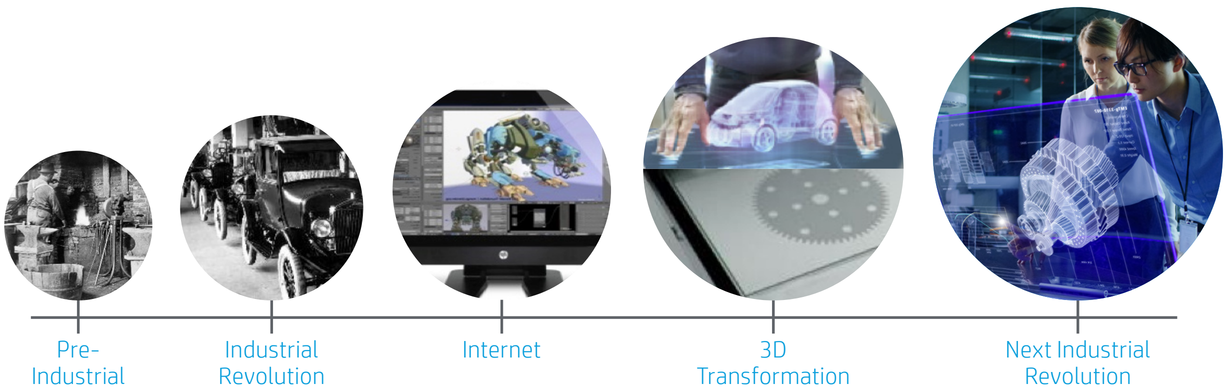

Figure 1: Driving the next Industrial Revolution through the democratization of design and ubiquitous production

Why consider 3D printing as a final part fabrication process?

During the next 10 to 15 years, socioeconomic forces, advanced design and production innovation, and highly automated printing processes will intersect to create a massive transformation of manufacturing as we know it today.

There has been a lot of talk about innovative part designs, designs that could not be fabricated by any of the historical analog processes. This begins now. Unique geometric designs can be made and printed even today. Improvements in function and aesthetics can be realized and in a much shorter development time than was ever possible. Eventually, design tools and printers will evolve to enable voxel-by-voxel differentiation, providing even more product competitiveness.

Figure 2: Real-time medical and prosthesis design. Orthotic helmet image courtesy of Invent Medical.

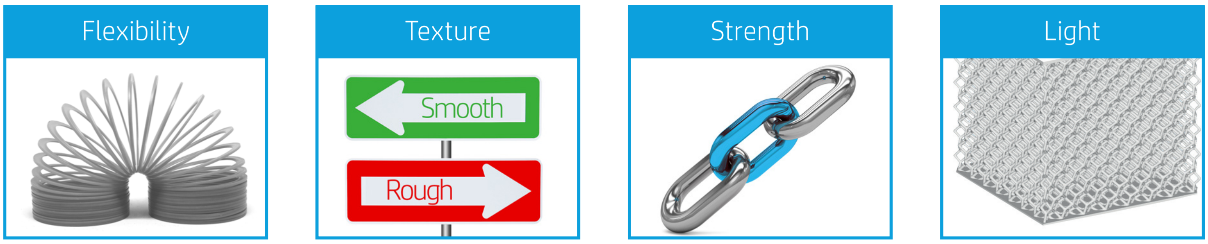

Figure 3: Designers can create customized, flexible, strong, and light 3D printed products.

Further, even if designs were not going to become more complex, there are some fundamental advantages to adopting processes that enable faster and less-expensive product development cycles. To illustrate, a typical return on investment graphic is shown in Figure 1.

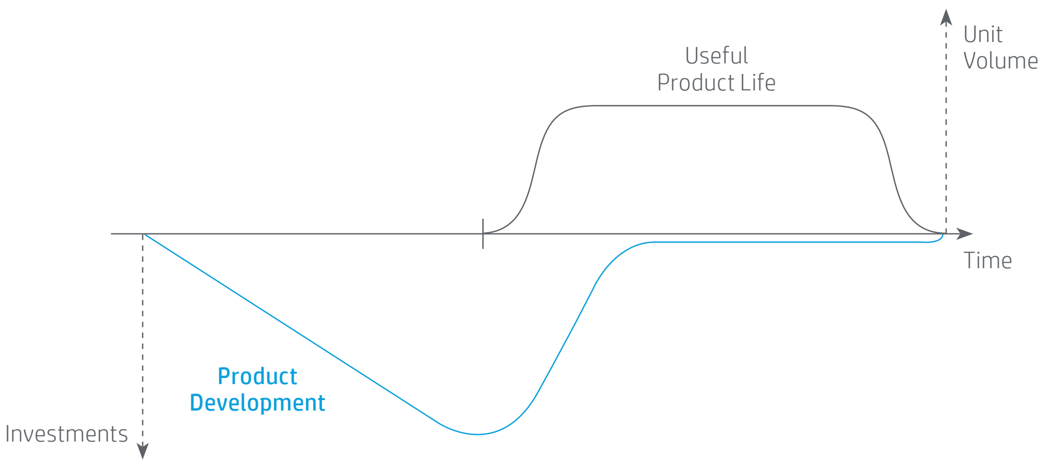

Figure 4: Illustration of return on investment for new hardware product development

The challenge with new hardware product development delays, until now, is two-fold. If you delay for a month, for example, not only do you continue to invest at peak levels for an additional month, but you also reduce the useful competitive life of the product by a month, missing a whole month of stable revenues. If you were to recalculate the return on investment from beginning to end, you might find that the investment no longer makes sense. This is illustrated in Figure 2.

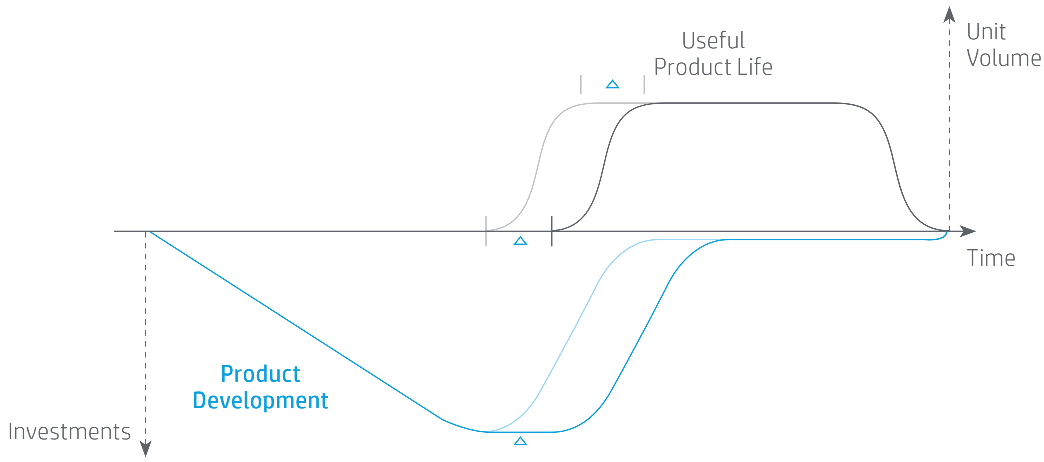

Figure 5: Illustration of a recalculated return on investment for new hardware product development

It is normal to consider the money spent as sunk costs and convince yourself that it still makes sense to move forward. But what if you did not need to delay? What if you had a process that would prevent you from tooling unstable part designs and allow you to begin manufacturing on time? If you had a 3D printer with equal quality and reasonable capacity, this would be possible. You may eventually tool these parts, but you use 3D printing to hold schedule. Applying this strategy—known as bridge manufacturing—it is possible to iterate more frequently on these unstable designs, and the product quality could actually improve.

If you had a 3D printer that had equal quality, the necessary long-term capacity, and a competitive cost, even at high volumes, you may not ever have to invest in tools for certain parts.

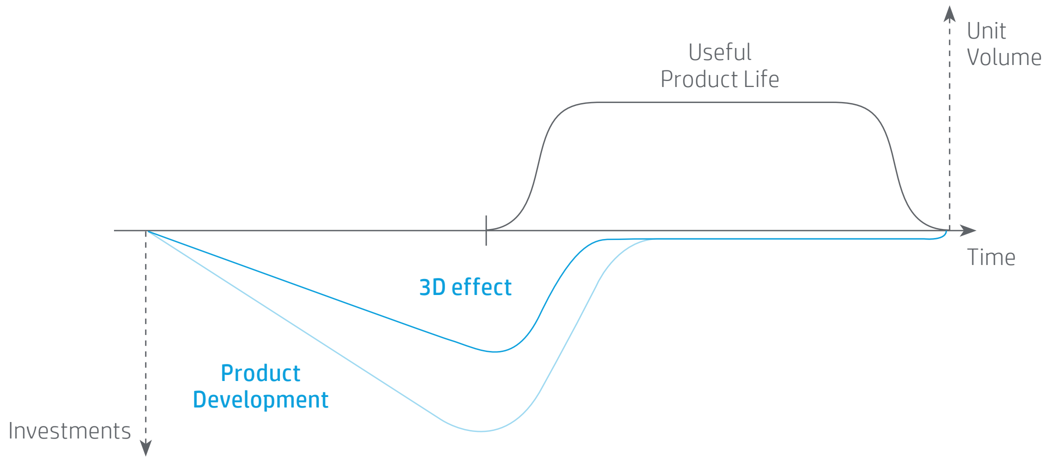

Figure 6: Illustration of the 3D printing effect on investment in new hardware product development

While complex products require parts from several different processes, eventually all parts could be 3D printed, and you could not only develop new hardware products for less investment, you could also introduce them sooner or, effectively, with higher frequency, allowing you to keep your competitive edge.

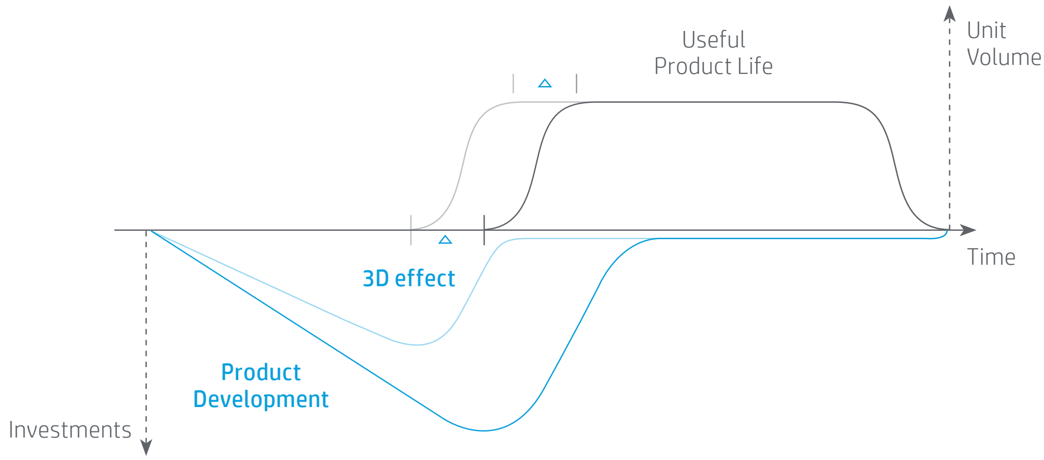

Figure 7: Illustration of the 3D printing effect on product life in new hardware product development

With the introduction of the HP Jet Fusion 3D Printing Solutions, based on a disruptive HP Multi Jet Fusion technology, new levels of 3D printing production speed can be achieved, at reduced operating cost, for parts which offer an unprecedented combination of both fine detail and end part strength. The product development cycle can now be disrupted.

Cost and quality: Former barriers to adoption

In choosing which process to use for final part manufacturing of a specific part, it's important to consider which may be the least expensive combination of process and material that meets the design requirements. Until now, the two main barriers to adopting 3D printing—cost and quality—were factors in making this decision.

The first barrier to adoption has been the effective cost per part and the ability for 3D printing processes to compete head on against Injection Molding. For years, the cost per part for the 3D printing digital processes has been considered a flat line, and the first part can cost the same as the 1,000th part, which would cost the same as the 10,000th part (shown in figure 5). This simplified view leads to a few negative assumptions.

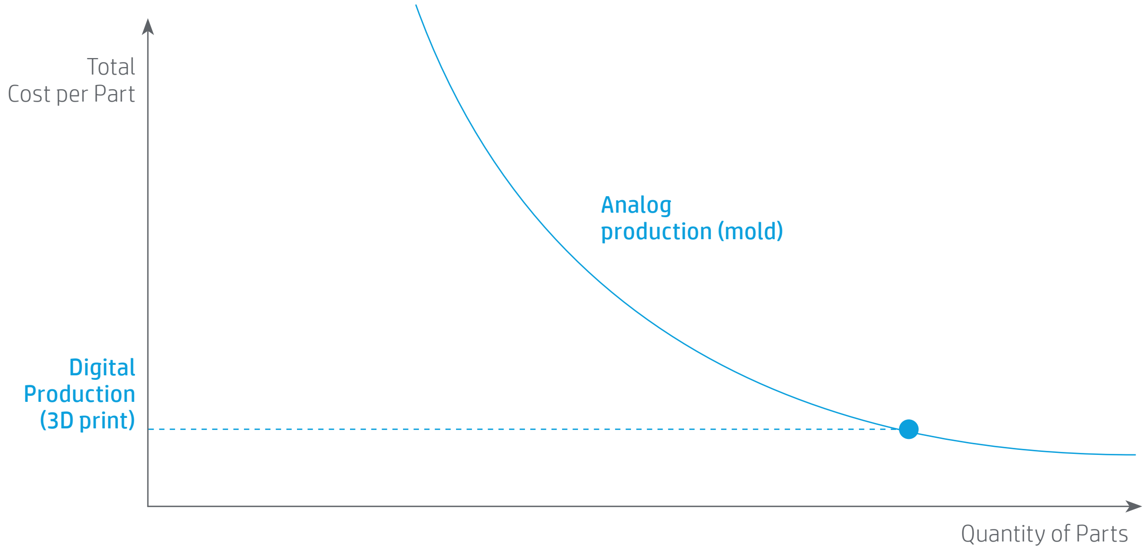

Figure 8: Breakeven curve assuming a productive 3D printer and no set-up costs or development time

Until the introduction of HP Multi Jet Fusion technology, the first negative assumption of 3D printing has been that the printers have reasonable capacity to meet a company's manufacturing forecasts. The fact is, however, that paying hundreds of thousands of dollars for a system that can only fabricate a couple of hundred parts per year results in a flat line that is really a step function (as shown in figure 6). With the high productivity of HP Multi Jet Fusion technology, the step can be tens of thousands of parts instead of hundreds (depending on the part size).

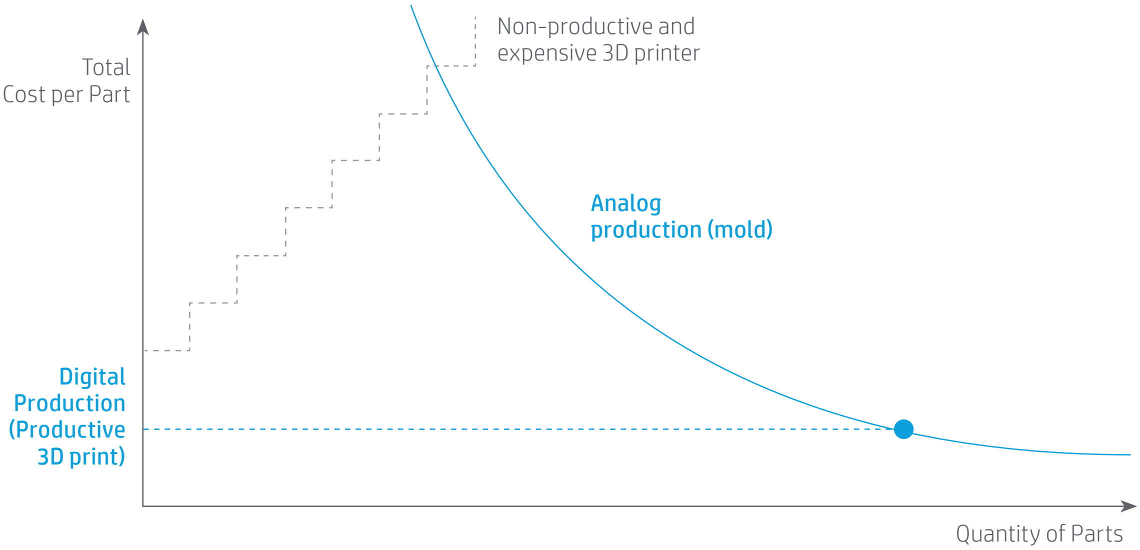

Figure 9: Breakeven curve for a non-productive 3D printer and no set-up costs or development time

The second negative assumption of 3D printing in that flat-line curve is that you can go from design to manufacturing without any development or set-up costs. The truth is that any process will need some sort of development phase in order to meet the quality requirements of the design. During this development phase, both the design and process will always require some tuning. The designer tunes the design to the final fabrication process, and the process engineer tunes the process to the design and its requirements. The beauty of this tuning in 3D printing, or digital fabrication, is that the tuning can be done digitally, and no expensive tooling, with expensive reworks, needs to be included.

There are several layers to optimizing and tuning a design to HP Multi Jet Fusion.

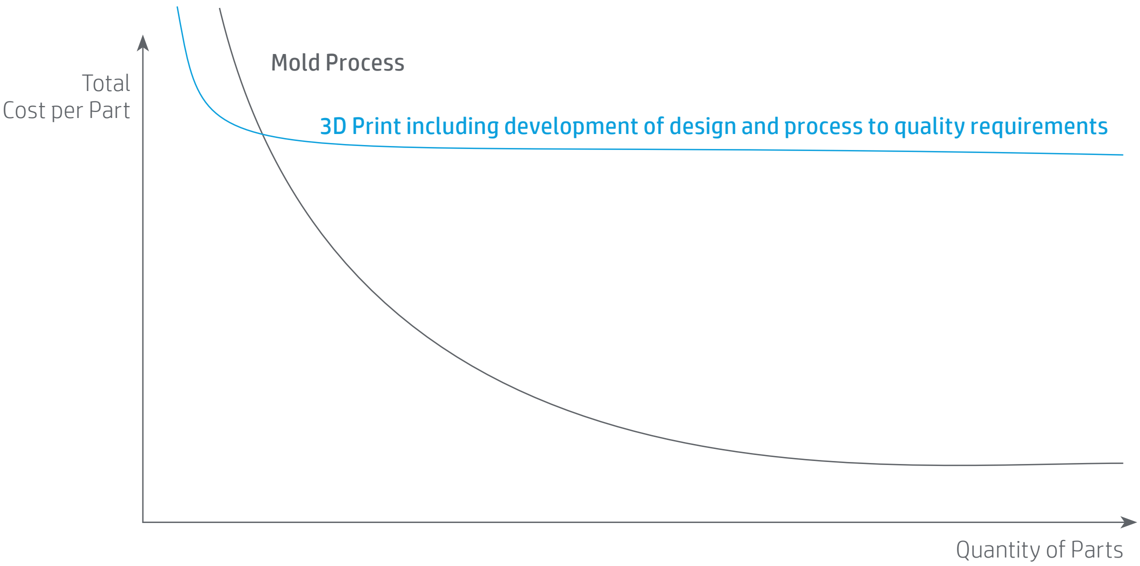

Figure 10: Breakeven curve for 3D printing including development of design and process to quality requirements

The first layer involves following the fundamental guidelines for the fabrication process. All processes have fundamental design guidelines as driven by the physics of the process itself. HP Multi Jet Fusion has such guidelines, like recommended wall thickness. If you choose to follow the guidelines, you will have improved quality and yield, and your effective cost per part will decrease.

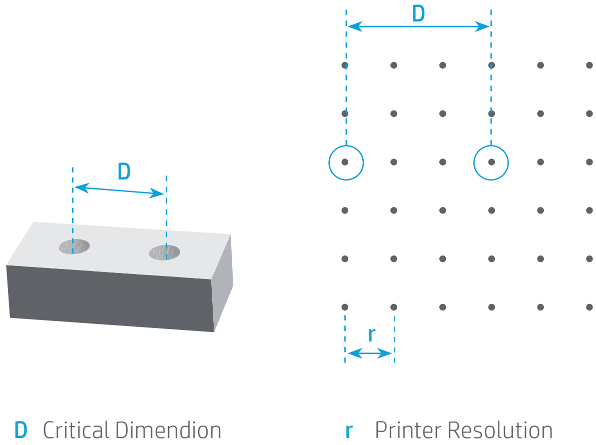

Figure 11: Example guideline: To attain maximum accuracy, critical dimensions should be an integral number of the printer resolution

The next level in optimization involves making slight changes to the design that allow for more efficient use of material or more efficient space management of the build volume. If less material can be used for the part and/or more parts can fit into the same build volume, the effective cost per part will decrease even further.

Figure 12: Optimized material use

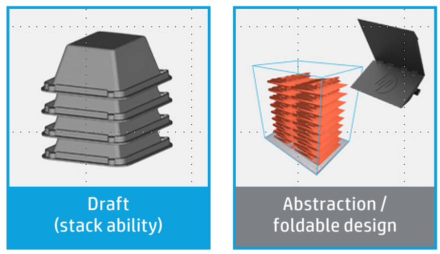

Figure 13: Optimized use of the build volume

The final design optimization for 3D printing is maintaining the third dimension and combining parts. When a mechanical designer takes a system function and breaks this into parts that can be easily Injection Molded, the resulting parts are largely 2.5-dimensional, meaning that they tend to have two larger dimensions and one smaller dimension. This is because molds must open and close easily. If you intend to 3D print the parts, the parts can remain integrated, and then the breakeven curve becomes a comparison of one part versus several parts from several molds.

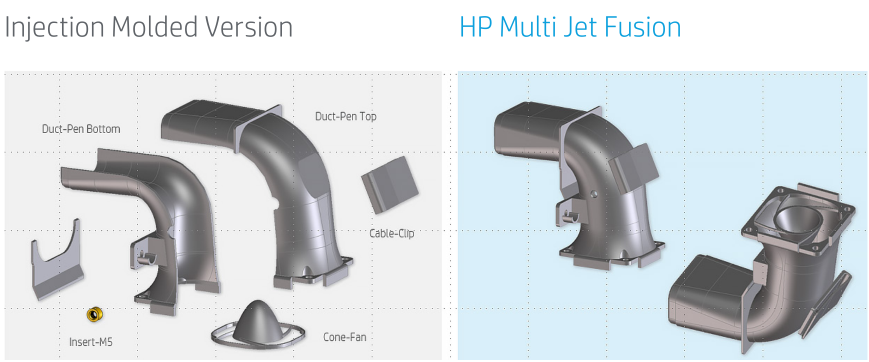

Figure 14: Maintain the integration of the functional design intent

What is the proposed solution?

In the mid-term, the HP Jet Fusion 3D Printing Solutions will complete the portfolio to best accompany our customers on their journey to adopting 3D printing technologies, from assessing where to start to how to design to how to maximize their HP Jet Fusion 3D Printing Solutions.

Software can be developed to help designers tune their designs to HP Multi Jet Fusion or allow process engineers to tune the HP Multi Jet Fusion process to the design. But domain knowledge must come first.

This HP Multi Jet Fusion handbook is a vehicle for capturing the domain knowledge around HP Multi Jet Fusion and sharing it with the world so that it can be applied immediately.

This handbook includes a design chapter to help designers understand the unique design guidelines for HP Multi Jet Fusion that should be followed to obtain optimal quality. Further, the design chapter will eventually provide additional guidelines on how to optimize designs for cost when fabricating with HP Multi Jet Fusion.

Approaching the perfect storm

When cost and quality can be achieved, the true potential of 3D printing can be realized. Future design tools will enable designers to develop more and more differential products through unique designs that cannot be fabricated by analog processes. The seamlessness of the interface between design tools and 3D printers will become even more important as future printers enable multiple properties within one object, enabling changing textures, transparency, strength, elasticity, and more.

What we design, as well as how and where we design, sell, and manufacture products will continue to become both hyper-global and hyper-competitive. To stay successful through this transformation, companies will need to either adopt or be left behind.

Along this journey, this handbook will help guide the transformation, with updates posted online at hp.com/go/MJFHandbook. In the meantime, welcome to the future of part fabrication.

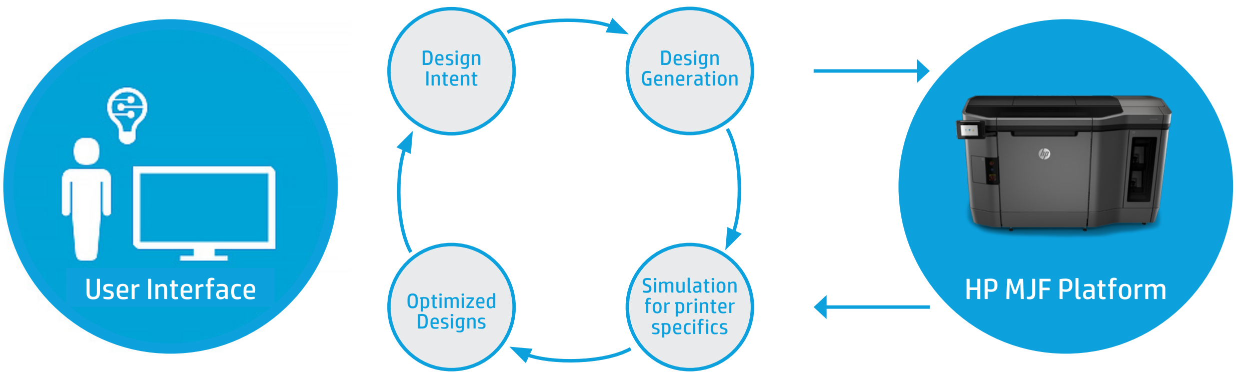

Figure 15: Designers can create customized predictable 3D printed products when printer capability is communicated upstream

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