



3DSYSTEMS®

# 3D Printer Buyer's Guide

---

Provided By



**ems-usa.com**

3D PRINTING ■ 3D SCANNING ■ PRODUCT DESIGN



# Table of Contents

---

<b>1</b>	<b><i>Introduction</i></b>	<b>3</b>
----------	----------------------------	----------

---

<b>2</b>	<b><i>What is the right 3D printer technology for your application?</i></b>	<b>4</b>
	Concept Models . . . . .	4
	Verification Models . . . . .	4
	Pre-production Applications . . . . .	5
	Digital Manufacturing . . . . .	5

---

<b>3</b>	<b><i>3D Printer Performance Attributes</i></b>	<b>6</b>
	Print Speed . . . . .	6
	Part Cost . . . . .	6
	Feature Detail Resolution . . . . .	7
	Accuracy . . . . .	7
	Material Properties . . . . .	7
	Color . . . . .	8

---

<b>4</b>	<b><i>Conclusion</i></b>	<b>9</b>
----------	--------------------------	----------

# 1 Introduction

## 3D Printing Has Come Of Age

3D Printing is more than just prototyping. Today, 3D Printing offers transformative advantages at every phase of creation, from initial concept design to production of final products and all steps in between. Today's competitive environment makes choosing the right 3D printers for every phase of creation more important than ever.

Just a few years ago in-house 3D printing was enjoyed by only a few professional design engineers and was often limited to printing concept models and some prototypes. Once considered a novel luxury, 3D printing has proven to yield long-term strategic value by enhancing design-to-manufacturing capabilities and speeding time to market. Today, 3D printing technologies have allowed an ever growing number of creators to unleash and multiply the benefits of rapid in-house 3D printing across the entire creation process.

Leading companies are now using 3D printing to evaluate more concepts in less time to improve decisions early in product development. As the design process moves forward, technical decisions are iteratively tested at every step to guide decisions, both big and small, to achieve improved performance, lower manufacturing costs, delivering higher quality and more successful product introductions. In pre-production, 3D printing is enabling faster first article production to support marketing and sales functions, and early adopter customers. And in final production processes, 3D printing is enabling higher productivity, economical customization, improved quality and greater efficiency in a growing number of industries.

# 2 What is the right 3D printer technology for your application?

Choosing the right 3D printer among the various alternatives may at first seem like a daunting task. There are significant differences in how each printing technology turns digital data into a solid object. Today's 3D printers can use a variety of materials with vast differences in structural properties, feature definition, surface finish, environmental resistance, visual appearance, accuracy and precision, useful life, thermal properties and more. It is important to first define the primary applications where 3D printing will be used to guide the selection of the right technologies that will provide the greatest positive impact for your business. This article will highlight some of the common 3D printing applications, and outline some key attributes to consider when selecting a 3D printer.

## Concept Models

Concept models improve early design decisions that impact every design and engineering activity that follows. Selecting the right design path reduces costly changes later in the development process and shortens the entire development cycle so you get to market sooner. Whether designing a new power tool, office accessory, architectural design, footwear or toy, 3D printing is the ideal way to evaluate alternative design concepts and enable cross-functional input from all stakeholders to make better choices.



During this early phase of creation, it is desirable to quickly, and affordably evaluate numerous design alternatives with models that look like the real thing, but do not typically need to be fully functional. Stakeholders can better visualize the design intent when they can see and touch alternative concepts side-by-side enabling faster, more effective decision making.

For most concept modeling applications the key performance attributes to look for in a 3D printer are print speed, part cost and life-like print output.



## Verification Models

As product designs begin to take shape, designers need to verify design elements to ensure the new product will function as intended. In-house 3D printing allows design verification to be an iterative process where designers identify and address design challenges throughout the design process to spur new inventions or quickly identify the need for design revisions.



Applications may include form and fit, functional performance, and assembly verification to name a few. Verification models provide real hands-on feedback to quickly prove design theories through practical application. For verification applications the parts should provide a true representation of design performance. Material characteristics, model accuracy and feature detail resolution are key attributes to consider in choosing a 3D printer for verification applications.



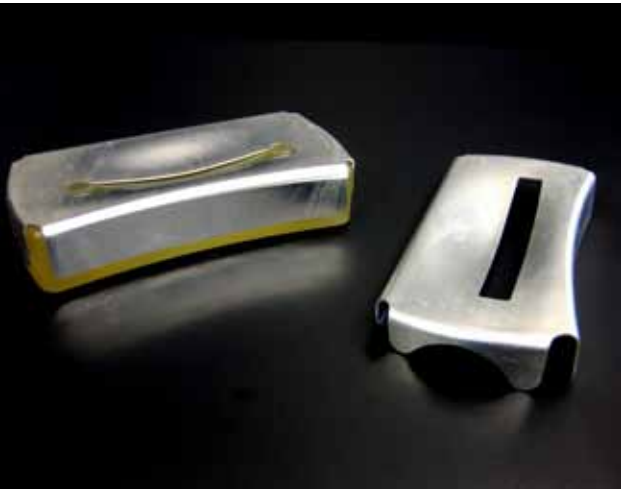
### Pre-Production Applications

As product development converges on the final design, attention rapidly turns to manufacturing start-up. This stage often involves significant investment in tooling, jigs and fixtures necessary to manufacture the new product. At this stage the supply chain expands with purchase commitments for the raw material and other required components. Lead time for these required items can stretch out time to market, and 3D printing can, in a variety of ways, reduce the investment risk and shorten the time cycle for product launch.



Pre-production 3D printing applications include rapid short-run tools, jigs and fixtures to enable early production and assembly of final products as well as end use parts to produce first article functional products for testing and early customer placements.

At this stage the functional performance of the print materials is critical. Accuracy and precision are also of paramount importance to ensure final product quality is achieved and manufacturing tooling will not require expensive and time-consuming rework.



### Digital Manufacturing

Some 3D printing technologies can print virtually unlimited geometry without the restrictions inherent with traditional manufacturing methods, thus providing designers greater design freedom to achieve new levels of product functionality. Manufacturing costs are reduced by eliminating time and labor intensive production steps and reducing raw material waste typical with traditional subtractive manufacturing techniques.



3D printed components may be end use parts or sacrificial production enablers that streamline the production flow. Leading companies in industries as diverse as jewelry, dental, medical instruments, automotive and aerospace have adopted 3D printing to produce end use parts, or casting patterns and molds, to reduce manufacturing costs, enable greater customization, improve product quality and performance, and reduce production cycle times.

For manufacturing applications the key 3D printer attributes are high accuracy and precision, and specialized print materials specifically engineered for application requirements. For some medical and dental applications, materials may need to meet specific biocompatibility requirements.



# 3 3D Printer Performance Attributes

Selection of the right 3D printer is driven by application requirements and matching the key performance criteria that will provide the best all-around value. Here are some specific 3D printer performance attributes to consider when comparing alternate 3D printers.

## Print Speed

Depending on the vendor and the specific technology, print speed may mean different things. Print speed may be defined as time required for printing a finite distance in the Z-direction (e.g. inches or mm per hour in the Z-direction) on a single print job. This method is usually preferred for 3D printers that have stable vertical build speeds independent from the geometry of the parts being printed and/or independent from the number of parts being printed in a single print job. 3D Printers with higher vertical build speeds and little or no speed loss due to part geometry or number of parts in the print job are ideal for concept modeling because they enable the rapid production of numerous alternative parts in the shortest time period.

Another method to describe print speed is time required to print a specific part or to print a specific part volume. This method is often used for technologies that quickly print a single simple-geometry part, but slow down when additional parts are added to a print job or when the complexity and/or size of the geometries being printed increase. The resulting degraded build speed can slow down the decision making process and defeat the purpose of having an in-house 3D printer for concept modeling. While higher print speed is always considered beneficial, it is especially critical for concept modeling applications. 3D printers that have high vertical build speed independent from part quantity and complexity are typically preferred for concept modeling applications because they can print a larger number of alternative models quickly for side-by-side comparisons to accelerate and improve the early decision making process.

## Part Cost

Part cost is typically expressed in cost per volume such as cost per cubic inch or cost per cubic centimeter. Costs for individual parts can vary widely even on the same 3D printer depending on specific part geometry, so be sure to understand if the part cost provided by a vendor is for a specific part, or a "typical" part that is an average across a group of different parts. It is often helpful to calculate part cost based on your own suite of STL files representing your typical parts to determine your expected part costs. In order to properly compare claims made by various vendors it is also important to understand what has, and has not, been included to arrive at the part cost estimate.

Some 3D printer vendors will only include the cost of a specific volume of the print material that equals the measured finished part volume. This method does not adequately present the true cost of the printed parts as it excludes the support material used, any process waste generated by the print technology, and other consumables used in the printing process. There are significant differences in the material efficiency of various 3D printers and understanding the true material consumption is another key factor in accurately comparing print costs.

Part cost is driven by how much total material a 3D printer consumes to print a given set of parts and the price of the materials consumed. The lowest part costs are typically found with powder based 3D printing technologies. Inexpensive gypsum powder is the base model material that forms the bulk of the part. Unused powder is continually recycled in the printer and reused resulting in part costs that may be one-third to one-half the price of parts from other 3D printing technologies.

Some plastic part technologies use one consumable material for printing both the part and the supports needed during the printing process. These technologies typically produce sparse support structures that are easily removed using less material to produce the supports than other plastic part technologies. Most single material 3D printers do not generate significant in-process waste making them extremely material efficient and cost effective.

Other plastic technologies may use a separate, less expensive support material that is removed after printing by either melting, dissolving or blasting with pressurized water. These technologies typically use greater amounts of material to print the supports. Dissolvable supports may require the use of strong, caustic chemicals that mandate special handling and disposal precautions. Water-blasting methods require a water source and drain that can add thousands to your site preparation cost. This method is labor intensive and can result in damage to fine part features as force is applied to remove supports. Also, supports located in hard to access cavities may be stranded and impossible to blast away. The fastest and most efficient support removal is available with 3D printers using melt-away wax support material. Melt-away supports can be quickly removed in batches using a specialized finishing oven with minimal labor and no surface force that can damage fragile fine features. Also, supports can be removed from otherwise inaccessible internal cavities providing the widest flexibility to successfully print complex geometries. Removal of the wax supports does not require the use of chemicals and the support wax can be disposed with ordinary trash eliminating the need for special handling.

Be aware that some popular 3D printers blend expensive build material into the support material during the printing process to create the supports thereby increasing the total cost of materials consumed during the print. These printers also typically generate greater amounts of in-process material waste thereby using more total material by volume to print the same set of parts.

## Feature Detail Resolution

One of the most confusing metrics provided on 3D printers is resolution and should be used with caution. Resolution may be stated in dots per inch (DPI), Z-layer thickness, pixel size, beam spot size, and bead diameter just to name a few. While these measurements may be helpful in comparing resolution within a single 3D printer type, they are typically not good comparison metrics across

the spectrum of 3D printing technologies. The best comparisons are visual inspection of parts produced on different technologies. Look for razor sharp edge and corner definition, minimum feature size, sidewall quality and surface smoothness. Use of a digital microscope may be helpful when examining parts as these inexpensive devices can magnify and photograph small features for comparison. When 3D printers are used for verification testing it is critical that the printed parts accurately reflect the design. Depending on the type of verification testing being done, compromise in feature detail quality can reduce the accuracy of testing results.

## Accuracy

3D printing produces parts additively, layer by layer, using materials that are processed from one form to another to create the printed part. This processing may introduce variables such as material shrinkage that must be compensated for during the print process to ensure final part accuracy. Powder-based 3D printers using binders typically have the least shrink distortion attributable to the print process and are generally highly accurate. Plastic 3D printing technologies typically use heat, UV light or both as energy sources to process the print materials adding additional variables that can impact accuracy. Other factors impacting 3D print accuracy include part size and geometry. Some 3D printers provide varying levels of print preparation tools for fine tuning accuracy for specific geometries. Accuracy claims by manufacturers are usually for specific measurement test parts and actual results will vary depending on part geometry, so it is important to define your application accuracy requirements and test the 3D printer under consideration using your specific application geometry.

## Material Properties

Understanding the intended applications and the needed material characteristics is important in selecting a 3D printer. Each technology has strengths and weaknesses that need to be factored in when selecting an in-house 3D printer. Claims about number of available materials should be viewed with caution as that does not guarantee the available materials will provide the real functional performance needed. It is vital that parts from 3D printers being evaluated be tested in the intended application prior to making a purchase decision. Stability of parts over time and across various use environments are not

discernible from standard published specifications and may lead to limitations in actual usefulness if not fully considered and tested.

For concept modeling applications, the actual physical properties may be less important than part cost and model appearance. Concept models are primarily used for visual communication and may be discarded shortly after being used. Verification models may need to simulate final products and need to have functional characteristics that closely resemble final production materials. Materials used for rapid manufacturing applications may need to be castable or may need high temperature resistance to perform in application. End use parts will typically need to remain stable over longer time periods.

Each 3D printing technology is limited to specific material types. For in-house 3D printing, materials are typically grouped as non-plastic, plastic, or wax. Your selection of 3D Printer should be based on which material categories provide the best combination of value and application range. Combining multiple technologies can provide additional flexibility and expand your addressable applications beyond what can be achieved with a single 3D printer. Often, the combination of two less expensive 3D printers may provide more value than one more expensive system and allow for greater application range and print capacity while staying within a similar investment budget.

Non-plastic materials typically use gypsum powder with a printed binder and result in dense, rigid parts that can be infiltrated to become very strong. These parts make excellent conceptual models and provide some limited functional testing opportunities where flexural properties are not required. The bright white base material combined with exclusive full-color printing capabilities can produce life-like visual models that do not need additional painting or finishing.

Plastic materials range from flexible to rigid and some provide higher temperature resistance. Clear plastic materials, biocompatible plastic materials, and castable plastic materials are also available. The performance of plastic parts produced on different technologies varies widely and may not be apparent from published specifications. Some 3D printers produce parts that will continue to change properties and dimensions over time or in varying environmental conditions. For example, one commonly reported specification used to indicate heat resistance of a plastic is Heat Distortion Temperature (HDT). While HDT is one indicator, it does not predict material usefulness in applications that exceed the HDT.

Some materials may have rapidly deteriorating functional properties at temperatures slightly above the stated HDT while another material may have slow degradation of properties thus expanding the temperature range in which the plastic is useful. Another example is the effect of moisture on the part. Some 3D printed plastics are watertight while others are porous, allowing the part to absorb moisture potentially causing the part to swell and change dimensions. Porous parts are typically not suitable for high-moisture applications or pressurized applications and may require further labor-intensive post processing to be useable under those conditions.

New "crossover" 3D printers by 3D Systems combine the proven performance of Stereolithography (SLA®) with the simple usability of in-house 3D printers. These in-house 3D printers offer an expanded range of plastic materials that truly offer the functional performance of ABS, polypropylene and polycarbonate plastics in a single 3D printer. They offer easy, fast and affordable material changeovers allowing one 3D printer to provide a wide range of addressable plastic applications. When looking at technologies that claim numerous materials, pay particular attention to material waste that is generated during material changeover. Some of these 3D printers have multiple print heads that must be fully purged, thus wasting expensive print materials in the process.

## Color

There are three basic categories of color 3D printers; color-choice printers that print one color at a time, basic-color printers that can print a few colors together in one part, and full-spectrum color printers that can print thousands of colors in a single part. The only 3D printers available today that print the full spectrum of colors are the ProJet® x60, by 3D Systems. They can achieve the same type of color on 3D printed models that color document printers display on paper with up to more than 6 million unique colors resulting in incredibly life-like models. In addition to putting life-like colors in all the right places, ProJet x60 printers can apply photos, graphics, logos, textures, text labels, FEA results and more, and can produce models that are difficult to distinguish from the real product.



# 4 Conclusion

3D printing can offer benefits across the entire creation process from initial concept design to final manufacturing and all steps in between. Different applications have unique needs and understanding those application requirements is critical when choosing a 3D printer. Multiple systems may offer broader use opportunities than a single system, so identifying your unique requirements to apply 3D printing across your entire design-to-manufacture process can shorten time-to-market, improve product performance, streamline and cost-reduce manufacturing, and improve product quality and customer satisfaction will help you define the ideal 3D printing capability for your organization.

Learn more about 3D Systems at [www.3dsystems.com](http://www.3dsystems.com).