STRATASYS WHITE PAPER

3D PRINTERS VS. 3D PRODUCTION SYSTEMS:

10 Distinguishing Factors to Help You Select a System

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When planning to purchase an additive manufacturing system, buyers will find capabilities and a price range wider than products from most any industry. Systems can range from several hundred dollars for a hobbyist unit to nearly $1 million for some high-performance systems. It's no wonder there is confusion with respect to the product segments.

This paper addresses the capabilities, roles and positioning of systems geared for professional use. Beginning with the most basic information — the definition of 3D printers — this white paper positions the two product classes.

3D Production System *3D Printer*

While clarifying the "typical" roles and strengths of each, it also shows that there is overlap between the 3D printers and their bigger brothers, sometimes referred to as 3D production systems.

As additive manufacturing system prices have decreased, interest has swelled in owning a system to produce rapid prototypes, patterns, tooling and manufactured goods. Further fueling that interest is an increase in the number of technologies, systems and options available. Choice is the operative word, and those choices include entry-level systems priced below $15,000 (USD) as well as machines selling for more than $900,000 (USD).

With so many options, how do organizations know which is the best choice? How do they know what is a reasonable investment for an additive manufacturing system that will do their job right? To answer these questions, they begin with an understanding of the differences between 3D printers and 3D production systems. Knowing the distinctions between the two classes of systems allows informed decision-making that balances needs, wants, and budget.

It is important to note that 3D printers and 3D production systems, at their core, work on the same principle. The term 3D production system is used because these higher performance systems are used to produce finished goods as opposed to making only prototypes.

There are 10 general factors that distinguish 3D printers from 3D production systems. For some, the first factor, price, may be the only consideration. But for those with some flexibility in their capital equipment budgets, the other nine factors will guide the selection process. But this does not necessarily mean that more money will be spent. Many companies are pleasantly surprised to find that they can do all that they want with a low-price 3D printer. Many others happily invest more in a 3D production system that offers higher performance. And countless others invest in both—running 3D printers and 3D production systems side-by-side.

3D Printers:	3D Production Systems:
• Compact • Low price • Easy to use	• Many materials • High performance • Large Capacity

Figure 1

What are 3D Printers and 3D Production Systems?

Additive manufacturing systems were once called rapid prototyping machines and simply labeled as "low-end" or "high-end," and distinguished by price. When opting for a "low-end" machine, there was a big price to pay in quality or performance.

As the market and technologies matured, a new term, "3D printers," sprang up. But instead of replacing "low-end" as a class descriptor, it became an over-used catch phrase that muddied the waters. To this day, there isn't universal agreement on the definition of 3D printers. For some, the term covers all additive manufacturing technologies. However, the majority defines 3D printers as compact, low cost, and easy to use. With this understanding, a 3D printer is analogous to a desktop paper printer that is dedicated to one person or shared among a small team of co-workers.

Conversely, a 3D production system is similar to a centralized copy machine with higher document output, more controls, and which serves an entire company's needs. They are the "high-end" systems in 1990s lingo. In general, they offer more capability and higher performance with a larger price tag. Yet, the distinctions between the two classes are not that clear cut. To appreciate the subtle differences, consider the 10 distinguishing characteristics.

Keep in mind that these characteristics are general and typical, but there are exceptions.

FDM® TECHNOLOGY	
3D Printers:	**3D Production Systems:**
Dimension® line	Fortus® line

Figure 2

10 Distinguishing Characteristics

1. PRICE:

- 3D printers: $10,000 to $50,000
- 3D production systems: $50,000 and above

The base price of machines is the simplest and most obvious differentiator between the two classes. Low-price is essential to the 3D printer definition, so price is a primary distinguishing characteristic. Generally, 3D printers have a base price — for just the machine — that ranges from $10,000 to $50,000. Anything over $50,000 typically moves an additive manufacturing system into the high-performance system class.

In the additive manufacturing market, low price does not translate to low value. Value is determined by considering all the characteristics to find the system that can do the job while bringing the best return on investment.

2. CAPACITY / BUILD ENVELOPE:

- 3D printer: Normally less than 10″ x 10″ x 10″
- 3D production system: Normally greater than 1′ x 1′ x 1′

The size of a machine's build envelope determines its capacity, typically both in terms of part size and total throughput. 3D printers, which are designed more for office use or desktop operation, have smaller build envelopes suited for small- to mid-sized parts. These devices typically have build capacities that do not exceed 12 inches in any dimension. 3D production systems, on the other hand, have the capacity to build parts that are measured in feet. In this class, two to three feet is a common measurement for the length, width or height of the build envelope.

Capacity is an important consideration because it is best to avoid building parts in pieces that have to be bonded together. Sectioning parts to fit in a build chamber adds time, labor and cost while decreasing quality. Also, running an additive manufacturing system multiple times to make one part decreases efficiency and machine availability.

To increase operational efficiency and total throughput, consider systems with the capacity to build many parts in a single run. So, even if a smaller 3D printer can handle a product's biggest parts, it can be a smart decision to go with a 3D production system that can build complete assemblies or dozens of parts. As more parts are consolidated in each run, operational costs decrease while efficiencies rise. A bonus is that a lot of parts can be packed into a single run that is launched Friday night and left to run unattended over the weekend.

3. MATERIALS:

- 3D printers: One or two
- 3D production systems: Eight or more

Material properties play a role in every process selection. Whether the application is for a "down-and-dirty" concept model or a high-caliber production part, there will be some degree of consideration given to the materials that are available. In every case, the application needs a material that will perform well.

3D printers typically do not offer broad material selections. Most give users a choice of just one or two general-purpose materials. In this class, the systems offer adequate, rather than exceptional, mechanical and thermal properties. In stark contrast, a strength of 3D production systems is the number of materials offered and the breadth of properties available. 3D production system users can specify a material that matches the specific needs of an application by selecting from a range of options that include specialized, highly engineered thermoplastics like ULTEM® 9085.

In general, the material offerings of 3D production systems make them better suited for functional testing, field testing, product trials, and creating manufacturing tools or finished goods. Each part in an assembly can be produced from a different material that is selected for the right combination of advanced material properties.

4. SPEED:

- 3D printers: Not applicable
- 3D production systems: Not applicable

The speed of the additive manufacturing process is an important consideration, but it is not one that clearly distinguishes 3D printers from 3D production systems. In this area, bigger investments do not guarantee shorter build times. For example, there are 3D printers that for one-tenth the price can build parts ten times faster than some 3D production systems. On the other hand, there are 3D printers that take days to build what can be completed in hours with certain 3D production systems.

For a manufacturer that offers both 3D printers and 3D production systems that do not share a common technology — there is no correlation between the speed of the process and the price tag. However, for a manufacturer with a technology that spans both classes, there is a direct link between speed and price.

FDM (fused deposition modeling®) is one example in which 3D printers and 3D production systems share a common technology. In this case, the higher performance systems' software offers sophisticated build parameter options, allowing the user to optimize the machine and wring out efficiencies that add up. Depending on these build parameters and the part geometry, the FDM 3D production system will outpace the FDM 3D printer by roughly 2 to 10 times.

If speed is measured in terms of throughput, 3D production systems will again outpace 3D printers. Combining build speed with capacity, the larger systems will, in general, deliver higher production rates on a weekly or monthly basis. This is an important point when faced with high-volume prototyping demands, and it is a critical factor when considering the technology to manufacture end products.

5. EASE-OF-USE:

- 3D printers: Occasional user
- 3D production systems: Trained operator

If a 3D printer isn't easy to learn and easy to use, it should not be called a 3D printer. Ease-of-use is imperative for these devices since they are intended to be used as a CAD-output tool. The occasional user is not a skilled machine operator and cannot afford to spend days in training or hours preparing and operating a machine. From start to finish, the process must be simple, straightforward and effortless.

A vision shared by most 3D printer manufacturers is to make their machines as transparent and unnoticed as the process of printing a document. Admittedly, these systems are not quite to this level, but some are close. From CAD output to finished parts, some are almost as labor-less as the process of printing a few dozen two-sided pages on a standard paper printer. In other words, it's not quite as simple as clicking print, but it requires only a few extra steps and minimal thought.

To gain higher performance and greater functionality, 3D production systems generally sacrifice ease-of-use. The advances in processes, materials and controls place additional demands on the user. To get the most out of 3D production systems, there will be operators who are responsible for the oversight, maintenance and operation of the machines. These technicians will have undergone advanced training on the system and will continue to learn the subtle nuances of operations with each part that it produces. The technicians will also learn the unique processing requirements for each of the materials they use.

NOTE:

Always evaluate the total process time for a technology. Build times alone are deceiving. So, include all time and labor needed on the front end to prepare a machine and on the back end to remove and finish the parts.

Figure 3

There is an exception, however. For the scalable technologies, like FDM, that are used in both 3D printers and 3D production systems, ease-of-use is possible in both classes. For everyday parts, the 3D production system can be run as easily as a 3D printer. However, when advanced capabilities are needed, someone other than a casual user may be called upon to leverage all that the system offers.

6. USER OPTIONS:

- 3D printers: Minimal
- 3D production systems: Substantial

In return for ease-of-use, 3D printers remove most of the operator control and user options. Instead of a computer screen filled with user-defined variables and selections, the casual user is presented with a limited number of pre-programmed routines and only a few options. And the choices must be applied globally to a part or across the entire job. In this way, 3D printers are analogous to point-and-shoot cameras.

3D production systems, on the other hand, are more like the sophisticated digital SLR cameras that have swappable lenses, variable flash settings, F-stop adjustments and ISO settings. 3D production systems, like their camera counterparts, give operators control of a multitude of variables to fine-tune part quality, adjust part characteristics and influence production rates. Unlike their 3D printer counterparts, the most advanced systems in this class allow the user to apply many control parameters at the feature level of the part. For example, to save time and material, the machine can make an ornamental feature hollow and a functional feature solid. This level of control, combined with material selection, is why 3D production systems are the likely candidates for advanced applications in prototype development and manufacturing.

7. ACCURACY:

- 3D printers: Acceptable to Good
- 3D production systems: Good to Excellent

"Geometry dependent" is the qualifier on any statement of dimensional accuracy and repeatability for additive manufacturing systems in both technology classes. Yet, it is safe to assume that in the case of accuracy and repeatability, buyers will get their money's worth. Overall, 3D production systems are more accurate and offer greater repeatability than their lower priced 3D printer siblings.

This is not to say that 3D printers cannot make parts with reasonable dimensional accuracy. They can. There is just less emphasis on this attribute and less user influence over it. 3D printers are designed to be simple, cost-effective machines targeted for early models and prototypes where looser tolerances are acceptable. With this target in mind, 3D printer manufacturers place less priority on accuracy. And as noted previously, the simplified user interface removes the option of fine-tuning to dial in parts for better quality.

With higher expectations of part quality, the manufacturers of 3D production systems are investing in high-grade components, tight process controls and precise calibration. No longer just for prototyping, the best 3D production systems are designed and manufactured as if they were any other machine on the manufacturing floor. Tight and repeatable tolerance is a reasonable expectation when investing in this class of additive manufacturing technology.

Although the quality difference may be difficult to see with the naked eye, they will show up when parts are scrutinized by quality control. It will also become apparent when seeking confirmation of a machine's accuracy capabilities. For 3D printers, there are general tolerance claims but no exhaustive studies that qualify accuracy and repeatability. For 3D production systems, it is reasonable to expect a study that is thorough, rigorous and statistically sound. Without this level of data, buyers would find it difficult to trust that a 3D production system could actually be used for production.

8. FACILITIES:

- 3D printers: Office-like environment
- 3D production systems: Lab or shop environment

The allure of 3D printing has been the vision of producing models and prototypes where the design and engineering work is being done. To make this vision a reality, the 3D printing process must be clean, quiet, cool, and odorless. Requiring no more than a wall outlet and network connection, the 3D printing process becomes an in-office output device. Major advances toward this goal have been made in recent years.

Although the vision for 3D printers is not quite a reality, there are several units on the market that fit nicely in an office environment. But even the most office-friendly 3D printer will likely have a separate workspace in a nearby room for part finishing. Access to a water supply and drain; well-lit and roomy work surfaces; and supply storage areas are conveniences that are likely to be located outside of the engineering offices.

3D production systems, for the most part, are located in workshops and labs or placed on the manufacturing floor. These machines are big, not something that most want in their offices. They often have shop-oriented requirements for power, compressed gas, temperature control, humidity control, vibration dampening or debris containment. For most 3D production systems, the projects often dictate that the parts go through secondary operations that may employ a variety of shop tools and supplies. This work must be kept in the shop. The added facility requirements for 3D production systems will have an effect on the initial system investment and ongoing operating expenses.

9. CENTRALIZED OPERATIONS:

- 3D printers: Distributed
- 3D production systems: Centralized

Additive manufacturing offers two modes of operation: centralized and distributed. Companies may choose to distribute machines throughout the organization or centralize them in one area that is managed by a dedicated staff. Some want the flexibility and independence that a distributed network of systems offers. Others prefer the control, oversight and efficiencies of a centralized grouping of systems.

The distributed network is the domain of 3D printers. In this operating mode, designers and engineers have direct access to their prototyping tools. Instead of sending jobs off to be scheduled and built, the engineering team gains the independence and control that comes from deciding its own priorities and making its own parts.

In a centralized operation, the shop staff receives all part requests, schedules production, manages runs, and oversees post processing. This department takes on the work of making models and parts for the whole organization. With responsibilities to maximize efficiencies, minimize cost, and maximize responsiveness, the build schedule has priorities beyond the urgent need for a single part. So, a rush job may be bumped to a later time because there are other priority jobs already in queue.

10. OVERHEAD:

- 3D printers: Minimal
- 3D production systems: Moderate to high

Distributed, self-serve operations do not place additional overhead burdens on an organization. The staffing remains the same since those who need the parts are those who build and finish them.

Centralized operations require someone to manage day-to-day operations, including the production schedule. When applying the 3D production systems to advanced applications, such as tooling and finished goods production, there will be additional demands for skilled technicians that can leverage the controls that these systems offer. Finally, depending on the complexity of the system, there may be a need for someone to perform post processing, part finishing, and secondary operations.

As the application progresses from simple concept models to advanced manufacturing, more is expected from the additive manufacturing systems and more is needed from the team that tends to their operations.

Subtle Differences

With additive manufacturing, organizations can get a lot of capability affordably. Being less expensive does not mean that a 3D printer is an inferior solution to a 3D production system. It is simply a different solution. Using the 10 differentiating factors, a solution may be found to best match the organization's needs, budgets, and operating style.

Choosing between 3D printers and 3D productions systems is not like picking a two-wheel scooter or an 18-wheel big rig. It is more like picking from a selection of compact cars, luxury sedans, SUVs and pickup trucks. The application will drive the decision. And continuing with this analogy, ultimately companies may find the need to have one for commuting and another for towing the pleasure boat, which is to say that they may find themselves running both 3D printers and 3D production systems.

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