A.T. Kearney

3D Printing: A Manufacturing Revolution

The question is not if but when companies need to consider 3D printing. A.T. Kearney is helping forward-thinking players overcome the challenges and take advantage of powerful opportunities in this next generation of manufacturing.

"Digital fabrication will allow individuals to design and produce tangible objects on demand, wherever and whenever they need them. The revolution is not additive versus subtractive manufacturing; it is the ability to turn data into things and things into data."

— **Neil Gershenfeld,** director of the Center for Bits and Atoms at the Massachusetts Institute of Technology

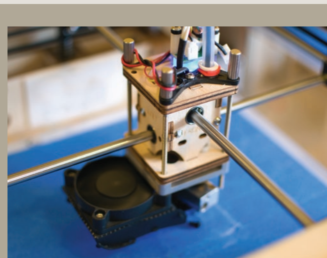
Is 3D Printing the Next Industrial Revolution?

Also known as additive manufacturing, 3D printing (3DP) creates physical products from a digital design file by joining or forming input substrate materials using a layer-upon-layer printing approach. There are seven major printing technologies today.

What is 3D printing?

1
Create an image using computer-aided design software.

2
Send the image to a 3D printer.



2
The 3D printer then builds the product by putting down thin layers of material.

Technology	Material type
Photo-polymerization	• Plastics • Ceramics and wax
Material extrusion	• Plastics • Sand
Sheet lamination	• Plastics • Metals
Binder jetting	• Plastics • Metals • Glass
Material jetting	• Plastics • Metals • Wax and biomaterial
Powder bed fusion	• Plastics • Metals • Ceramics, sand, and carbon
Direct energy deposition	• Metals

Source: A.T. Kearney analysis

Each has a different way of processing input materials into a final product. Combined with advanced scanning, 3DP technologies allow physical products to be converted into digital design files and vice versa. Going forward, 3DP has the power to transform the digital-physical interface for product design, development, and manufacturing.

3DP Creates Breakthrough Value in Product Design and Production

Across five dimensions, 3DP offers distinct benefits that traditional manufacturing cannot deliver:

Mass customization. The ability to create custom-built designs opens doors to unlimited possibilities.

New capabilities. Complex products can be mass produced without high fixed-cost capital investments and at a lower variable cost than traditional methods.

Lead time and speed. Shorter design, process, and production cycles get products to market faster.

Supply chain simplification. Production is closer to the point of demand with much less inventory.

Waste reduction. With unused powder being reused for successive printing, much less material is wasted.

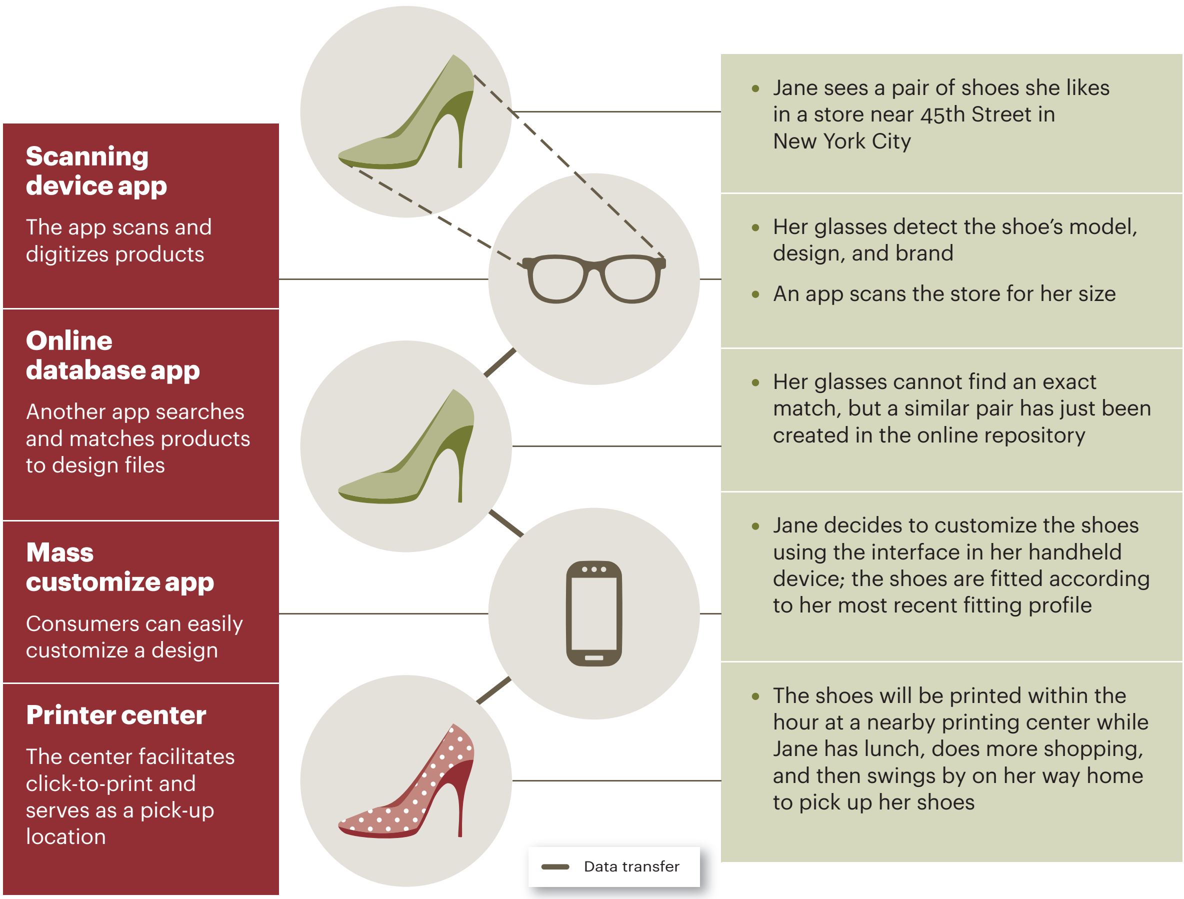
3D printing offers distinct benefits that traditional manufacturing cannot deliver.

Although traditional manufacturing will have cost advantages in large-scale production settings for the foreseeable future, 3DP's role will grow in settings where these five dimensions are crucial for success, such as prototyping (lead time and speed), personalized medical implants (mass customization), and jet components that require a complex assembly and have high fly-to-buy ratios (new capabilities and waste reduction).

3DP Creates New Value Chains

In addition to transforming how products are designed and made, 3DP will disrupt value chains. Consider this retail scenario, where 3DP transforms how a consumer shops, co-creates, and buys shoes.

3D printing allows shoppers to create custom-made shoes



Source: A.T. Kearney analysis

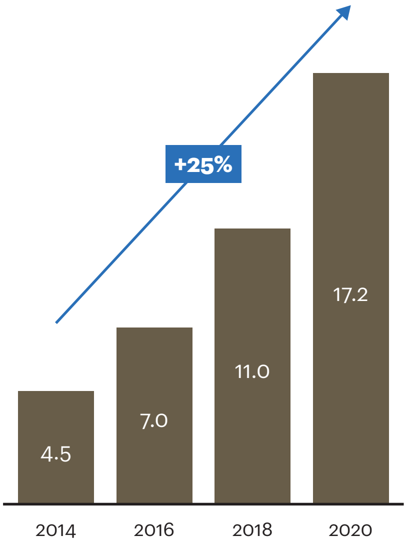
Opportunities

By 2020, 3DP is expected to be a $17 billion market.

The use of 3D printing is expected to grow

Global 3D industry market for hardware, supplies, and services

$ billion



3D printing market

Sector	2014	Five-year CAGR
Aerospace (including defense)	$0.8 billion 18%	15–20%
Industrial (including construction)	$0.8 billion 18%	15–20%
Healthcare	$0.7 billion 15-17%	20–25%
Automotive	$0.5 billion 12%	15–20%
Jewelry	$0.5 billion 12%	25–30%
Energy	Less than 5%	30–35%
Other (many sectors)	Less than 20%	20–25%
Total	**$4.5 billion**	**25%**

Sources: Wohlers Report, SmarTech Markets, Credit Suisse; A.T. Kearney analysis

Already, 3DP is prevalent in prototyping and small-batch production.

Several industries have embraced 3D printing

	Current applications	Imminent applications	Ideal applications
Automotive	• Specialized components for engine production • Innovative designs, such as concept car chassis	• New products with prior design for manufacture limits • Lightweight structures, such as chassis	• Low to medium volume • High value-to-weight ratio • High fly-to-buy and material waste ratio • Complex geometry • Complex multi-part assembly under traditional manufacturing • Need for form-function-fit customization
Aerospace	• Production-approved components, such as fuel nozzles • Prototype jet engine parts	• High-performance parts, such as sensor housings • Full-scale manufacture of semi-standard components	
Medical	• Orthodontic implants for hips and spines • Surgical guides	• Stents • Personalized prosthetics	
Consumer	• Custom jewelry • High-performance sporting goods	• Apparel production • Fashion accessories production	

Source: A.T. Kearney analysis

Challenges

Hardware could be five to seven years away from achieving the technical and cost requirements needed to go beyond its current prototyping role into supporting production across broad, multi-material categories.

Hardware must improve for 3D printing to succeed with complex items

Current capability | Capability in five to seven years | Capability in more than seven years

Complex ↕ Simple

	Throughput	Number of materials	Assembly complexity	Precision and tolerance
Cars	Hundreds per hour (needs a volume-based processing breakthrough)	More than 100	Complex assembly, safety, and functional testing	+/- 0.05 mm
Apple watches	Thousands per hour (needs a surface-based printing breakthrough)	More than 50	Complex assembly, safety, and functional testing	+/- 0.0001 mm
Cosmetics		More than 15	Complex functional testing	5 ppm
Helmets		More than 10	Complex assembly and safety testing	+/- 0.001 mm
Cameras	Hundreds per hour	More than 10	Complex assembly and functional testing	+/- 0.001 mm
Biomedical device kits	10 to hundreds per hour	More than five	Simple assembly and flow testing	+/- 0.025 mm
Toys	10 to hundreds per hour	One to three	Minimal assembly	+/- 2 mm
iPhone cases	Thousands per hour	One	None	None

Note: mm is millimeters; ppm is parts per million.
Source: A.T. Kearney analysis

New software platforms will be vital to support 3DP applications.

The 3D printing software ecosystem

Scanning and digitization app	Online database app	Mass customize app	Printer center	Intellectual property management and payment system	3D data and records management
• Rapid image-to-design matching • High-performance scanning embedded in high-quality scanners • Accurate and easy to use	• Single-source repository of all product and component design templates ("the iTunes of design") • Integration with original equipment manufacturers and crowd-sourced designers	• Instant and flexible design customization • Visual dashboard with final price and sustainability information • Integration with medical and user guide advice app	• Low-cost, high-throughput, high-quality production of 3D printed products • Centralized factories, local printers, or storefronts	• Bitcoin and design credit payment options • Segmented licensing and royalties • Last-mile fulfilment	• 3D services subscribers and providers database • Secure information processing and transaction • Records management and web services

Source: A.T. Kearney analysis

In both education and design capability, 3D design thinking is preventing mass adoption by companies and consumers.

Better education and design capabilities could give 3D printing a boost

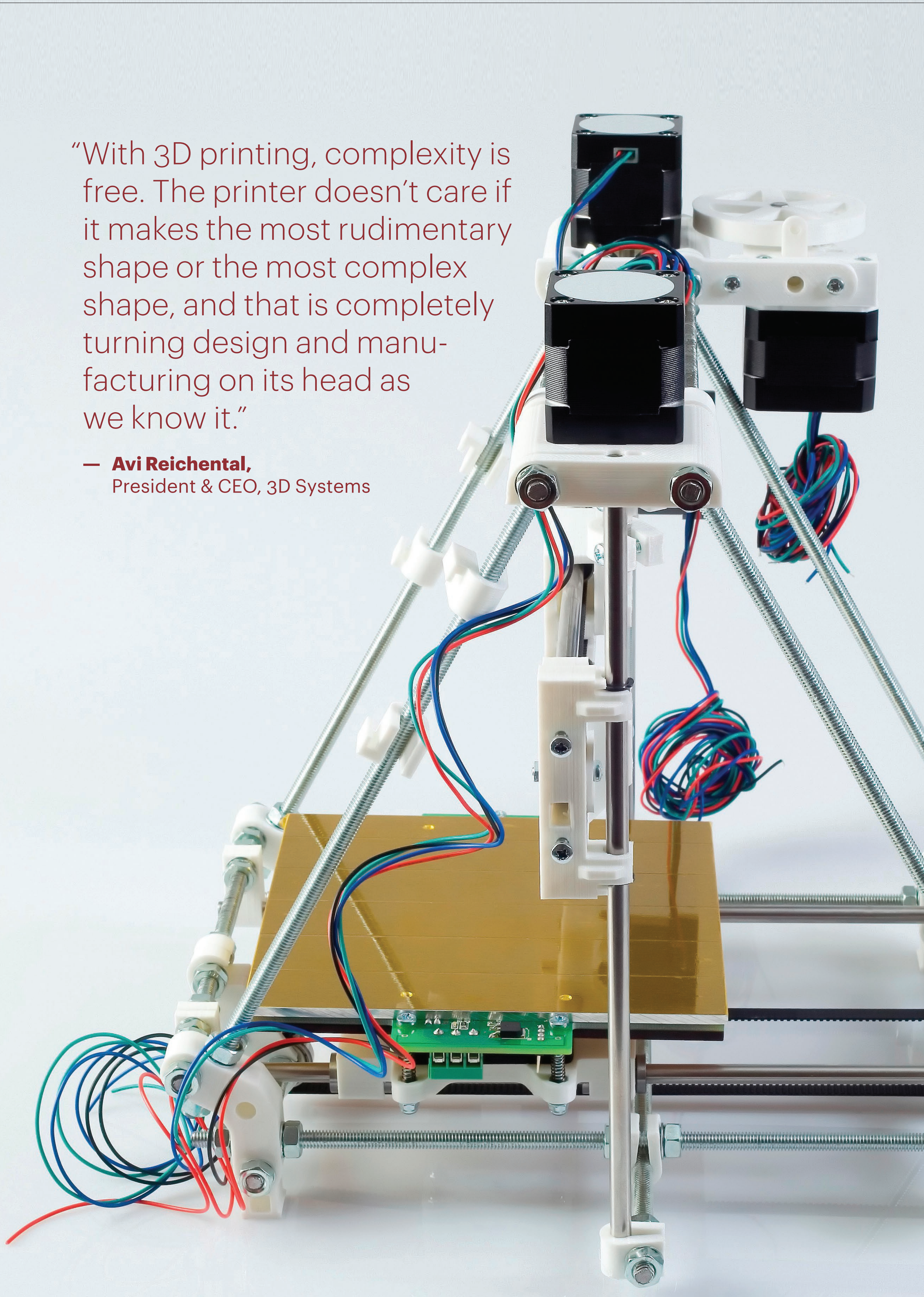
Design thinking ⟷ DIY movement

Education	Tools and ideas	Social media and online resources
• Only 1 percent of the United States is 3D-printing literate, meaning they understand how the process is used, according to the Illinois MakerLab at the University of Illinois • 3D printing "is still relegated to industry and tinkerers due to the high learning curve," one 3D enthusiast said	• "Nearly all—95 percent—say they intend to go online via a PC to find design ideas" for home improvement, according to Planese • "No one understands how product development works," one 3D printing entrepreneur said	• More than a third of homeowners start their home improvement projects online, according to Zillow • Seven in 10 use the Internet for information or to get help when starting a project, and 25 percent research a specific brand, according to compete.com

Note: DIY is do it yourself.
Source: A.T. Kearney analysis

"With 3D printing, complexity is free. The printer doesn't care if it makes the most rudimentary shape or the most complex shape, and that is completely turning design and manufacturing on its head as we know it."

— **Avi Reichental,**
President & CEO, 3D Systems



Planning for the Future

The question is not if but when companies need to consider 3DP in their strategic planning. Forward-thinking players will need to sense and anticipate the future and create an adaptive response by answering five questions:

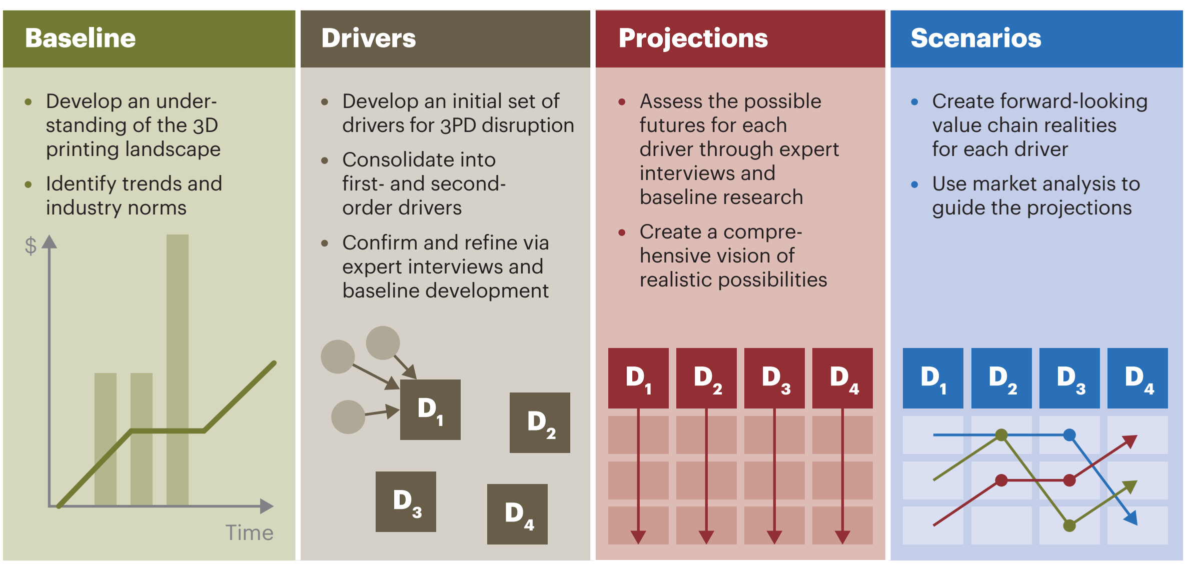
- How will 3D printing shape the end-to-end value chain in my sector?
- How robust is my firm's five- to 10-year value chain strategy against 3D disruptions?
- What are the most relevant 3D disruption scenarios?
- What are the leading indicators and trigger points for anticipating 3D disruption?
- What are the immediate action items to future-proof against 3D disruption?

A.T. Kearney and 3D Printing

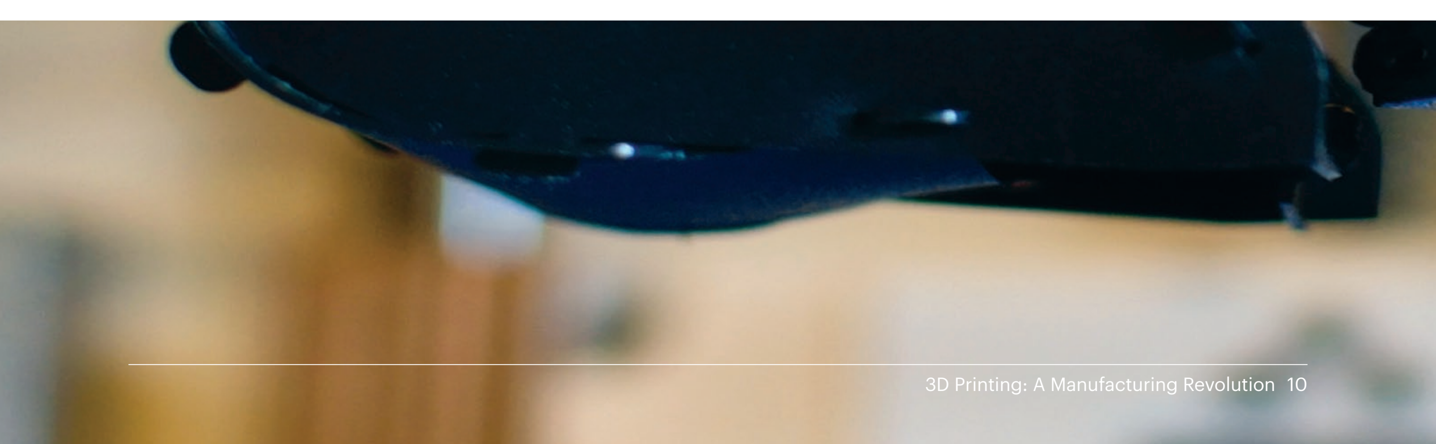
We collaborate with leading companies in the 3D printing ecosystem, including hardware OEMs, software platform companies, academics and researchers, and specialized marketing research firms, to help organizations understand and capitalize on 3DP opportunities.

We help our clients embrace opportunities by creating scenarios and future-proofing for 3DP disruptions in the value chain.

Scenarios and future-proofing help our clients prepare for 3D printing



Note: D represents various levels of disruption drivers.
Source: A.T. Kearney analysis

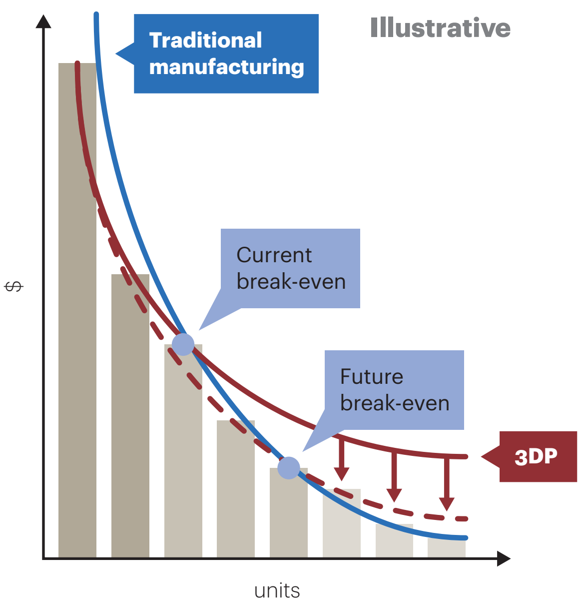


Our cost modeling compares 3DP and traditional manufacturing. We help answer three vital questions:

- At what point is 3DP cheaper than traditional manufacturing?
- How might the value chain get realigned?
- What is the impact of extreme demand variability?

Break-even comparison: traditional manufacturing vs. 3DP

Should-cost analysis by materials, functional performance, and structural characteristics



Sensitivity[1]	Change	Impact on break-even quantity[2]
Buy to fly ratio[2]	+10%	14 → 35% ↓
	−10%	50 → 125% ↑
Raw material $/lb	+10%	14 → 35% ↓
	−10%	50 → 125% ↑
Setup/run hours ratio	+10%	21 → 5% ↓
	−10%	23 → 5% ↑
Shop rates	+10%	11 → 50% ↓
	−10%	100 → 350% ↑
Material application (lb/hour)	+10%	4 → 82% ↓
	−10%	100 → 350% ↑

[1] Sensitivity analysis of underlying cost drivers. Broadly speaking, sensitivity refers to a measure of how far altering an input will vary the output.
[2] "Buy-to-fly ratio" is an aerospace term that refers to the ratio of the weight of the raw material used for a component to the weight of the component itself.

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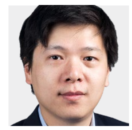

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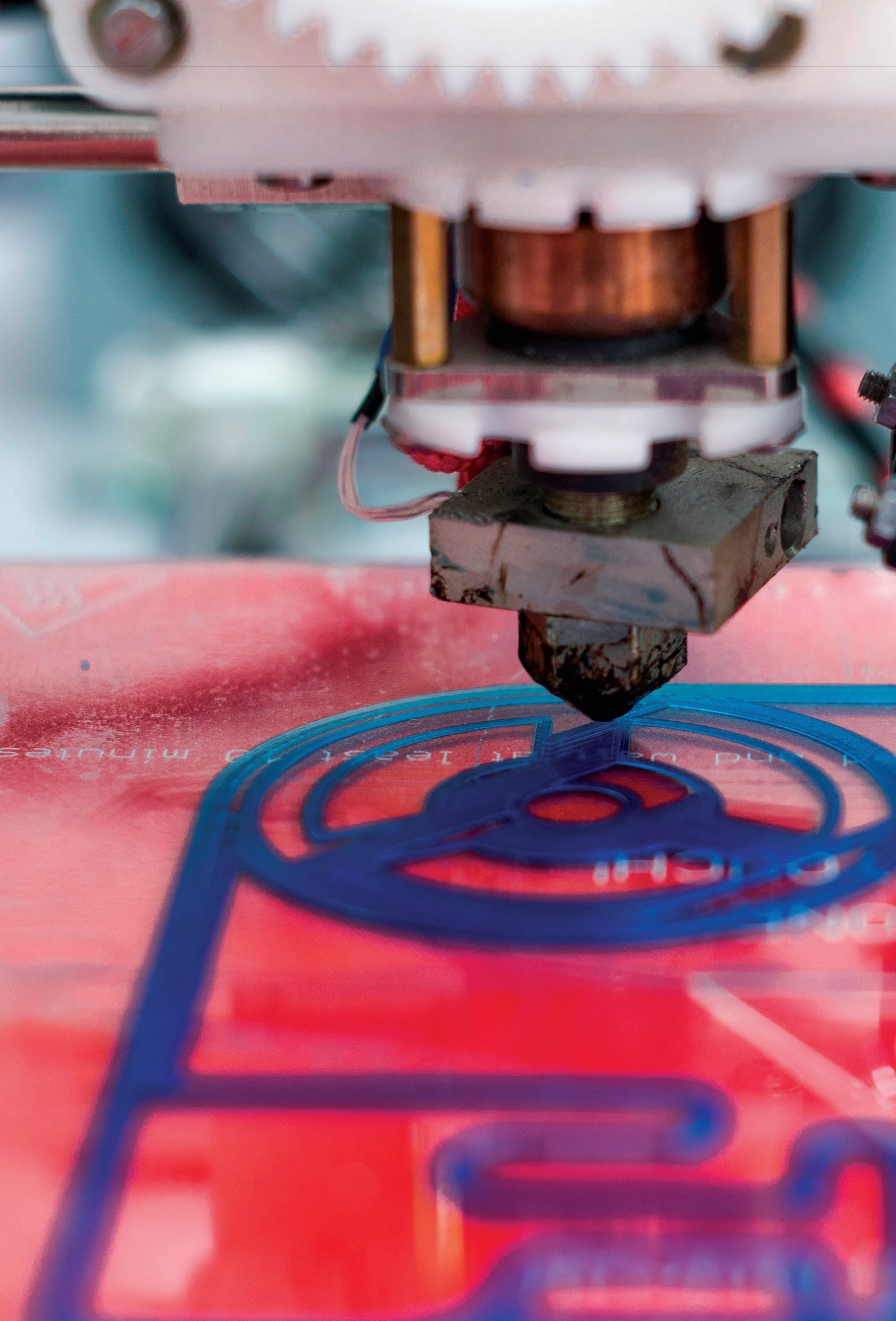

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The signature of our namesake and founder, Andrew Thomas Kearney, on the cover of this document represents our pledge to live the values he instilled in our firm and uphold his commitment to ensuring "essential rightness" in all that we do.