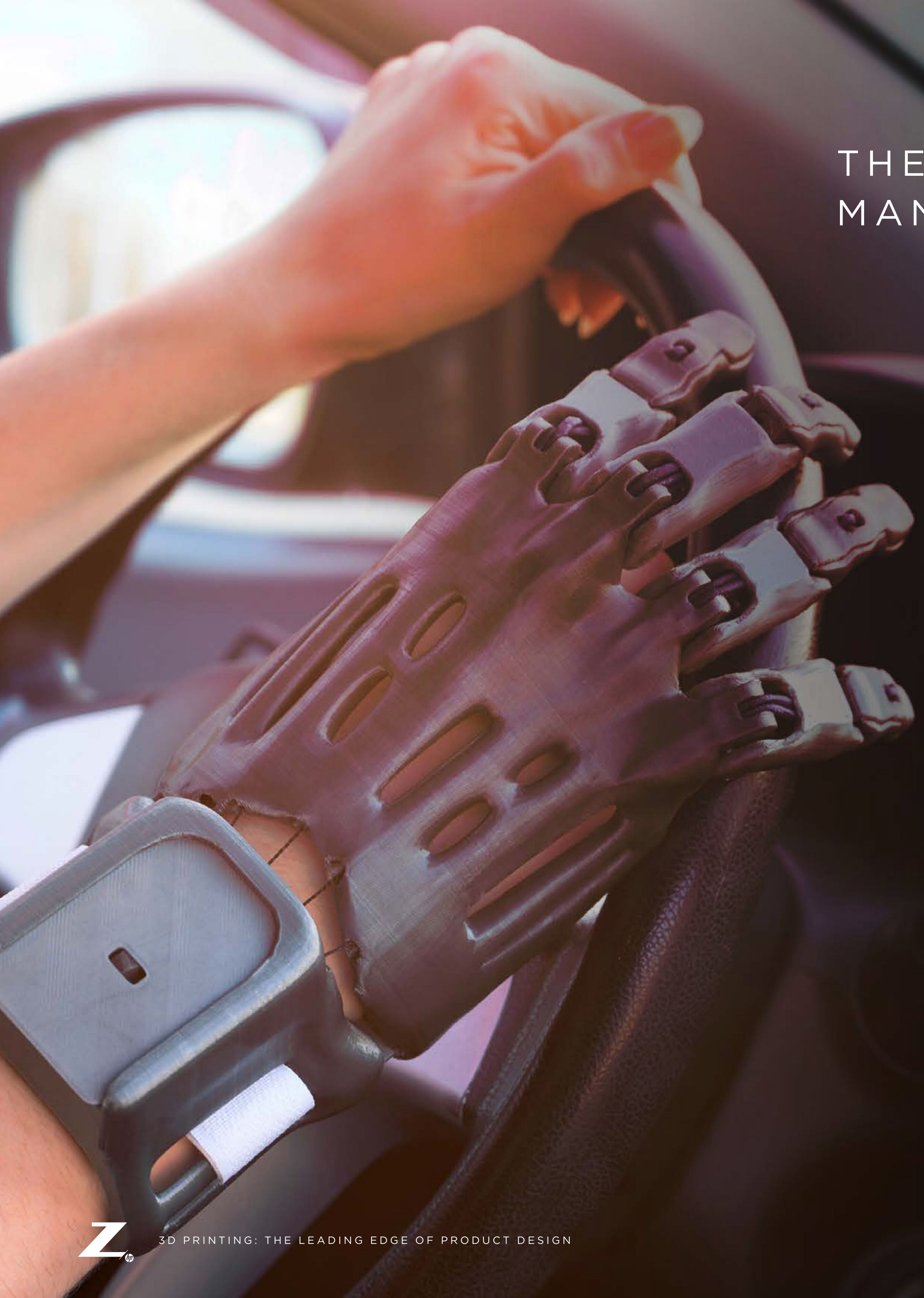
3D PRINTING:

THE LEADING EDGE OF PRODUCT DESIGN

AN **EXCLUSIVE REPORT**
BROUGHT TO YOU BY



THE TRANSFORMATION OF ADDITIVE MANUFACTURING

Some might be tempted to think of 3D printing as a novelty or a one-off process most commonly used for rapid prototyping, however it is now taking an essential role in manufacturing. Known in the industrial world as additive manufacturing (AM), 3D printing is one of the rare innovations that go beyond making an existing business process better, faster, or cheaper. AM promises to transform manufacturing in fundamental ways, diminishing the traditional reliance on specific tooling, concentrating capital and skills in fixed locations. With AM, production can be truly distributed. Products can be both designed and 3D-printed anywhere in the world, on a micro or macro scale. The implications for process economics and supply chains are profound.

Companies use 3D printers in place of traditional manufacturing methods to build three-dimensional objects based on a computer design model. Some of these products have complex geometries for which there is no conventional mass-production process.

"Software-driven generative design processes and 3D printing are allowing designers to mimic nature," says Kristin Mulherin, Founder and Managing Director of AM-Cubed, a Portland, Oregon-based consultancy focused on additive manufacturing.

"Nature organically designs living things for optimum function. That's essentially what a designer in the aerospace industry does by generating a prototype bracket optimized for performance under the forces and loads that part will experience, manufactured at an 80% weight reduction versus what could be achieved through conventional injection molding or machining," she says.

AM often will complement more conventional manufacturing methods. 3D-printed products may be post-processed using a variety of processes, Mulherin notes, such as heat-treating or polishing. Many products are subjected to hybrid manufacturing, both additive and subtractive.

"Additive manufacturing isn't a replacement for conventional manufacturing," she adds. "But in some applications, it can solve problems that molding or machining can't, especially in markets like aerospace and implantable medical devices, where high strength and light weight are critical priorities."

Across industries—consumer products, automotive, manufacturing, aerospace and defense, and more—product dev teams are using AM to create innovative products and speed production, using a range of materials and at an increasingly broad range of size and complexity.

DRIVING CREATIVE INNOVATIONS

Additive manufacturing has been on a stable growth path over the last decade. Although 3D printing is still less than 1% of the global manufacturing market, the technology is becoming an invaluable tool for production workflows.[1] Between 2018 and 2019, the number of manufacturers using 3D printing for full-scale production increased from 21% to 40%.[2] Even with the growth in full-scale product, in 2019, proof-of-concept and prototyping still dominated 3D printing applications.

More than 70% of enterprises have found new applications for 3D printing.[3] It also has spawned a variety of specialist contract manufacturing companies who can help transition their clients into hybrid production that includes AM. "We think of what we offer not as a factory but as a digital manufacturing ecosystem," says Dave Evans, CEO of Fictiv, one such contractor.

> "The purpose of additive... is to complement traditional techniques to make parts that were never feasible to produce before."
>
> **DAVE EVANS**
> CEO, Fictiv

Fictiv doesn't own its machines; it provides access via a digital platform machine shops or factories with extra capacity, globally, allowing product innovators to order from this distributed system. Many of Fictiv's partners are small. In the U.S., 65% of manufacturers are 15 people or fewer, with three to five machines, Evans notes. AM is part of a "catalog" of manufacturing services; clients often contract for a process that includes both AM and more traditional machining. "The core benefit is agility," he asserts.

Contract manufacturing is likely to be a permanent model for additive manufacturing, Mulherin suggests. "We'll always have machine shops," she says. "It makes sense for AM, because the capital investment required to set up 3D printers is high, and the specialized knowledge to run them and keep them running is scarce."

FROM PROTOTYPES TO PARTS

3D printing is mostly being used for product prototyping, producing low-volume components, and creating customized objects to meet specialist specialized needs. The technology can be used to generate scarce end-user products on short notice—witness the many maker-scale projects to produce personal protective equipment for healthcare workers during the 2020 COVID-19 pandemic. Higher levels of 3D printing innovation mean the technology is increasingly being found in larger-scale manufacturing too.

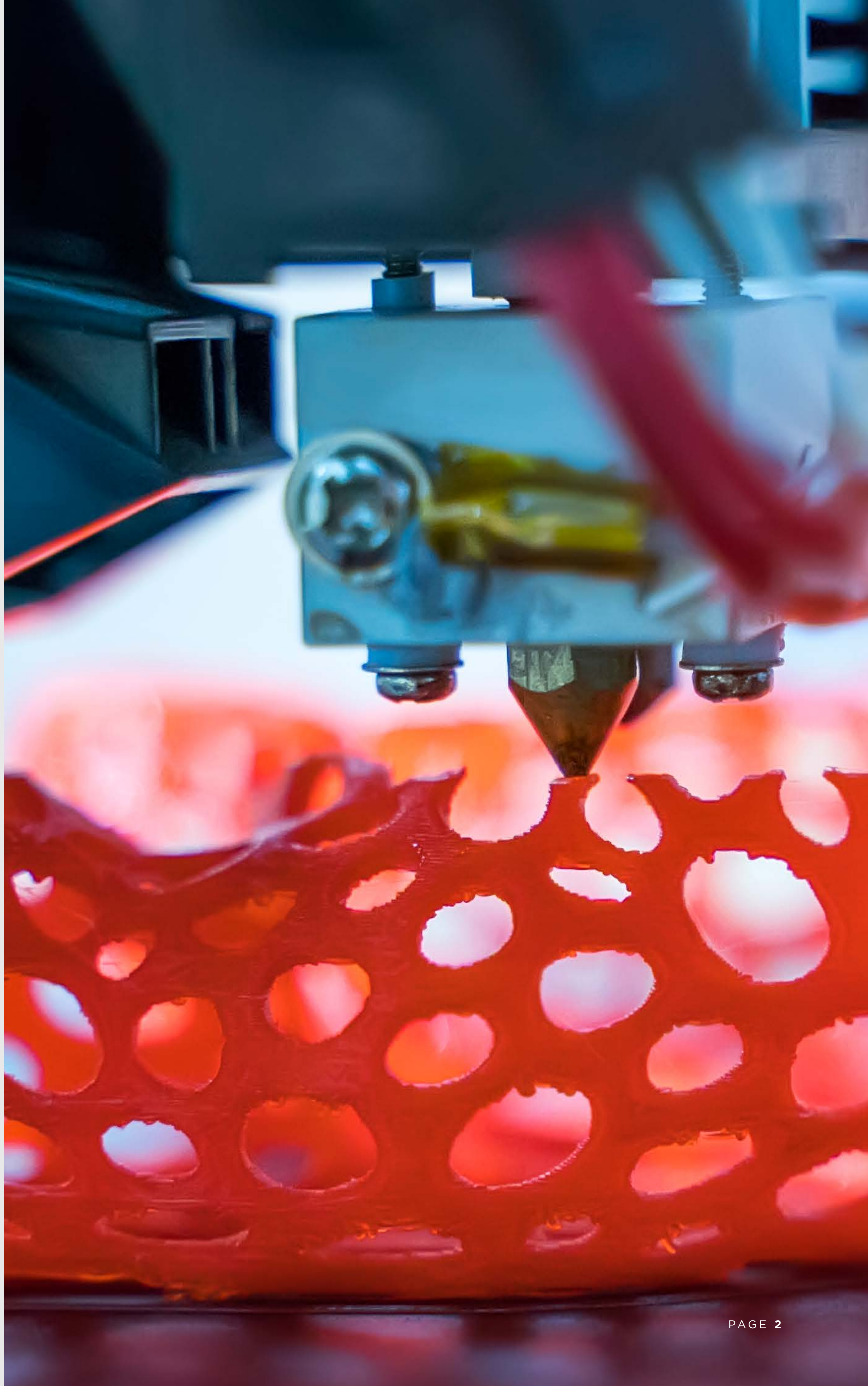
"The purpose of additive is not to replace injection molding," Evans says. "It's to complement traditional techniques to make parts that were never feasible to produce before—things that were only recently even imaginable."

But 3D printing is a full-scale manufacturing process for everything from artificial knees to aircraft engine turbines. It has grown from a hobbyist tool to make small objects from plastic filament to an industrial process generating products in an array of specialty metals and other materials.

3D PRINTING TECHNOLOGY

Recent advancements in printing technology, such as HP's Multi Jet Fusion (MJF) technology, are acting as catalysts in additive manufacturing by increasing the rate of throughput at which printers can produce functional parts, while also reducing the cost of production.

The HP 3D printing technology can make products at a higher level of customization, with more complex geometries, at a cost that is competitive with traditional manufacturing.



99%

OF THE TOTAL RESPONDENTS TO AN ESSENTIUM SURVEY: 99% SAID THEY EXPECTED THEIR USE OF 3D PRINTING TO GROW, WITH 41% SAYING "DRAMATICALLY" SO[2]

BRINGING TODAY'S INDUSTRIES CLOSER TO TOMORROW

As 3D printing technology has advanced, the cost of adoption has fallen.

Now, mid-sized and smaller organizations can increasingly use additive manufacturing in innovative ways—even while managing the manufacturing process from remote locations—to gain a competitive edge and quickly take their new designs to market quickly. A NASA partnership called Made In Space even maintains small-scale 3D printing operations aboard the International Space Station.

INDUSTRIES LEADING THE CHARGE

North America and Europe have led the adoption of 3D printing, with Asia fast becoming a strong competitor in the additive manufacturing market. The U.S., UK, Germany, France, and China are the top five countries in 3D printing adoption and investment rates.[1]

The market for additive manufacturing is growing due to the high demand from industries like healthcare, aerospace and defense, and automotive.[6] These same industries are among the most mature adopters of the technology and are also key contributors to the industrialization of 3D printing.[1]

HEALTHCARE

The medical sector was an early adopter of 3D printing, using the technology to produce prosthetics, implants, and customized orthopedic products that fit individual patients. The market for medical 3D printing, including materials, services, software, and hardware, is currently estimated to be worth $1.25 billion, and it is estimated to grow to $6.08 billion by the year 2027.[1]

"Medical device companies like Stryker Corporation use AM to produce implantable devices like artificial knees, hips, and spinal implants, usually from titanium," Kristin Mulherin notes. "They've developed proprietary algorithms to solve the problem of osteointegration—getting the metal device to bond with the patient's bone. The 3D printer produces a strong, lightweight implant whose surface is treated to create a strong bond with the bone tissue."

The advent of 3D printers that can print functional parts in color has also created new possibilities and applications of the technology. Complex anatomical models of organs have been 3D-printed for years, helping surgeons prepare for procedures. Because additive manufacturing can print in color, doctors are able to differentiate between individual veins and arteries. They sometimes print 3D models of individual patient's hearts to practice surgeries and find the best surgical path.

AEROSPACE AND DEFENSE

The aircraft industry is one of the early adopters of 3D printing technology, using it to produce complex parts. 3D printing technology has gained widespread adoption in the aerospace and defense industry.

3D printing materials such as metals are used in the making of many aircraft parts, including wings, jigs, and engine parts. Titanium materials are mostly used as a 3D printing material in the aerospace industry, as it offers excellent mechanical properties and high-dimensional accuracy during production.[6]

AUTOMOTIVE

One of the industries most reliant on 3D printing is automotive.[1] It is common practice for both the aerospace and automotive industries to use 3D printing to generate a single part that previously was composed of multiple pieces (an expedient known as "part consolidation"). 3D printing can remove the costly process of assembling and testing products, while also producing a higher-quality product faster.

3D-printed parts use less material and weigh less, resulting in better fuel efficiency compared with traditionally manufactured parts. The technology has helped the industry in making more complex and lighter structures at optimized costs.

USE CASE:

Employing generative design for better manufacturing

Generative design enables engineers to specify a set of precise requirements and constraints for the product they need, and then trust the AI in their 3D design software to provide a range of alternative versions of the product that satisfy those requirements. From visualizations of the computer-generated designs, the engineers and their business counterparts can choose a small set to prototype for full-scale production, quickly and cheaply.

Using generative design for manufacturing can create lightweight parts—minimizing mass while maintaining high-performance standards that fit within engineering constraints.

By using additive manufacturing in tandem with generative design, manufacturers can select more sustainable and durable materials. Designers can eliminate areas of weakness, specify stronger materials, and design to improve performance.[8] And They can also consolidate multiple components into single parts.

Designers can now combine electronics with mechanical design in a single process. Electrical design is now available with Autodesk's Fusion 360 3D CAD software, and designers can integrate MCAD design and electronics for mechatronics work.[9]

Many Formula 1 racers and concept cars are using 3D-printed parts. For instance, in the first quarter of 2018, the elite car manufacturer Bugatti revealed a 3D-printed brake caliper made with titanium.[6]

Major car manufacturers such as Tesla and BMW Group are highly inclined towards using 3D printing to manufacture automotive components. BMW is also collaborating with major 3D printing companies, including EOS GmbH Electro Optical Systems and Carbon to manufacture 3D-printed parts for commercial vehicles.[6]

FAR OUT: ARTIFICIAL INTELLIGENCE AND THE FOURTH DIMENSION

3D printing is evolving in tandem with an array of complementary technologies, with each discipline enabling and spurring advancement in the others.

The convergence of AM with technologies such as artificial intelligence (AI) and robotics means that advanced printing technology and automation can work together to drive new levels of productivity.

As 3D printing technology continues to evolve, it is becoming more accessible at lower prices. Smaller, more agile businesses are likely to quickly adopt the technology quickly to innovate and disrupt established players. Meanwhile, leading enterprises will increasingly use additive manufacturing to gain a competitive edge by integrating 3D printing with automation and robotics.

Companies will continue to use new computing and software tools to unlock the potential of additive manufacturing. This will lead to the creation of new materials and drive the development of 4D printing—using 3D printing techniques with the added dimension of time or an energy source to create objects that transform their shape or properties over time.[13]

2X

THE 3D PRINTING MARKET IS SET TO DOUBLE IN SIZE EVERY THREE YEARS[7]

$3B ↗

THE 3D PRINTING MATERIAL MARKET IS PROJECTED TO GROW FROM $1.5 BILLION IN 2019 TO $4.5 BILLION BY 2024[5]

25%

3D PRINTING MATERIAL MARKET COMPOUND ANNUAL GROWTH RATE 2019 TO 2024[5]

OBSTACLES AND INCENTIVES

Additive manufacturing will have a massive impact on the global workforce. One potential challenge is raw-material supply.

"Raw goods like plastic filament represent a key bottleneck in the supply chain today," Dave Evans cautions. "For example, the reason we couldn't produce enough N95 masks for hospitals wasn't manufacturing capacity—it was material availability. There are only two suppliers around the world for the resin to make those masks. If that supply of a component like that is disrupted, there's disruption everywhere down-stream in the supply chain. It's called the bullwhip effect. The lesson of COVID-19 is that every product marketer needs a digital strategy for the supply chain."

Even when additive manufacturing materials are in plentiful supply, cost can be an issue, Mulherin notes—especially for metals like stainless steel, titanium, specialty aluminum alloys, and cobalt chrome, a metal typically used in biomed-ical applications like dental or orthopedic implants. Metals generally are introduced into 3D printers in the form of powders, which can be expensive to produce, especially for applications where the particles must be precisely spherical and uniform in size.

Another issue for AM adoption is interoperability. A complex manufacturing ecosystem with large and small shops using diverse 3D printing equipment needs a common file format to transmit digital designs. The industry has standardized hardware interfaces, and there is a common file type—the .STL or .STEP file offers a .PDF-like standard for 3D printing. But the leading CAD software vendors, like Autodesk and Dassault Systèmes, have proprietary formats for full-featured design files—an obstacle to full interoperability.

THE FUTURE OF ADDITIVE MANUFACTURING

The factory of the future will be multi-purpose and programmable. Manufacturers will produce customized, complex devices on-spec for individuals at the same price as large-scale manufacturing, but with lower overheads.

While this will likely lead to fewer people on the factory floor and the end of large scale, single-purpose factories, integration of AI with 3D printing will offer more localized, customized, and creative workforce opportunities.

It also will make manufacturing supply chains much more resilient against the kinds of shocks witnessed as Chinese suppliers shut down during the COVID-19 crisis. Enterprises suffered because they had become too reliant on Chinese sources; additive manufacturing could allow marketers to shift production to redundant suppliers virtually overnight.

IT decision-makers (ITDMs) in all sectors are analyzing how the use of additive manufacturing and robotics will impact roles in the workforce. These advanced technologies will help companies develop products quickly and in ways that might previously have been impossible, establishing new opportu-nities for product creation.

As with other transformative technologies, companies will have the option to shift employees away from resource-intensive tasks associated with traditional product iteration and instead focus them on invention and creativity.

3D PRINTING DESIGN ACCELERATES THE BAC MONO STREET-LEGAL RACE CAR

One of the most effective ways to make a car go faster is by slashing its weight in half. That is why additive manufacturing is the fabrication method of choice for the BAC Mono street-legal race car.

About 40 parts of the new BAC Mono are 3D-printed, including the headlights, wing mirrors, rear-light casings, and many of the panels. One material used for these parts is graphene-enhanced carbon fiber, known for its low weight, high strength, and thermal durability.

BAC used generative-design technology in Autodesk Fusion 360 to produce the wheels, which are 35% lighter than standard wheels. The biomorphic honeycomb look of the wheels blends rectilinear and curvilinear geometries—a computer-generated design for optimization.

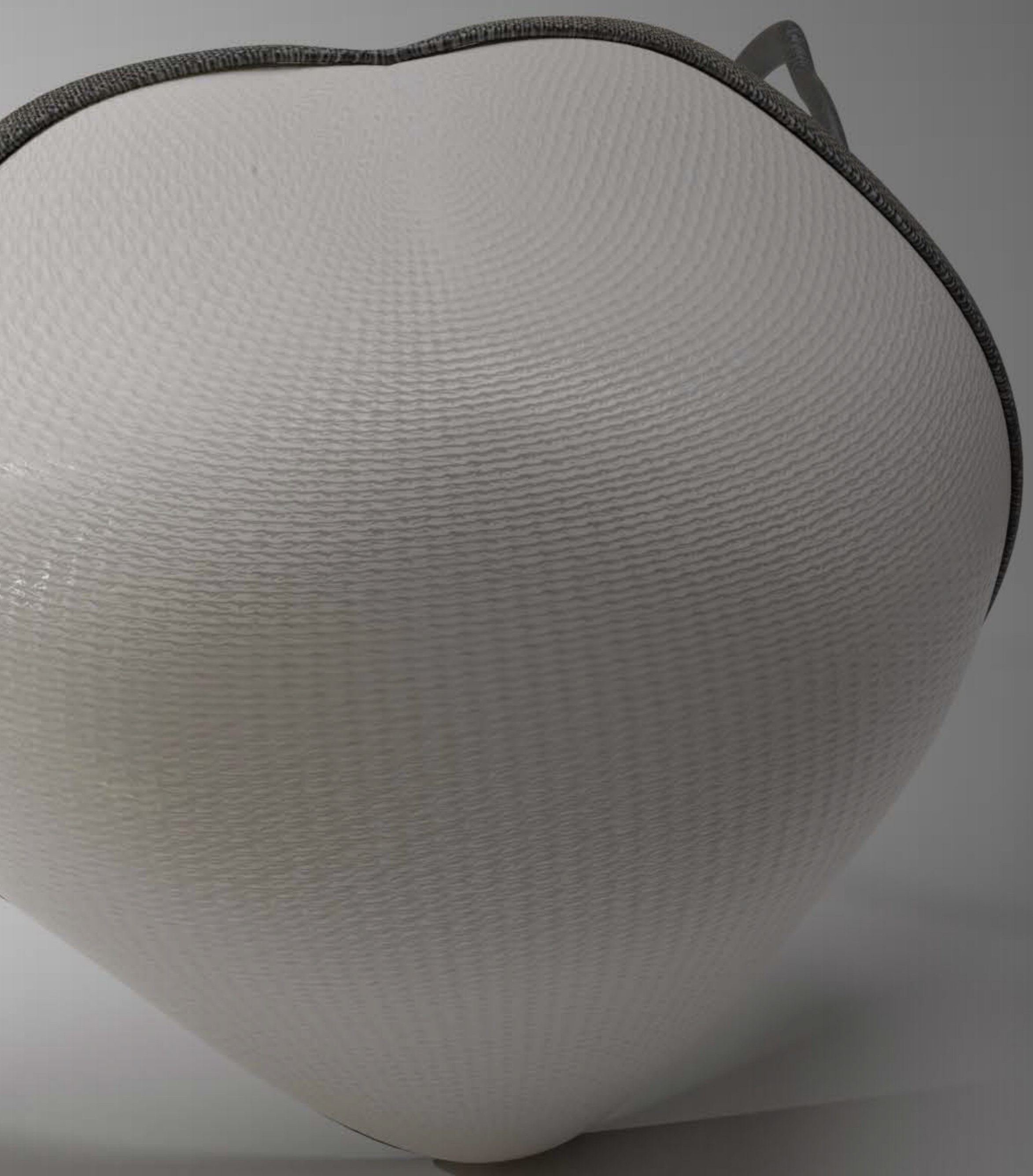
In the future, BAC sees suspension systems and chassis elements as the next targets for rendering biotic metal components (using generative design to invent fabrication methods inspired by biological processes).

These design optimizations save weight and unlock fuel efficiency, thereby limiting the car's carbon emissions. BAC Mono sees that as a good return on their investment.[10]

> "The lesson of COVID-19 is that every product marketer needs a digital strategy for the supply chain."
>
> **DAVE EVANS**
> CEO, Fictiv

BAC Mono uses additive manufacturing on the Mono R, incorporating 3D printed parts using high-performance polymers. Photo credit: BAC Mono.

SOLVING URGENT, TIME-SENSITIVE ISSUES WITH 3D PRINTING



The COVID-19 pandemic led to global shortages critical personal protective equipment (PPE), including desperately needed facemasks, face shields, and field ventilators.

Collaborating across borders and industries, HP worked with digital manufacturing partners to identify the parts to prioritize, validate designs, and print them for delivery.

Before the end of March 2020, right about the time that states around the U.S. began enforcing lockdown procedures, HP helped put face masks, face shields, mask adjusters, nasal swabs, hands-free door openers, and respirator parts, and other 3D-printed parts in the hands of medical professionals.

By collaborating with its global network of manufacturing partners, HP worked to meet the need for rapidly printing and delivering 3D-printed parts around the world.[11]

To print medical devices and components, local companies with 3D printing technology had to find ways to deliver without the option to tap into the problematic global supply chain.

HP offered 3D printer designs of medical equipment for free download, including hospital-grade face masks, emergency ventilators, face shields, and hands-free door openers. Then corporations globally went to work.

3D printing company Carbon made and delivered face shields to its customers. Ford made masks for local Michigan hospitals. Belgian company Materialise worked to produce hands-free door openers. U.S. Formlabs designed and 3D-printed nasal swabs for testing kits. Prusa Research in the Czech Republic donated 10,000 face shields to the Czech government.[12]

Z equips designers with the powerful tools they need to fuel their creative evolution. **Check out more at hp.com/product-designers.**

Sources

1. AMFG, “40+ 3D printing industry stats you should know [2020],” Jan. 14, 2002, https://amfg.ai/2020/01/14/40-3d-printing-industry-stats-you-should-know-2020.
2. Fabbaloo, “Survey indicates massive growth in industrial 3D printing,” Nov. 22, 2019, https://www.fabbaloo.com/blog/2019/11/22/essentium-commissioned-an-extensive-survey-of-manufacturers-to-determine-additive-manufacturing-usage-and-intentions-the-results-were-very-surprising.
3. Sculpteo, The State of 3D Printing Report 2019, https://www.sculpteo.com/en/ebooks/state-of-3d-printing-report-2019.
4. 3D Hubs Blog, “HP’s MJF: The fastest growing 3D Printing Process of 2019,” March 15, 2019, https://www.3dhubs.com/blog/mjf-fastest-growing-3d-printing-process.
5. Investor.hp.com, “HP Propelling Industry to 3D Production, More Than 10 Million Parts Produced on Multi Jet Fusion Technology Last Year Alone,” March 28, 2019, https://investor.hp.com/news/press-release-details/2019/HP-Propelling-Industry-to-3D-Production-More-Than-10-Million-Parts-Produced-on-Multi-Jet-Fusion-Technology-Last-Year-Alone/default.aspx.
6. 3D Printing Materials Market, May 2019, https://www.marketsandmarkets.com/Market-Reports/3d-printing-materials-market-1295.html.
7. 3D Hubs, The 3D Printing Trends Report 2019, https://www.3dhubs.com/blog/3d-printing-trends-q1-2019.
8. Autodesk, “Generative design for manufacturing with Fusion 360,” https://www.autodesk.com/solutions/generative-design/manufacturing.
9. John Peddie, “Autodesk adds on to Fusion 36- with electronics design” by Kathleen Maher, Tech Watch Stories, Feb. 4, 2020 [p. 27].
10. Redshift by Autodesk, “Generative design accelerates the BAC Mono street-legal race car into the future,” March 3, 2020, https://www.autodesk.com/redshift/mono-car.
11. Production Engineering Solutions (PES), “HP mobilises 3D printing expertise to fight COVID-19,” March 26, 2020, https://www.pesmedia.com/hp-coronavirus-response-260320.
12. Stockhead, “Australia might be able to 3D print its way out of a COVID-19 supply shortage,” March 26, 2020, https://stockhead.com.au/tech/australia-might-be-able-to-3d-print-its-way-out-of-a-covid-19-supply-shortage.
13. Rose De Fremery, “What is 4D Printing Technology?”, Tektonika, Feb. 14, 2019, https://www8.hp.com/us/en/tektonika/index.php/2019/02/14/what-is-4d-printing-technology/.

4AA7-7929ENW, July 2020