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# *In-depth Insights: Inkbit's Vision-Controlled Jetting*

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## Summary

Inkbit's unique Vision-Controlled Jetting technology platform enables the serial manufacture of quality production-grade parts. Vista, the first VCJ 3D printer, is a viable alternative for manufacturing operations and service bureaus that produce high-volume, high-quality 3D printed goods.

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- Vision-Controlled Jetting (VCJ) is an additive manufacturing process that employs in-process high-speed 3D scanning techniques to precisely deposit material droplets according to the CAD model
- Inkbit's unique material jetting technology, closed-loop feedback control, and intellectual property differentiate VCJ from other plastic additive manufacturing technologies
- VCJ enables high speed, repeatable production of prototypes and finished goods made with stiff, rigid epoxy and soft, flexible elastomer materials singly or in combination
- VCJ applications include manufacturing operations and finished goods used in a wide range of industries
- The investment cost, including finishing and facility costs, material costs, and high throughput of Vista, the first VCJ 3D printer, offer a compelling return

## Vision-Controlled Jetting Defined

It's not very often that a new additive manufacturing (AM) technology comes along. Sure, many companies say their 3D printers employ a unique technology. Still, they are simply applying a brand name to one of the seven AM technologies defined by the ISO/ASTM 52900:2021 standard. Inkbit's Vision-Controlled Jetting technology is the exception to other vendors' branding tactics. A unique material jetting technology, closed-loop feedback control, and intellectual property that dynamically generate the next print layer based on scan data from the previous one differentiates VCJ from other plastic additive manufacturing technologies.

Vision-Controlled Jetting (VCJ) is a material jetting additive manufacturing process that employs in-process, high-speed 3D scanning to precisely deposit material droplets according to the CAD model. Industrial print heads combined with proprietary materials, software, and voxel-by-voxel scanning architecture enable Inkbit's Vista printer to produce durable, cost-competitive, 3D-printed parts with fine, high-resolution features and tight tolerances. Coupled with VCJ's melt-away wax support material, Vista enables production-scale additive manufacturing with high-performance polymers.

ISO/ASTM defines material jetting as an "additive manufacturing process in which droplets of feedstock material are selectively deposited." VCJ's closed-loop jetting technology, which incorporates proven contactless industrial printheads, patented in-line vision, and machine learning techniques, is a unique technology subset of material jetting.

Figure 1. Vision-Controlled Jetting Process

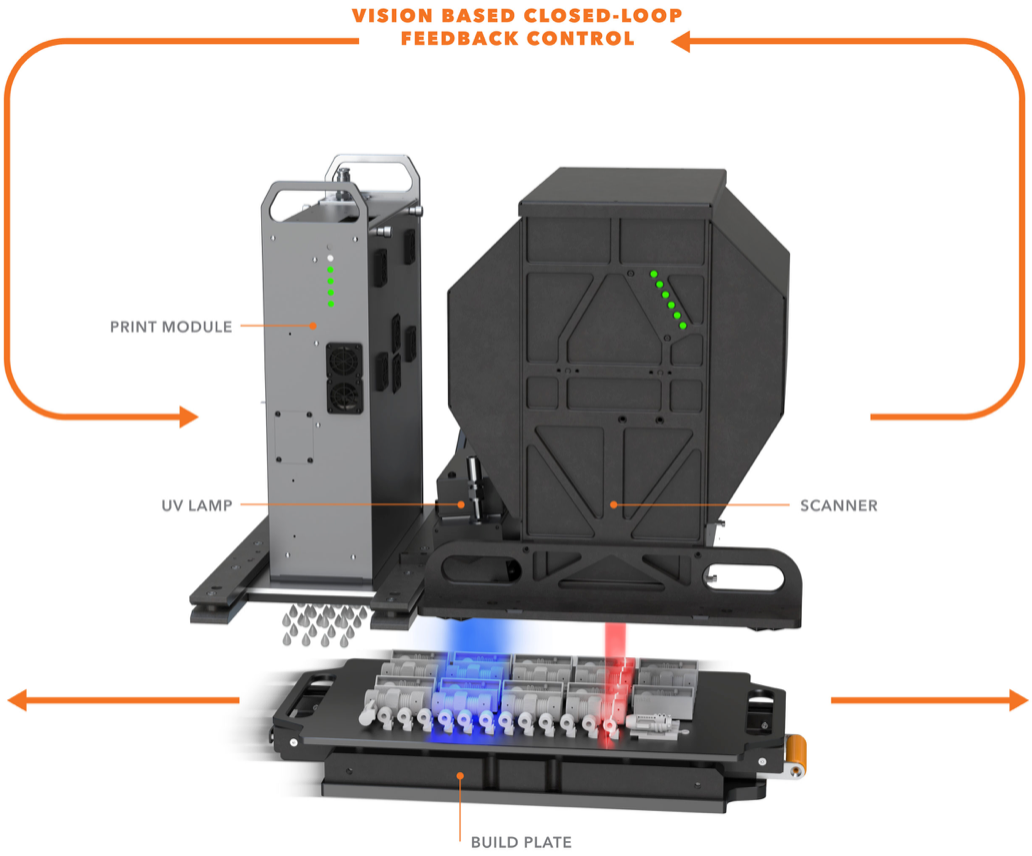


Image source: Inkbit

Inkbit's "Vista" is the first commercially available 3D printer to incorporate VCJ. Vista uses laser surface profilometry to create a topographic map of each layer, combining the scan data with the part's geometry to generate the next layer dynamically.[1] VCJ's dynamic, real-time layer analysis and generation ensures your parts are built quickly and accurately every time.

VCJ does not require CAD file modifications before 3D printing with Vista, unlike other additive manufacturing technologies. "Inkbit Construct" adds support deposition patterns, layer slices, and build plate packing in the STL file format, with STEP and 3MF support planned for July 2022. For your multi-material parts, Inkbit Construct also assigns materials to regions of the part and creates transitions between materials, mixtures, and gradients.

Vista jets the part and support materials with four interleaved FUJIFILM Dimatix piezo printheads that span the build plate, maximizing throughput. Dimatix is a long-time provider of commercial-off-the-shelf and modified industrial printheads used in a wide range of high-volume industrial applications. The printheads jet material across the build plate's width without gaps.

[1] Laser (or optical) surface profilometry employs a light or laser beam that scans the item without touching its surface, in contrast to the metal probe used in contact profilometry.

Importantly, VCJ technology does not require a roller or knife to planarize each layer as other UV polymer 3D printing technologies do. This unique contactless printing process, which means no mechanical flattening is required and enables continuously curing chemistries and ultimately better materials, enables Vista to jet materials that do not contain acrylates. As a result, Inkbit has introduced new high-performance, dark cure, long-chain polymer chemistries that deliver superior mechanical properties compared to other UV resin.

The VCJ printing and finishing steps are:

1. Create solid CAD models of the parts to be printed
2. Prepare the files for printing with Inkbit Construct
3. Download the print file using the on-press user interface or remotely with Inkbit's build prep application
4. Printheads jet the part material(s) and wax support material as the build plate moves left, right, and down, while UV lamps simultaneously cure each layer
5. Laser surface profilometry inspects the layers in real-time
6. Closed-loop vision control software analyzes the data and instantly adjusts the following material jetting sequence if needed
7. Remove the completed build and place the plate in an oven to melt the support wax
8. Place the parts in a basket, submerge in a de-waxing solution, and rinse with water before drying
9. Summarize production and quality assurance data with Inkbit's print management program for use in your enterprise resource planning and costing tools

Figure 2. VCJ Topographical Map

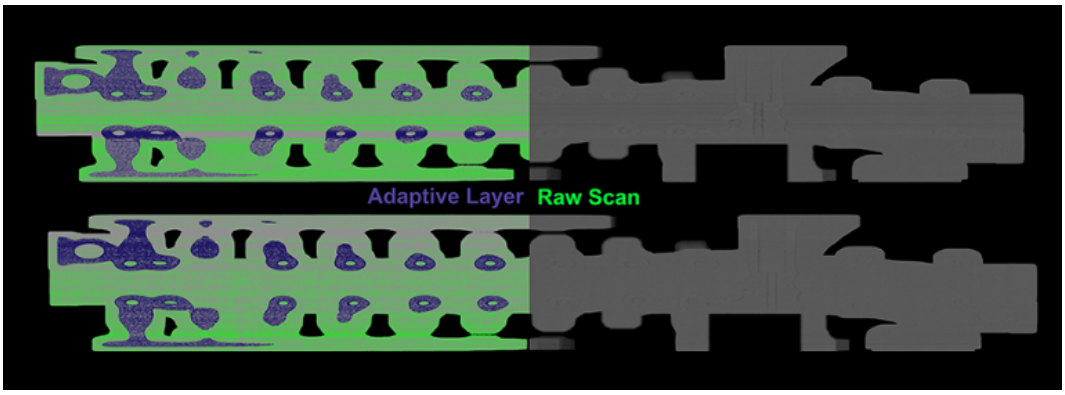


Image source: Inkbit

## About Inkbit

VCJ's core jetting and layer scanning technology was developed at MIT's Computer Science and Artificial Intelligence Laboratory (CSAIL) and licensed exclusively to Inkbit, which named the process "Vision-Controlled Jetting." Inkbit spun out of MIT CSAIL in May 2017. The company's R&D, manufacturing and general offices are in Medford, MA, five miles from Boston and the research and development resources of one of the world's AM technology hubs.

Inkbit has an exclusive license to use MIT's technology for the life of the university's patents. Subsequent and ongoing R&D has resulted in more than 20 patents issued to Inkbit. Moreover, the company has received approximately $50 million in investor funding as well as revenue from DARPA and other joint development activities.[2] Inkbit senior managers and its board of directors have extensive entrepreneurial, start-up, and additive manufacturing industry backgrounds, including critical roles at Arcam, DSM, Objet, and Stratasys.

## VCJ Markets

VCJ is optimized for high-volume additive manufacturing of components that go into finished goods. Inkbit Vista's material range, high throughput, accuracy, and precision are ideal for your parts' true series 3D print production.

Inkbit's initial customer focus includes manufacturers of industrial components, medical equipment, medical devices, and AM service bureaus. The range of VCJ markets will expand due to Vista's ability to manufacture high-volume parts with up to three rigid epoxy and soft elastomer materials, singly or in combination. For example, VCJ has excellent potential in the service bureau market for conventional and additive manufacturing of parts on-demand and under contract.

Vista can certainly produce small quantities as precursors to much longer runs. Give your salespeople examples of what will eventually be injection-molded parts as demonstrators while waiting for injection mold tooling to become available. VCJ-printed parts can also span the supply chain gap caused by lengthy tooling or other delays, enabling you to generate revenue sooner.

## Vista Specifications & Features

Every 3D printer, regardless of manufacturer, has specific material and performance characteristics. No one 3D printer does it all and likely never will. Anyone assessing a production 3D printer's capabilities must address these six questions:

- Print engine—Does the AM technology utilize the materials you require? Is the 3D printed part an acceptable replacement or equivalent to conventionally manufactured parts?
- Build volume—Do the width, depth, and height dimensions meet your needs?
- Materials—Does the range meet your present and projected requirements?
- Orientation—How must parts be positioned within the build volume to ensure adequate strength and durability of the finished pieces?
- Feature resolution—Can the 3D printer produce the resolution, depth, hole and thread precision, dimensional accuracy, wall thickness and other features that your customers require?
- Speed—How does your current manufacturing time compare to the 3D printer's projected throughput, including set-up and clean-up, cool down, and post-processing time?

[2] Total funding as of April 2022

Figure 3. Vista Specifications[3]

| Specification | Inkbit Vista |
|---|---|
| Print Engine | Vision-Controlled Jetting (VCJ)<br>Closed-loop jetting and *in situ* scanning of polymer and wax materials with piezo drop-on-demand printheads<br>Single-pass printing of the build plate width in each pass |
| Build Volume (X, Y, Z-axis) | 500 mm x 250 mm x 200 mm<br>19.6 in x 9.8 in x 7.8 in |
| Materials | EP-R-017, a rigid, durable epoxy with good impact and temperature resistance<br>EP-C-003, a rigid, chemical and temperature resistant epoxy<br>TE-E-016, a low durometer (Shore 25A), temperature resistant elastomer<br>Wax support material (recyclable)<br>Provided as a "bag-in-box" for easy storage and handling |
| Printable Materials per Build | Up to four concurrent (three engineering, one support) |
| Build Plate Density | Minimum gap between parts: 1mm |
| Maximum Vertical Build Rate | Up to 16mm/hour, independent of XY coverage or build plate density |
| Source: Inkbit | |

Parts can be packed into the build plate with 1mm gaps, which means the number of pieces per build depends only on part geometry. VCJ does not have thermal or other constraints that would limit build density. Operators quickly start jobs and change Vista from one build to the next within minutes.

Post-processing is a batch process that occurs outside the Vista printer. Post-processing time depends on the build's height and density and the wax melt time. After melting, the de-waxing, rinsing, and drying processes are quick and easy.

[3] Specifications and features are accurate as of the report's publication date. Visit Inkbit for current information.

## Quality of 3D Printed Parts

3D print quality is critical to your success as a manufacturer and your customers as users. Just one unsatisfactory job may end a business relationship. To ensure a 3D printer meets your needs, ask these questions, and determine the results by testing your designs on the device you are considering:

- Do the 3D printed parts shrink or warp?
- Is surface roughness adequate or require post-processing?
- Do the results measure up to your quality assurance standards?

In this regard, the quality and mechanical properties of Vista's VCJ output will meet or exceed many users' quality requirements.

### Figure 4. Vista Quality Characteristics

| Characteristic | VCJ Capability |
|---|---|
| Printer resolution | 32µm x 63.5µm x 20µm adaptive |
| Layer thickness | ~20µm layers |
| Wall thickness | Minimum wall thickness: ~300µm |
| Dimensional tolerance (without post-processing) | +/- 75µm |
| Surface roughness (without post-processing) | 5-10 µm Ra |
| Orientation | Isotropic properties based on material<br>~15% lower tensile strength on the Z-axis than X or Y[4] |
| Feature Resolution | Positive feature resolution: ~300µm<br>Negative feature resolution: ~300µm |
| Source: Inkbit | |

Over time, Inkbit anticipates using higher density printheads with enhanced capabilities for those applications that require them.

[4] Approximate value as of the report's publication date; isotropic properties are being characterized

Figure 5. Select VCJ Mechanical and Thermal Properties

| Property | EP-R-017 Epoxy | EP-C-003 Epoxy | TE-E-016 Elastomer |
|---|---|---|---|
| Ultimate Tensile Strength | 55.8 MPa | 39.5 MPa | 0.8 MPa |
| Elongation at break | 6.2% | 1.6% | 179% |
| Shore Hardness | 78 D | 81 D | 25 A |
| Glass Transition Temperature | 75 °C | 131 °C | -31 °C |
| Source: Inkbit; Consult their website for the latest and complete specifications | | | |

Vista incorporates in situ monitoring and correction to ensure the 3D printed parts meet or exceed these results. The printer scans each layer to make sure it is optimized as the build plate moves back and forth, analyses the results, and provides feedback to the operating control system, all in real-time. This tight control during Vista's build process assures the quality of the current part and the repeatability of future orders.

Figure 6. Examples of Elastomer and Epoxy VCJ Parts

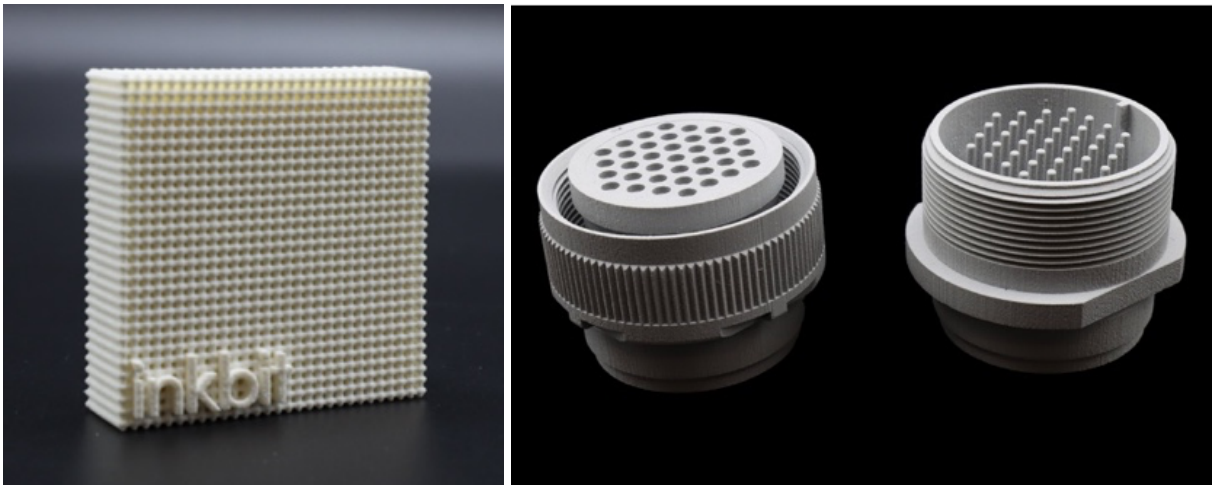


Photo source: Inkbit

## Facility Requirements

Anyone who has installed production machinery has stories about what went wrong or very nearly did. For that reason, you must ask two questions:

- Do you have the space to safely and efficiently produce and finish 3D printed parts in current and expected volumes?
- Does your insurance company agree with your assessment of operator and workplace safety?

Vista reduces the need for costly facility modifications by utilizing pre-packaged materials that are easy to store and dispense. Unusual building configurations, personnel safety, or material handling precautions are unnecessary, enabling you to potentially place Vista in a factory or office building with minimal site modifications. For example, install Vista's materials cabinet where you see fit, whether beside or behind the printing unit. Post-processing may occur beside the printer or in another room according to your needs.[5]

Figure 7. Facility Requirements

| Characteristics | Vista Facility Requirements |
|---|---|
| Printer dimensions (L x W x H) | 2.8m x 1.5m x 2.2m |
| Materials cabinet dimensions | 2.30m x 0.91m x 2.35m (1.87m without riser) |
| Printer weight | Approximately 1,500 kg |
| Materials cabinet weight | Approximately 1,000 kg |
| Printer power requirements | 200-480 VAC 50/60 HZ 15 KW three-phase<br>200-240 VAC 50/60 HZ 5 KW single phase<br>System requires both |
| Materials cabinet power requirements | Flying lead 3Ø 200-480 VAC 50/60 Hz; 12 kW - 25A max current<br>Flying lead 1Ø 200-240 VAC 50/60 Hz; 5 kW - 20A max current |
| Source: Inkbit | |

## Operating and Workflow Software

When you think about industrial 3D printers, the question that comes to mind is, "Does the 3D printer work with the OBJ, STL or 3MF formats?" Vista uses STL, the de facto standard for AM devices and will support 3MF and STEP. Vista's software enables your operator to move/rotate/scale, center on the build platform, set process parameters, and slice.

[5] Always consult your landlord, insurer and local fire and safety officials prior to installing any industrial 3D printer to ensure local building codes and other facility requirements are met.

Another frequently overlooked question is more critical: Does the vendor enable the integration of its 3D printer into your digital order processing, design, and production workflow, including supply chain integration, spare part production, and costs? The answer for most 3DP providers is either "No" or "Somewhat." Inkbit is developing an API that connects Vista to your network, enabling the operator to download jobs and manage their production while uploading performance and quality assurance data.

## Operating Vista

One of the most overlooked aspects of capital equipment purchases is the people who will operate the machinery. Engineers and senior managers do their best and may have worked from the factory floor into their current roles. Still, they may not understand what it takes to cost-effectively produce quality parts every day.

Vista's operator interface is clean and intuitive. Machine loading, cleaning, and material changeover are simple, easy to learn and quick. Material loading is simple, using 20-liter boxes of raw material emptied into 80-liter storage containers, providing enough product to run for 72 hours. The control software monitors the volume of liquid resin in each tank, ensuring new jobs begin only when sufficient material is available. Importantly, Vista continues non-stop while more material is added to the containers.

Part off-loading is straightforward: Unlock the build platform, remove it from the printer, and place the platform in an oven to melt the support wax. Operators do not handle individual parts, maximizing their productivity.

## Staff Skillsets

No doubt you have designers and operators willing to implement an exciting new technology. However, just as a teenager learns to drive before buying a car, you must ensure that your staff has the skills necessary to implement VCJ printing before embarking on this road.

Inkbit provides operator training before and during installation. However, the relative simplicity of VCJ technology and Vista's ease of use, coupled with Inkbit's staff support, means the learning curve is not steep.

Your non-production personnel will experience significant changes as they transition from conventionally manufactured goods to VCJ printing. Inkbit ensures their clients' salespeople know how to sell VCJ output, designers can create printable files, and accountants correctly cost finished goods.

Figure 8. Staff Skillset Requirements

| Personnel | Staff Skillsets |
|---|---|
| Designers, engineers, or CAD specialists who create the digital models to be 3D printed | Requires an understanding of VCJ design guidelines, especially orientation and packing of parts on the build plate<br>Inkbit is developing tools that will automatically orient and pack parts in the build |
| Personnel who operate Vista and support staff | Must understand VCJ operating parameters and their influence on printer output and part quality<br>Must be competent in raw material handling, post-processing techniques, and packaging finished parts |
| Marketing and sales personnel | A thorough understanding of VCJ technology, how it compares to other 3DP and conventional manufacturing technologies<br>An ability to overcome prospective customers' objections based on the fear they will lose their jobs if the additive manufacturing project fails |
| Source: Monadnock Insights | |

## Vista's TCO & ROI

A new machine's total investment depends as much on whether you already have similar systems in place as it does on the purchase price. Retrofitting a facility currently used for additive manufacturing, especially one with space available for the new system, its accessories and related finishing equipment, is much less expensive than constructing a new building. A new machine's operating cost may involve expenditures ranging from simple protective gear to storing and conveying raw materials and finished goods.

Essential questions to ask when developing the Vista printer's total cost of ownership (TCO) and the return on investment (ROI) for your unique operation include:

- Negotiated hardware, software, and material purchase prices
    - The investment cost for a 3D printer and auxiliary equipment (the list price of a Vista printer and its accessories is $750,000)
    - Price for the materials used to 3D print the parts, including production and post-processing material that may be required
- The cost of facility modifications, post-processing equipment, personal protective equipment
    - Facility buildout or retrofit
    - Safety and material handling systems
- 3D printer throughput when producing typical parts
    - Job downloading and printer preparation
    - Printer run time
- Post-processing and packaging costs

Always consider the total processing time, labor costs, and overhead charges when evaluating the industrial 3D printers that you may purchase. Vista's capital investment, including finishing and facility costs, competitive material prices, and high throughput, offers a compelling return.

## Advice

Undoubtedly, the industrial additive manufacturing market is growing in terms of the number of users and technologies. Jetting technology has tremendous upside potential, whether 2D, 3D, 4D printing or plastic, metal or bioprinting. Inkbit's Vision-Controlled Jetting enables you to capitalize on polymer printing's promise.

As of this report's publication date, Vista is too new to have many user references and use cases. Nevertheless, VCJ's unique technology, throughput and quality mean leading-edge corporations, research facilities, and additive manufacturing service bureaus should evaluate Vista for their operations.

Clients interested in acquiring a Vista printer, or using a service bureau's output from one, should:

- Test Vista's ability to produce parts with the same or better quality and performance characteristics you and your customers' demand
- Accurately determine the capital investment (machine cost and delivery) and the cost to outfit your facility with proper safety equipment and material handling systems
- Determine how quickly Inkbit provides support and service, prioritizing rapid response times from technicians and parts depots
- Involve your operations personnel and managers in the 3D printer evaluation, encouraging hard questions about training and day-to-day machine operation

Vista, the first 3D printer with Inkbit's proprietary VCJ technology, offers ease of implementation, a compelling TCO, and high throughput manufacturing of production-grade parts. Vista is a viable option for firms seeking an alternative for prototyping products and producing serial parts and deserves strong consideration as your polymer production 3D parts printer.

## Glossary

| Term | Definition |
|---|---|
| Additive manufacturing (AM) | A production technique that uses a device to create physical objects layer by layer from digital models<br>*Synonym:* 3D printing |
| Build volume | Total space available within the 3D printer's build chamber for producing items |
| Binder jetting | An AM technology in which a selectively deposited liquid bonding agent joins powder materials |
| Directed energy deposition | An AM technology in which focused thermal energy fuses materials by melting as they are deposited |
| Material extrusion | An AM technology in which material is selectively dispensed through a nozzle or orifice |
| Material jetting | An AM technology in which droplets of liquid materials are selectively deposited |
| Powder bed fusion | An AM technology in which thermal energy selectively fuses regions of a powder bed |
| Vat photopolymerization | An AM technology in which liquid photopolymer in a vat is selectively cured by light-activated polymerization<br>*Synonyms:* Stereolithography, SLA |
| Sheet lamination | An AM technology in which sheets of a material bond to form an object |
| 3D Manufacturing Format (3MF) | A 3D printing file format that allows design applications to send full-fidelity 3D models to a mix of other applications, platforms, services, and printers |
| Sources: Monadnock Insights; 3MF Consortium | |

## Disclaimer

All specifications and features are accurate as of the report's publication date. Visit Inkbit for current Vista features and specifications.