

White Paper

Figure 4[®] Same-Day Prototyping: New Levels of Speed, Quality and Affordability



The next chapter in additive technology is written by Figure 4® technology – a new manufacturing solution using non-contact membrane printing, state-of-the-art plastic resins, and a light-based UV curing process that takes minutes versus hours with heat-based curing processes.

The system architecture of Figure 4® enables superior final part and material quality, including improvements to toughness, durability, high temperature deflection and elastomeric properties.

This is possible due to the speed of the non-contact membrane process combined with the low static volume print tray, which allows for more highly reactive material chemistries that might not be achievable with other photopolymer 3D printing methods.

Fastest throughput via technology

Extensive testing* shows the Figure 4® system offers print speeds up to 100mm/hr (Table 1).

These print rates remain constant regardless of how many parts are being built due to the non-contact membrane technology that powers the 3D Systems’ Figure 4® platforms.

Taking the fast curing process into consideration, Figure 4® enables a time to first part-in-hand (printed, cured, washed, dried) of 160 minutes (2.67 hours) in draft print mode, or less in standard print mode (Table 2). This is a newly achieved benchmark in the 3D printing industry.

Here it is important to note the critical distinction between throughput and raw print speed. True industrial 3D printing throughput must account for the print process, any required curing time, as well as other post-printing requirements (such as washing or drying).

Only when the part is ready for manufacturing or shipping can it be considered complete. Print technologies that offer fast raw print speeds but require extended cure times can be highly deceptive. A 3D printing process must be looked at holistically to determine the true productivity that is possible.

TABLE 1. PART PRINT SPEEDS ON 2 MATERIALS

SPEED (MM/HR)	DRAFT	STANDARD
Figure 4™ TOUGH-GRY 10	103	77
Figure 4™ TOUGH-GRY 15	71	41

Figure 4® technology provides breakthrough printer speed at up to 100 mm/hr (Preliminary data. Both Draft and Standard print quality used).

TABLE 2. TIME TO PART-IN-HAND

MATERIAL	TIME TO PART
Figure 4™ TOUGH-GRY 10	160 min (2.67 hr)
Figure 4™ TOUGH-GRY 15	280 min (4.67 hr)

Time to first part-in-hand, including printing, curing, washing and drying based on test geometry on run on a Figure 4® Standalone using Draft mode (Preliminary data).



*Internal benchmark completed by 3D Systems

Fastest throughput via scalability

Early benchmark testing by 3D Systems shows that within 11 days, eight Figure 4® Standalone printers can turn out 10,000 units of a textured automotive vent. In those same 11 days the injection molding process would still be in the mold design stage.

The CAD-to-production speed of direct production makes it ideal for Low Rate Initial Production (LRIP) or bridge manufacturing.

Companies can go to market faster, with the option to convert to injection molding to ramp up volume as demand grows.

Figure 4® Standalone is an affordable and versatile solution for low volume production, and fast prototyping in the tens and hundreds of parts per month.

With a compact and easy-to-use design, Figure 4® Standalone delivers ultra-fast speed at an affordable price and low total cost of operation.

Much like digital photography, digital printing, and digital video, digital production with Figure 4® is the result of combining complementary technologies to achieve a result greater than the sum of its parts. Advances in CAD software, 3D printing technology, materials science, and robotics—along with new tools for digital texturing—come together in the Figure 4® platform.

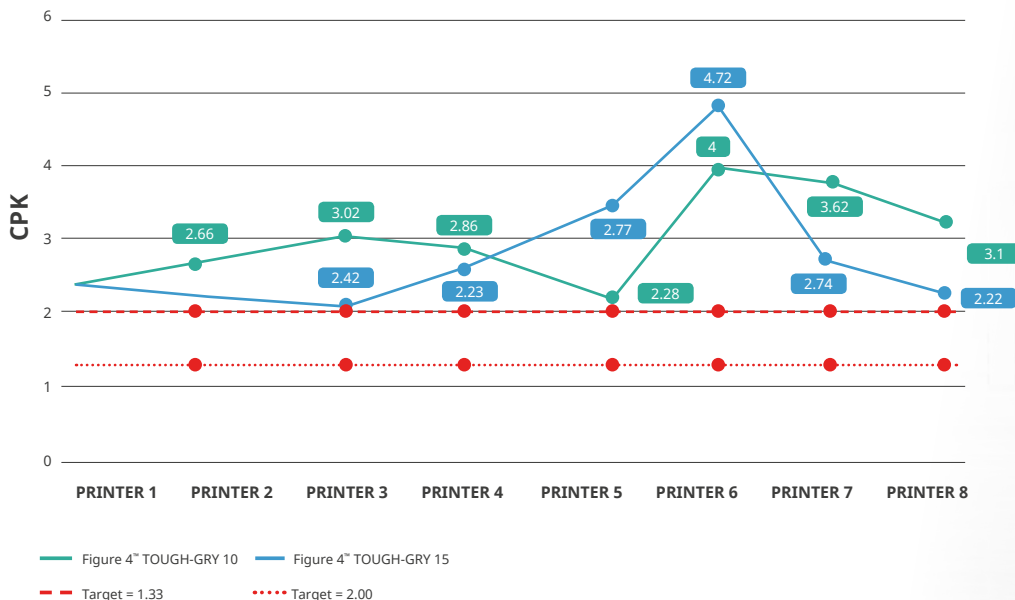
DIRECT DIGITAL PRODUCTION:

An alternative to traditional injection molding that enables designs to go straight from CAD to manufacturing without tooling or delay.

FIGURE 4® STANDALONE:

A single unit configuration of Figure 4® offering very fast prototyping, low volume production and jewelry casting patterns.

IMAGE 3B. FIGURE 4® SIX SIGMA REPEATABILITY



Results from eight Figure 4® printers with two different materials consistently deliver a Cpk > 2. This equals 0.002 parts per million are out of spec (Preliminary data).



Fastest throughput, highest accuracy

Figure 4® delivers the fastest non-contact membrane printing in the industry with repeatability that is unmatched. Test results show that Figure 4® offers print speeds up to 100 mm/hr—at six sigma repeatability.

The statistical result is stated as Cpk > 2, where Cpk is the process capacity index. A result of 2 or higher is considered a “six sigma” quality process (Image 3A).

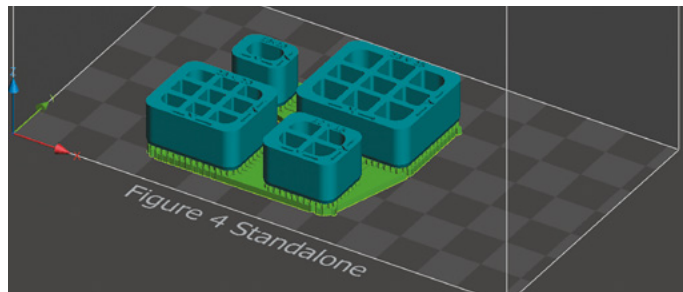
IMAGE 3A. FIGURE 4® SIX SIGMA REPEATABILITY

	FIGURE 4® TOUGH-GRY 10	FIGURE 4® TOUGH-GRY 15	TOLERANCES
C _{pk}	2.46	2.03	+/-100um

Repeatability results from 3 Figure 4® printers consistently deliver a Cpk above the target 2.0.

Cpk is a statistical measure of the ability to produce output within specification limits. Cpk takes into consideration how much natural variation a process experiences relative to the specified limits. Using a standard statistical measurement allows different processes to be compared without ambiguity.

To establish a Cpk value for the Figure 4® 3D printing platform (Image 3B), tests were run on eight machines individually. Cpk testing requires running 30 samples. The test part was printed on each Figure 4® printer and measured using micrometers four times; the average was used for the statistical sample.



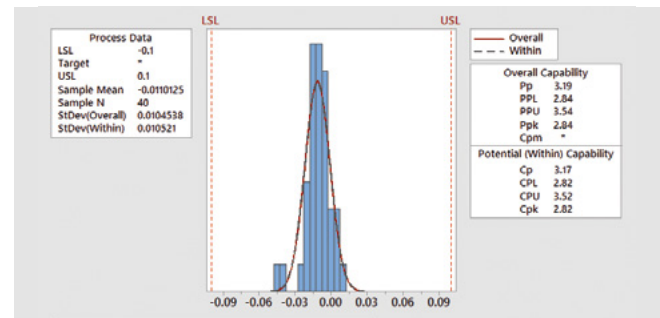
Testing parts on the 3D Sprint build tray set up

IMAGE 4. PRINT BUILD SETUP

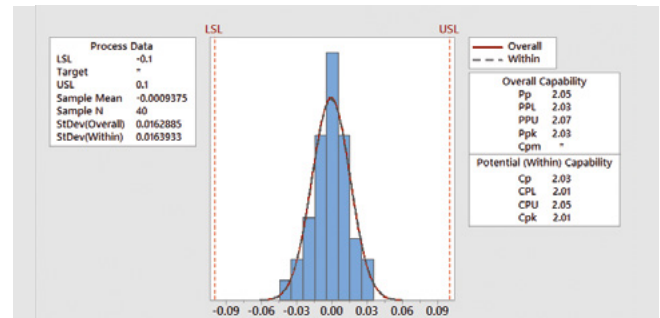
Next the physical model was adjusted, and new objects were printed and measured again. The results for each printer from both runs were given their own results chart. The combined results scored 2 or higher, establishing six sigma quality in the repeatability of the process. Certain individual results scored Cpk = 1.94, which is not a six sigma result, but remains much higher than the other nearest standard of 1.67 for “safety or critical parameter for a new process” (Image 5).

*Internal benchmark completed by 3D Systems

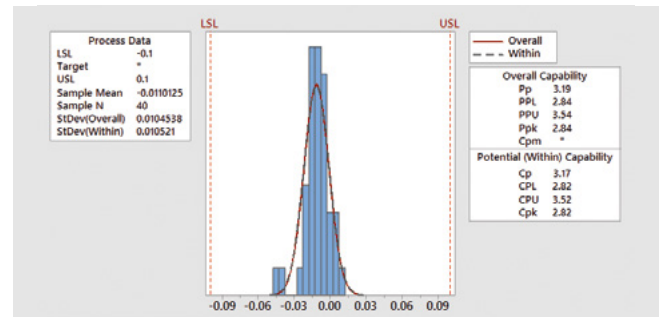
IMAGE 5. PROCESS CAPABILITY RESULTS



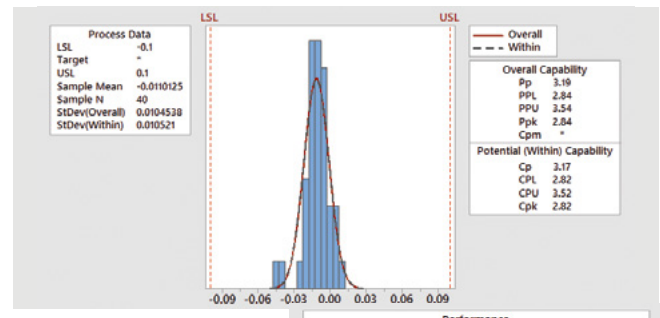
003: Printer 1 Stats (5-prints)



004: Printer 2 Stats (5-prints)



005: Printer 3 Stats (5-prints)



006: Printer 4 Stats (5-prints)

The advent of new materials

The processing speed of Figure 4® technology enables use of reactive materials with short vat lives, leading to functional parts across a range of mechanical properties, such as those used in thermoplastic applications.

Unlike other photopolymer 3D printing, Figure 4® is capable of manufacturing parts in hybrid materials (multi-mode polymerization) that offer toughness, durability, biocompatibility, high temperature deflection, and even elastomeric properties. This opens the door to new end-use applications in the fields of durable goods, automotive, aerospace, healthcare and beyond.

The material portfolio for 3D Systems' Figure 4® technology offers a diverse range of characteristics developed to address a breadth of prototyping, production and application-specific use cases, and the selection of available materials continues to expand rapidly.

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The following materials can be used for rapid prototyping to accelerate product development:



Figure 4™ TOUGH-BLK 20, Figure 4™ TOUGH-GRY 10, and Figure 4™ TOUGH-GRY 15: high contrast black material and high contrast gray materials, respectively.

- Figure 4™ TOUGH-BLK 20 offers industry-leading long-term environmental stability for high performance parts;
- Figure 4™ TOUGH-GRY 10 is capable of print speeds up to 100 mm/hr and offers 25% elongation at break;
- Figure 4™ TOUGH-GRY 15 offers 35% elongation at break.



Figure 4™ FLEX-BLK 10 and Figure 4™ FLEX-BLK 20: flexible and durable black materials with excellent shape retention. These materials offer a combination of flexibility, durability, and impact strength for functional assemblies and prototypes.



Figure 4™ ELAST-BLK 10: a high contrast black elastomeric material for design and validation of rubber-like parts.



Figure 4™ RUBBER-BLK 10: a malleable material for hard, rubber-like parts with high tear strength and slow rebound. Great for high performance functional and touch applications such as grips, handles and bumpers, as well as strain-relief applications, couplings and over molds.



Figure 4™ MED-WHT 10 and Figure 4™ MED-AMB 10: a rigid white and a translucent amber biocompatible material, respectively. Both materials are recommended for use in general medical applications that require sterilization and are each capable of withstanding high heat, making them good candidates for many high temperature industrial applications. The translucency of Figure 4™ MED-AMB 10 also makes it a good option for applications requiring fluid flow visualization.

- Can meet ISO 10993-1 standards for biocompatibility
- Thermal resistance over 100 °C
- Sterilizable by autoclave



Figure 4™ JCAST-GRN 10: a high-contrast green material optimized for clean and easy burnout in direct casting applications. This material is designed for jewelry casting professionals to facilitate the rapid production of accurate, reproducible, and highly detailed master patterns for casting.

- Suitable for a range of precious metals
- Patterns are stable enough to ship
- Enables direct casting without tooling

The following Figure 4™ materials can be used for prototyping as well as for direct production applications:



Figure 4™ EGG SHELL-AMB 10: a process-optimize material for the production of sacrificial tooling for casting silicone parts in any durometer. It is specifically engineered to withstand liquid silicone injection at high temperature and pressure, with intentional brittleness to shatter easily from silicone once the mold is filled and cooled. Its amber color allows for visualization of the injected silicone, and it also has high HDT, high tensile modulus and low elongation at break which are preferred properties for molds to be injectable.

- Engineered to withstand silicone injection at high temperature and pressure;
- Easy to peel away once mold has set
- Excellent surface finish leaves no evidence of mold once removed



Figure 4™ HI TEMP 300-AMB: an ultra-high temperature plastic for use in applications requiring high heat resistance. It has an HDT over 300 °C at both low and high pressure (HDT @ 0.455 and 1.82MPa). This material is well suited for the testing of high temperature components in applications including HVAC, consumer appliances, motor enclosures, hair dryers and the like.

- Over 300 °C HDT
- No secondary thermal post-cure



Figure 4™ PRO-BLK 10: a production-grade additive manufacturing material with game-changing thermoplastic-like mechanical properties and environmental stability for direct production of plastic parts.

With a fast print speed at up to 60 mm/hr and simplified post processing that includes a single curing cycle and single solvent cleaning, this material delivers exceptional throughput.

It is a high precision resin producing parts with a smooth surface finish and exceptional sidewall quality, and has excellent mechanical properties.

- Environmental stability means parts remain consistent over time in terms of mechanical properties, color, opacity, and dimensions
- Print speeds of up to 60 millimeters per hour at 50 µm layer thickness
- No secondary thermal post-cure, making this a simple and effective approach to tool-less production



As discussed throughout this paper, the reduced costs enabled by tool-less digital production, as well as the anytime manufacturability of parts and newly enabled complexity of parts, offer real and compelling advantages over traditional injection molding.

Designed to fit your production needs

An integral part of the solution is the 3D Sprint® additive manufacturing software which supports the preparation and optimization of CAD data and then manages the additive manufacturing process on Figure 4® 3D printers.

With a broad set of additive manufacturing preparation, editing and management tools, 3D Sprint enables a significantly decreased cost of ownership of Figure 4® by reducing the need for software seats by third party vendors. 3D Sprint's single user interface delivers the tools needed to go from design to 3D print.

With standard 3D data translators provided, import and repair of 3D meshes is enabled. Access to a wide range of 3D editing tools supports immediate printability analysis, and takes advantage of the built-in, intelligent software to optimize part placement and supports for your 3D printer.

3D Sprint's management and monitoring tools allow engineers to accurately estimate print time and optimize material levels and usage both before and during the print operation.

Management of print queues, job priorities, and monitoring of printers enables immediate understanding of all print jobs, helping to reduce total cost of operations.

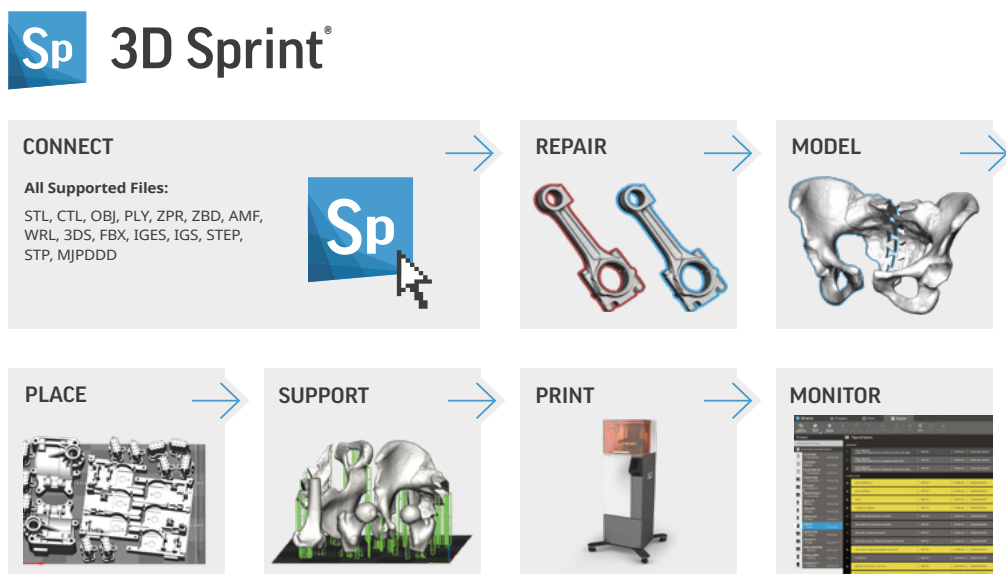


Figure 4® Standalone

Ultra-fast and affordable for rapid, same-day prototyping

With fast part throughput, repeatability and accuracy, Figure 4® Standalone sets a new benchmark for rapid prototyping. Parts can be designed and printed in the same day, allowing for fast design iteration and verification, and same day shipping.

AFFORDABILITY

Industrial-grade durability at an affordable price

VERSATILITY

Performance from a wide variety of materials

SPEED

Fast throughput speed for accelerated “parts in hand” delivery

LOW TOTAL COST OF OPERATION

Cost efficient and productive

What's Next? Interested in Learning More About Figure 4[®] Standalone?

Talk to an expert about which material
and solutions would work for you

Get in Touch

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