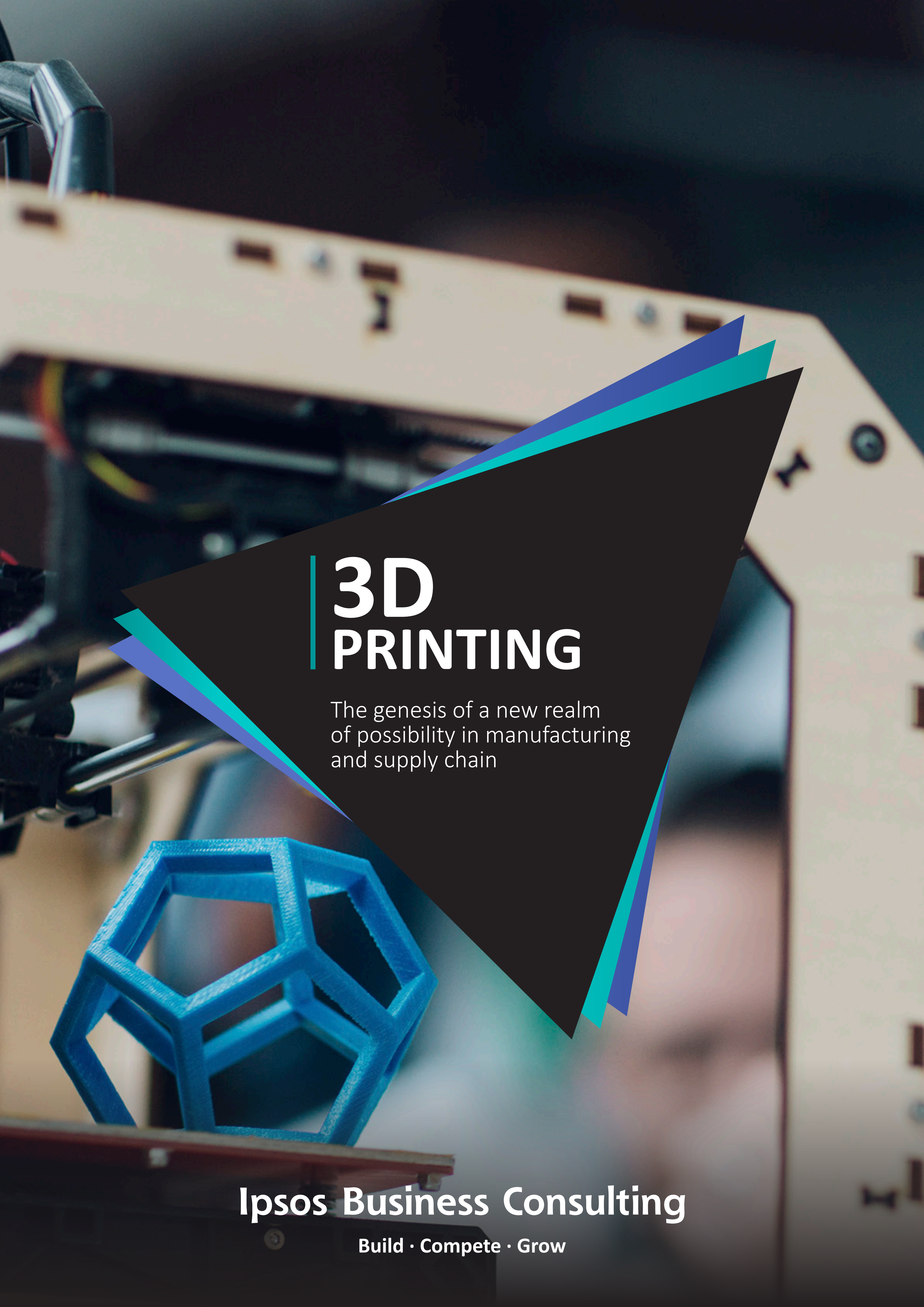


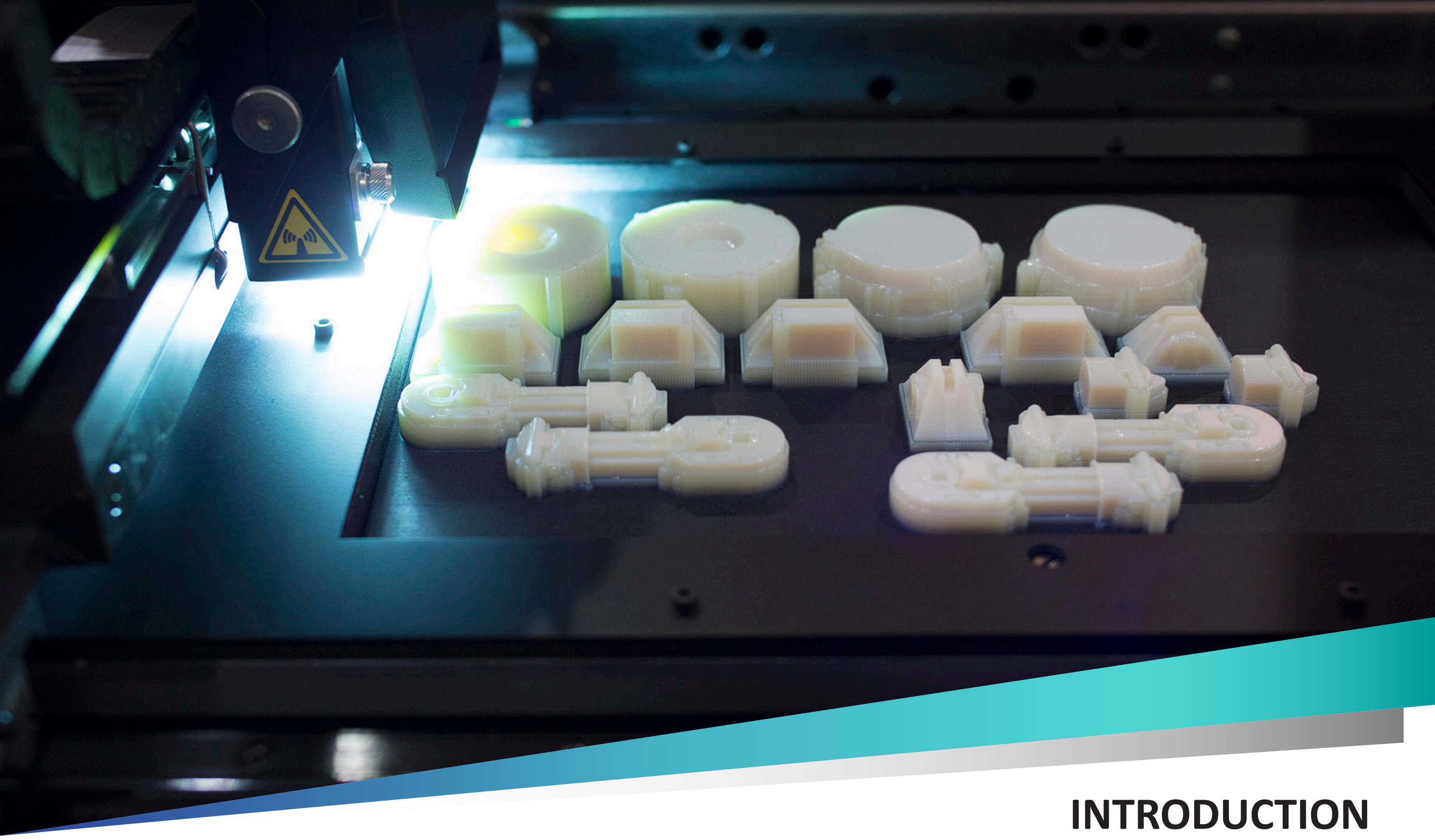
3D PRINTING

The genesis of a new realm
of possibility in manufacturing
and supply chain

Ipsos Business Consulting

Build · Compete · Grow

January 2017



INTRODUCTION

On display in the Berlin Air Show in June 2016 was ‘Thor’ – the small Airbus marvel that is the world's first aircraft wholly produced by additive manufacturing (AM). Windowless weighing in at just 21 kilos (46 pounds) and less than four meters (13 feet) long, the drone Thor – short for "Test of High-tech Objectives in Reality" – resembles a large, white model airplane. Yet to the European aerospace giant Airbus, the small pilotless propeller aircraft is a pioneer that offers a taste of things to come – a future for aviation where 3D printing technology promises to save time, fuel, and money. Airbus and its US rival Boeing are already using 3D printing, notably to make parts for their huge passenger jets, the A350 and B787 Dreamliner, respectively. The printed pieces have the advantages of requiring no tools, being made very quickly, weighing 30-50% less than traditional pieces, and producing almost zero manufacturing waste.

As a significant number of companies are looking to embrace future technologies, the manufacturing and supply chain industries are going through a time of rapid and unprecedented transformation. The road to the future of these industries is paved with innovation and technology, whose merchants and service providers are prudently adopting technologies like 3D printing, internet of everything, augmented reality, and drone delivery to provide faster, cheaper, more reliable, and more sustainable business practices.

According to some trade pundits, among the putative technologies that are poised to disrupt global commerce, 3D printing (another name for AM) along with the “Internet of Things” and industrial robotics will potentially have a greater impact on the world over the next 20 years than all of the innovations from the industrial revolution combined. It accomplishes at a single stroke two goals seemingly at cross purposes with each other: it simplifies and streamlines manufacturing for large enterprises while enabling infinitely customizable products to individual users, allowing democratized access to manufacturing while still creating economies of scale. Industries such as fashion, aerospace, medicine, and food have already been showing signs of disruption with the introduction of AM technologies.

The possibilities have caught the imagination of the general public and the manufacturing community like nothing since the invention of the personal computer and the internet. Within only a few years, the technology has evolved so much that it is now possible to produce almost any component using metal, plastic, mixed materials, and even human tissue. It has forced engineers and designers to think very differently when thinking about product development. The proliferation of 3D printing has the potential to create a new, powerful product category in AM by eliminating the need for complex supply chains while decentralizing production, wealth and knowledge. Though AM technology is still evolving and maturing on fronts such as the speed of printing and the range of available printing materials, as more manufacturers adopt and use 3D printing technology, there is little doubt that 3D printing will change the face of mass manufacturing forever and, in so doing, shorten and simplify the supply chain.

RETHINKING MASS PRODUCTION

HOW 3D PRINTING IS CHANGING MANUFACTURING

AM is generally viewed as a complementary technology rather than a competitive one, when it comes to assembly line manufacturing.

It is well known today that there are tremendous benefits to 3D printing, mainly the fact that each print a machine makes can be totally different than its last. All the while, there is no need to change out equipment, teach new techniques to production line employees, or reprogram the movements of robotic arms. If manufacturers could just overcome the problem of speed, the entire industry would be turned inside out.

"Just as the last three years have seen a boom in 3D printing in the home, the next five years will be characterized by a much bigger growth of industrial additive manufacturing," noted a recent paper in the Journal of Materials Research by professors from the University of Sheffield in the U.K. The paper pointed to just what needs to change to exploit that potential, and for the cost of the part to come down: if additive techniques could pick up the pace, to the tune of somewhere between four and ten times as fast as the current rate of 3D-printing production, the technology would become competitive with anything coming from on a factory floor.

A case in point is the recent acquisition in September 2016 by GE Aviation of two of the world's top suppliers of metal-based 3D printing manufacturing equipment, Arcam AB and SLM Solutions Group AG. Both companies' technology will be used to increase GE's production of aircraft components and other parts via AM, through which the company expects to generate business to the tune of USD1 billion by 2020 at attractive returns. Apart from lowering costs by using 3D printing instead of external suppliers, GE Aviation is also expecting 3D printing to drive USD3-5 billion of new products over the next 10 years.

To put this in perspective, according to Alan Amling, Vice President of Marketing at United Parcel Service (UPS) Global Logistics & Distribution, even if just 5% of manufacturing moved to 3D printing, that would represent USD640 billion of goods (at ex-factory value) enabled using AM.

That being said, there are plenty of product categories where the benefits of 3D printing are already beginning to make a significant difference. Specifically, these include products that are made in relatively low quantities, made with a high degree of individualized design or personalization, or in some cases designs that cannot be made with conventional manufacturing technologies.

Widespread adoption in factories of AM for mass-producing designs will eventually lead to economies of scale by reducing the long run average costs of production and overhead costs. The following factors play important roles in supporting this trend:

- Enabling shifts in manufacturing philosophy: Before 3D printing, products were designed so that they could be made with a traditional manufacturing method called "design for manufacturing." 3D printing eliminates such limitations and enables "manufacturing for design." This allows designers to create products that never existed before and to give existing products a radically different look and feel.

- Lightweighting made possible: Where the weight of a part affects costs over the part's lifetime, 3D printing may prove to be cost effective. For example, if a 3D printed aircraft part is 15% lighter than a traditionally made part, the aircraft fuel savings over the life of the part justifies paying more to 3D print it.

- Economies of scale will set in, as 3D technology becomes faster and more widely available:

    - The cost of 3D printing will decrease, just like that of 2D printing, with new advancements in technology

    - Existing companies can see that high volume AM is on the way, and materials suppliers are preparing to get those materials ready for market

    - The prices for both the hardware and the "ink" used by the printer (primarily thermoplastics but recently also metal powders for laser sintering) will continue to drop, allowing more manufacturing designs to reach economic viability

    - Using several 3D printers at the same time in parallel will be cheaper, since a single controller can be shared and the printing material supplied from a central bin

- Manufacturing at the point of use: Manufacturing of products can be localized by setting up 3D printing hubs, and this can save tremendously on transportation and logistics costs. Additionally, the lines are blurred between manufacturer and customer because the customer has become the manufacturer. For example, consider a company that needs turbine blades used in power generation. The blades need to be replaced from time to time, at great expense. By using 3D printing to repair the blades, the customer no longer needs to buy new ones.

Design and development of new water pump housing for the Volvo Construction Equipment's A25G and A30G articulated haulers

	Cost of Tooling	Cost of Part	Total cost of development
Traditional Manufacturing Method	USD9,090	USD909	USD9,999
3D Printing Manufacturing Method	NIL	USD770 (90% time savings)	USD770 (92% cost savings)

Traditional Manufacturing Method: Development time = 20 weeks

VCE management tasked the engineering team with cutting development costs and reducing the lead time on large engine projects. With adoption of 3D printing, the printed parts could withstand functional testing.

3D Printing Manufacturing Method: Development time = 2 weeks

Each new generation of engines typically requires 15 to 20 new cast metal parts and 12 to 15 profile molded hoses for each engine. 3D printed prototypes can be produced in about 1/10th of the required time to produce prototypes using traditional manufacturing methods, which adds up to a hefty time savings.

A Volvo A30G Articulated Hauler

VCE 3D printed this water pump housing in transparent material for quick functional testing ▶ Housing installed on a water pump ▶ Water pump installed in an A30G for functional testing

Source: http://www.stratasys.com/resources/case-studies/automotive/volvo-ce#sthash.bI2bqdsI.dpuf

- Buy the design, not the product: The cost of designing a 3D object in the software will be cheaper with the availability of large volumes of open-source designs and free or low-cost software being made available, offering the creative freedom to customize one's own design. Also, more original equipment managers (OEMs) will adapt, or else start selling 3D printable digital blueprints rather than making parts as more consumers begin to have a 3D printing capability.

- Possibility of precision manufacturing: 3D printers can precisely manufacture designs with less than 0.1mm dimensional error, as is frequently required in industries like aviation, automotive, and medical devices.

- Environmentally friendly technology: AM can offer substantial reductions in energy consumption and CO2 emissions, providing greener products. A recent study by the Michigan Technology University showed that 3D printed products require 41% to 74% less energy than large-scale manufactured goods.

Mass produced 3D printed products could transcend the limits of 20th century manufacturing models, as AM provides a whole new degree of freedom regarding how people and organizations think about component design and production. They no longer need to confine their designs to the technical and financial limitations of traditional assembly line manufacture.

For example, GE is taking mass production to a lofty new level. The company is pulling 3D printing out of the lab and installing it at the heart of the world's first factory for printing jet engine fuel nozzles in Auburn, AL. The USD50 million plant will operate several AM machines simultaneously to meet demand, while employing approximately 300 workers when the factory reaches full capacity.

With more than 6,700 orders for engines from 20 countries, and each engine having nearly twenty 3D printed fuel nozzles and fan blades to be made from fourth-generation carbon-fiber composite blades and a hot section that includes parts from groundbreaking ceramic matrix composites, GE aviation is redefining mass AM.

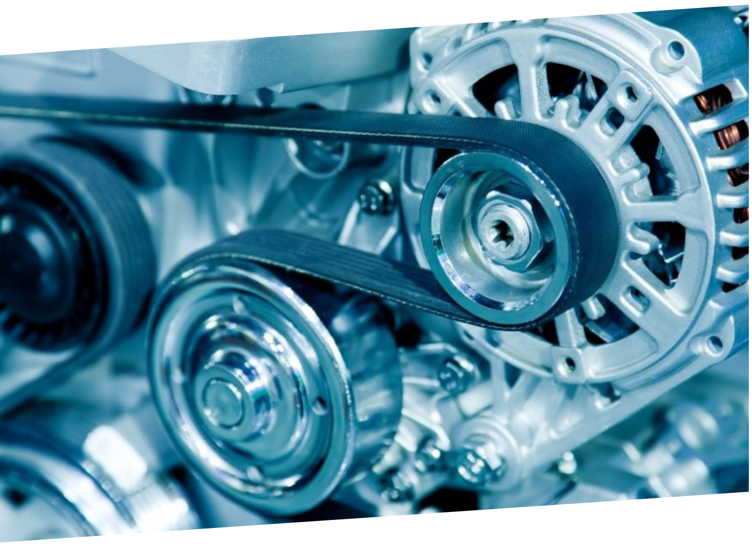
The nozzles are five times more durable than the previous model. 3D printing allowed engineers to design them as one part rather than as 20 individual parts, reducing the number of brazes and welds that would have been necessary using traditional methods. The housing for the sensor, known as the T25, recently also became the first 3D printed part certified by the U.S. Federal Aviation Administration to be housed inside GE commercial jet engines. GE Aviation is currently working with Boeing to retrofit more than 400 GE90-94B jet engines – some of the world's largest and most powerful, in the family of engines that power Boeing's 777 planes – with the 3D printed part.

Other forward-looking companies have already started mass producing using AM, or at least have carried out very pilot trials and the results have been extremely promising. Industries such as aviation, automotive, industrial product prototyping, electronics, fashion and medical devices are taking the lead in the application of AM to commercial processes.

One of the world's most innovative companies, Google will be printing millions, and perhaps billions of smartphone modules for its Project Ara, in association with 3D Systems. The project will use an entirely new mass manufacturing system, relying almost solely on 3D printing and based on a continuous motion system around a racetrack architecture. This design will allow the module shells to move in a continuous flow with additional "off ramps" for various finishing steps, including inserts and other module manipulations. The system could utilize dozens or even hundreds of print heads, each printing in a single direction for hundreds of feet, at high speeds, along a single conveyor belt.

The end result of these innovations is that companies no longer would require a specific manufacturing facility for specialized parts. Instead, an entire facility could be transformed from producing tiny tweezers to large automobile engine casings within minutes, merely by switching the software that operates the printers. Traditional manufacturing won't go away completely – we still make glass in essentially the same way as the Romans, after all – but it may never be the same again.

AM will democratize the manufacturing process, enabling manufacturers to "print" on demand, which will shorten the supply chain by making it unnecessary to have large quantities of finished products stacked in warehouses.



SHORTENING THE SUPPLY CHAIN

HOW 3D PRINTING IS POSED TO FUNDAMENTALLY CHANGE GLOBAL LOGISTICS AND SUPPLY CHAIN MANAGEMENT

The new paradigm of software-defined supply chain using 3D printers and open-source designs will usher in an era of dramatically reduced lead times and lower costs, in part through the elimination of capital investments such as molds, casts and machine tools. The implication of 3D printing for the logistics industry has many potential upside implications. 3PL and 4PL providers of the future will deliver raw materials instead of finished products and may even provide 3D printing services at the point of delivery by collaborating with various 3D printing hubs (both to the individual consumer and at an industrial scale), which will be an additional source of revenue for them.

So what are the key drivers for supply chain companies to start worrying about the explosion of AM technologies and products? The first driver has to do with the continuing increase in consumer demand. The second key driver is related to a mismatch in scale between supply, demand, and the transportation networks that connect them. The current manufacturing and distribution system involves significant numbers of drivers hauling full-size trailers containing significantly less-than-full-size loads. Combined with dwell time, lag time and driver delays, these inefficiencies combine to slow down today's supply chain functions.

AM along with other technologies like the Internet of Things and robotics' growing role in manufacturing and logistics commerce are expected to change the playing field as they drive real-time operational efficiencies, reduce risks, and at the same time create new opportunities for innovation and business impact such as:

- Near-sourcing: Goods which are produced in other countries could be near-sourced, leading to a reduction in shipping and air cargo volumes.

- Reduction in warehouse requirements: Inventory levels and the need for warehouses will shrink as goods made to order and customized products continue to replace mass-produced goods.

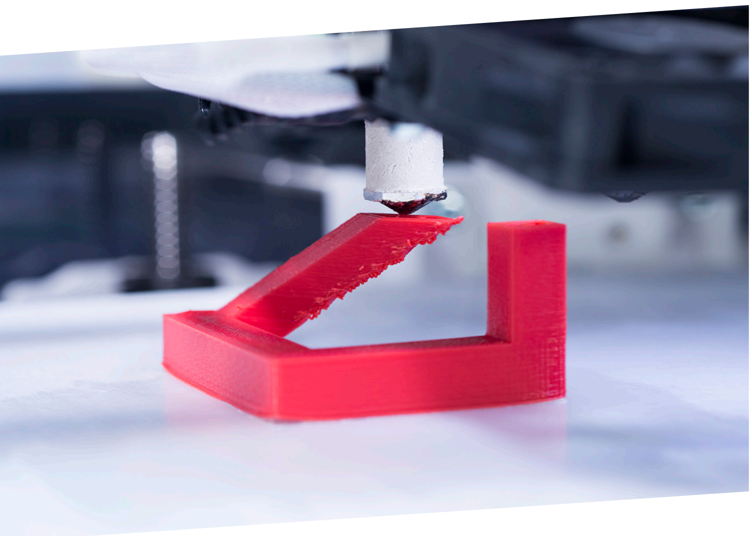
- Omni-facility for the value chain: There will be fewer opportunities for logistics suppliers to be involved in companies' upstream supply chains, as manufacturing processes are increasingly re-bundled within a single facility. Entire tiers of component suppliers may disappear, as will the need for supplier villages, line side supply, etc.

- New logistics channels: Logistics deals with the storage and movement of the raw materials which 'feed' the 3D printers. As 3D printers become more affordable to the general public, the home delivery market of these materials will increase.

- Push- to pull-supply chains: The technology will accelerate a shift from "push-supply chains" to "pull-supply chains." With 3D printing, the long production runs for mass manufacturing will often give way to limited production runs for customer-driven mass customization and build-to-order products.

- Agile manufacturing: With 3D printing, manufacturing will become more agile and better able to react to customer demands. This means that at any given moment there will be less work in progress, less finished product in transport and in stock, and less obsolescence of existing stock. Although the manufacturing cost per unit may be higher, with reduced storage and less outdated product, the overall supply chain system cost may still be lower than that of traditional manufacturing supply chains.

Ancillary industries, such as the logistics of service parts or ancillaries of machinery, will be among the first to be affected. At present billions are spent on holding stock to supply products, from car parts to components of x-ray machines and others. In some cases huge redundancies are built into supply chains to enable parts to be dispatched in a very short timescale to get machines up and running again as fast as possible. It does not take much imagination to understand how a service parts engineer's job is made easier by being able to download a part design from an online library, 3D-print it and then fit it within a very short time window. Developments along these lines would make global and national parts warehouses, as well as forward stock locations, unnecessary for fulfilling customer needs.



WHAT WILL CHANGE IN THE WAY 3PLS AND 4PLS CONDUCT BUSINESS?

3D printing will enable many new supply chain models such as:

- A streamlined logistics model: Manufacturers use 3D printing at their own sites, reducing inventory levels and warehousing requirements. This practice is most suitable for items in the inventory "long tail" or where further finishing, assembly, or testing is needed before the product or part is shipped.

- Customer-managed inventory: This is an extension of the vendor-managed inventory model, in which suppliers install 3D printing at the customer's site, providing software design for products and parts to be manufactured on demand. This model could also involve customers acquiring printers, with suppliers providing the design data on a license or pay-per-print basis.

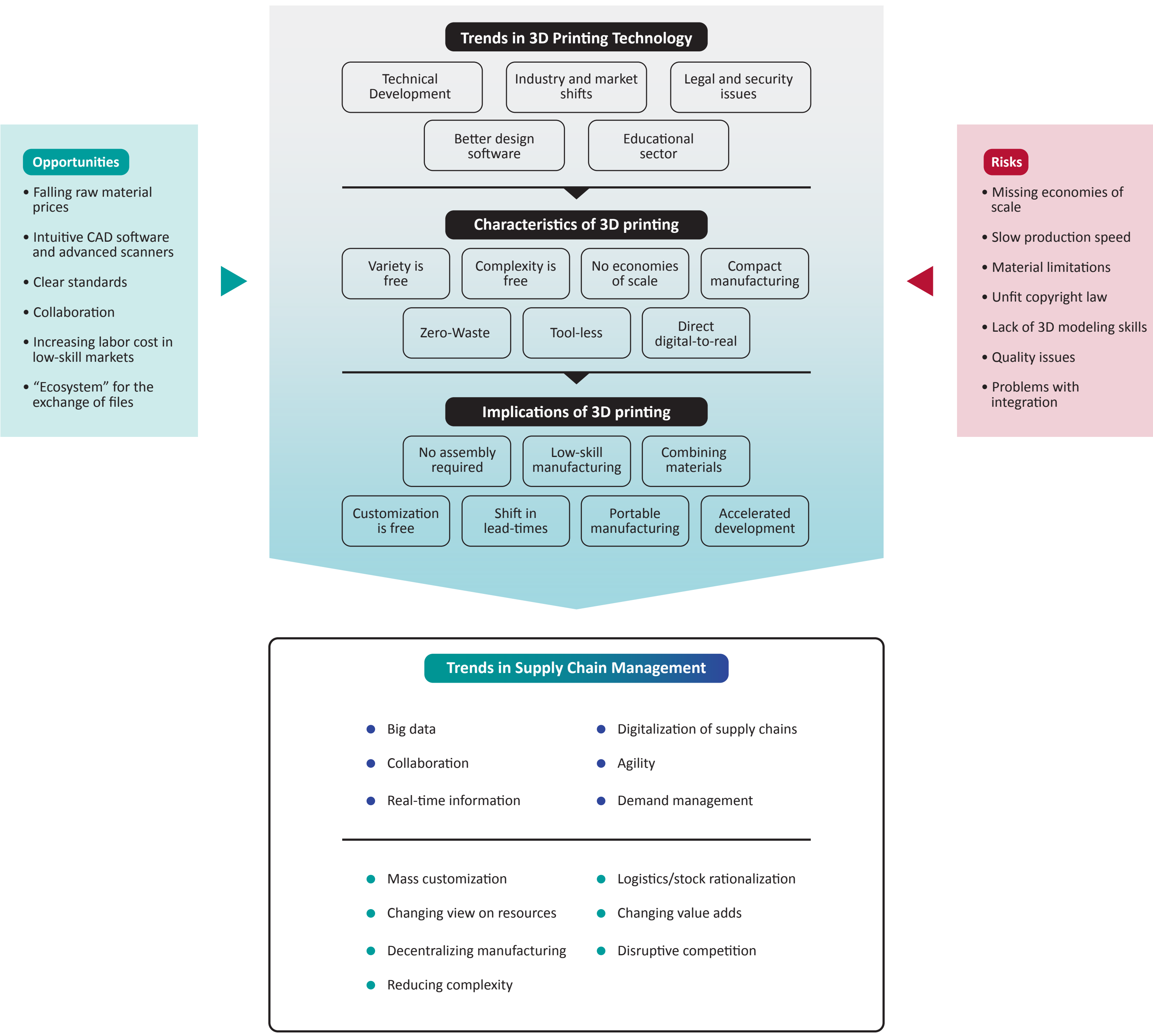
- 3D printing hubs: Firms can offer 3D printing services locally or remotely. Companies will have the option to custom-make most things in small factories right in their customers' neighborhoods or towns, close enough for them to go pick up a delivery, or even have it dropped onto the porch by a drone. Factories will essentially get broken up, scattered and made local; such is the promise of "distributed manufacturing." The World Economic Forum last year named it one of the most important technology trends to watch; it is expected to have a significant impact on jobs, geopolitics, and the climate. And while a massive redistribution of the combined manufacturing capacity of the factories might seem a little far-fetched in 2016, a handful of companies are starting to make it happen. UPS announced last year that it was installing several Stratasys printers at its sites across the US to provide this service, whereby consumers and businesses can obtain printed products by submitting their own designs. UPS can also partner with thousands of independent service providers doing business as 3D printing hubs in order to further localize their supply chains. The faster provision of parts, for example through the installation of printers at client sites, will drastically reduce delivery times and improve on-time, in-full, and e-fulfillment indices. Supply chain networks will be simplified and warehousing needs reduced by lower inventory levels. Other logistics companies and service providers are also coming to terms with the creation of a global network where thousands of intelligently connected 3D printers are located all around the world, creating elastic and on-demand manufacturing that will ultimately streamline the supply chain.

IS ANYBODY WORKING ON IT ALREADY?

One of the top three freight and logistic companies in the world, UPS, believes in being ahead of the curve and is already pursuing this new business model. UPS maintains more than 1,500 global field stocking stations, and these warehouses store critical spare parts for companies around the world.

Several major changes are expected in this significant segment of the business when inventory is stored virtually and can be created using 3D printing. UPS enabled these changes by partnering with a company called CloudDDM, to establish a shared services model at its Louisville, Kentucky supply chain center that could ultimately use up to one thousand 3D printers to make on demand prototypes and product parts for corporate customers.

Enablers and barriers for 3D printing's impact on supply chains



Source: https://hicl.org/publications/2015/20/147.pdf

By shaving weeks off manufacturing times and in-house production, this technology may reverse the trend of low-cost global manufacturing outsourcing, distribution, production, and retailing – posing a threat to the global transportation industry. Although many supply networks are likely to be altered, it is predicted that some supply chains and distribution networks will remain intact due to the rapid growth in businesses' and consumers' need for raw materials to supply 3D printers. These changes could lead to the birth of a new logistics sector for the storage and movement of these powders and supplies, as well as recycling and waste disposal.

According to Wohlers Report 2013, North America and Europe currently lead the 3D printing market with 60 percent of the market share; however, There are many who believe that the Asia Pacific region is poised to take the lead in 3D printing in the future. While that's the prediction from trade pundits, the reality today is that most Asia-Pacific countries are still struggling with adoption due to insufficient capital investment, as well as a "wait and see" attitude on the part of investors. The main drivers of growth and expansion of 3D printing in Asia remain governments' own efforts to push and incentivize the new technology, as well as foreign direct investment (FDI).

In this report, we dive deep into the trends impacting the 3D printing industry in three distinct but thriving markets in Asia.

- The ASEAN market has expressed strong interest in prototyping and advanced manufacturing using 3D printing, but sluggish investments in the sector have inhibited growth so far.

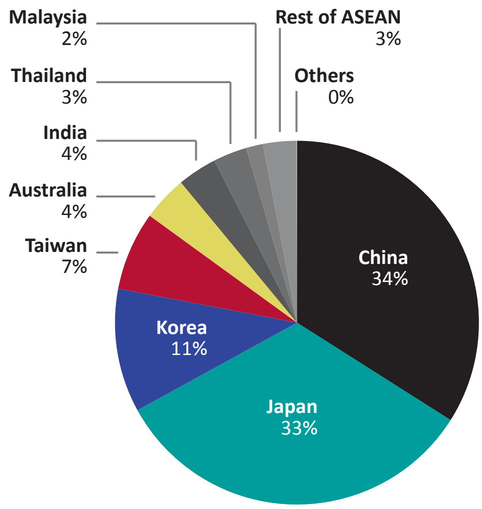
- The Chinese market is expected to see a significant impact from the growth in the adoption of 3D printing (due to slow but steady replacement of manufacturing assembly lines), and presents the greatest opportunity due to the manufacture of 3D printers and consumables to be supplied around the globe. Chinese 3D printer manufacturers are gaining prominence within the country with the rapid advancement of their technology.

- The Indian market, with its vast skilled knowledge base and potential to excel in the 3D printing market, has recently seen significant government initiatives in manufacturing that could propel the sector forward. 3D printing is increasing in visibility as local 3D printer start-ups begin to emerge and demand for the technology rises, especially within the engineering design and research centers of major multinational organizations.

3D PRINTING LANDSCAPE IN ASEAN

While the adoption of AM technology in ASEAN has picked up speed in recent years, it still falls behind China, Japan, Korea, and Taiwan. Singapore, Malaysia and Thailand are countries to watch within the AM space.

Industrial AM installed base in Asia/Oceania



*Rest of ASEAN refers to Singapore, Brunei, Philippines, Laos, Cambodia, Vietnam and Indonesia
Others include New Zealand, Sri Lanka, Nepal, etc.

Slightly more than a quarter of the world's industrial AM machines are installed in Asia and Oceania. With ASEAN countries making up approximately 8% of Asia and Oceania's installed base, the market is still relatively small when compared to the likes of China and Japan.

The key industries driving AM adoption in ASEAN are projected to be the aerospace and medical industries. Aerospace companies have already adopted AM, and a key enabler for their embrace of the technology has been that they have their own qualification processes. In the medical field, the adoption of AM is driven by the congruence between the nature of the manufacturing technology and relatively high demand for low-volume or highly customized products, such as surgical implants.

Industry players have indicated that an ecosystem to support AM and greater economic incentives for adopting advanced manufacturing technology (especially in countries with low cost of factor inputs) are two necessary prerequisites to the adoption of AM technology in ASEAN.

Singapore, Malaysia, and Thailand have shown significant interest in developing AM technology. Singapore's government has expressed a particularly strong interest in popularizing the use of AM. Of the three AM research institutes in the ASEAN region, two are located within Singapore while the third is located in Thailand. Malaysia's installed AM base instead has resulted from the introduction of the technology by the multinational corporations (MNCs) in the medical and healthcare sector. Moving forward, the mold and die (tooling), aerospace and medical industries will be key sectors where AM technology should be leveraged within the ASEAN region.

Singapore 3D printing industry

Singapore has been developing itself as an AM hub through pioneering research and development and the creation of a robust ecosystem for the application of the technology.

Strong government support leads to widespread institutional adoption

Singapore can be considered a late adopter of the technology, but Singapore's government has prioritized the development of the technology as part of its push for Singapore to become an innovation hub within the ASEAN region. Singapore has always positioned itself as a gateway to the ASEAN markets, citing its business friendly environment (such as a highly educated workforce and favorable taxation policies), coupled with a sound legal and regulatory framework. It comes as no surprise that they have adopted a similar approach for the AM industry.

The AM movement in Singapore was given a boost with the formation of the National AM Innovation Cluster (NAMIC) in 2015 under the Innovation Cluster Programme. Government agencies such as the Economic Development Board, SPRING and National Research Foundation have been allocated a portion of the SGD200 million set aside for the Innovation Cluster Programme to develop the sector.

Twin levers of the government's push for AM technology adoption

Pioneering research

At the heart of the NAMIC will be the Nanyang Technological University (NTU) which will lead the new cluster, in partnership with the National University of Singapore, the Singapore University of Technology and Design and A*STAR, a government research agency. An example of research-led innovation would be NTU initiating a joint program with A*STAR to work on AM process design and development for direct manufacturing of components.

Industrial application is a key research focus. The NAMIC will partner with well-known foreign and local firms to help push upstream research to companies keen to adopt such technology. Firms will be allowed to try out AM and assess its usefulness before committing to buying industrial AM machines. Singapore is also a good testing ground for Research and Development not only for AM players, but for industry players that will potentially leverage the technology as well. For example, Proctor & Gamble is working with A*STAR to investigate the uses of AM on skin-based materials to test certain of its healthcare products.

Supporting the development of an ecosystem through attracting major international players, marketing proactively and developing standards

With attractive policies to encourage FDI, Singapore has succeeded in attracting foreign companies such as Ultra Clean Technologies (UCT) to set up regional headquarters there. UCT recently launched its largest commercial AM facility in Singapore, which will be made available commercially across the ASEAN region. An example of collaboration within the industry will be UCT Singapore partnering with an AM software giant, Materialise, to develop an online printing service to serve the region. Another large international player, Stratasys, opened its AM Experience Centre in Singapore to provide local support for the growing AM needs in the South Asia and Pacific regions.

As AM is relatively new and the properties of 3D printed components are still not fully understood, the development of AM-related standards is still at a relatively immature stage compared to that of other manufacturing technologies. As most of the standards are inherited from the US, Singapore has looked ahead and co-invested with United Laboratories (UL) to open a global AM center of excellence in Singapore. Through developing its own research capabilities coupled with the capabilities of testing and inspection, Singapore is endeavoring to be a knowledge center for the rollout of AM industry standards within the ASEAN region.

Industrial adoption can be boosted with greater industry participation

The government's high profile investment and propagation of AM has yet to see a stark increase in the overall readiness of the country in terms of AM technology adoption. Mr. Terrence Oh, EOS's VP of AM, indicated that a participatory community for adoption of AM is still lacking. Funding should be channeled towards the development of such a community, made up of Singaporean manufacturers, to build the number of case studies in terms of industrial re-design and application development. These companies should identify present day manufacturing challenges, create prototypes, and explore ways to solve those challenges through the use of AM technology. Such endeavors require not only funding from the government but support from research and design institutes to educate and collaborate with these companies.

Malaysian 3D printing industry

The adoption of AM in Malaysia is taking a curious trajectory that appears to skip ahead of the industry development curve. While AM in mass production has yet to establish itself as a serious option in the manufacturing industry (due to a combination of lower value-chain manufacturing coupled with a lack of economies of scale), it has begun to take root in the medical and healthcare industry as a promising–sometimes even essential–technology. The technology is looking to establish itself as a mainstay in the field of specialized surgery that has ranged from facial bone implants, heart operations, and limb replacement/prosthetics, thanks to AM's 'holy trinity': customizability, light weight, and precision.

The trend emerging in Malaysia is variant of the supply chain shortening phenomenon happening worldwide, albeit not in the traditional sense. While the macro driver at the global stage appears to stem from the mismatch between higher demand for standardized goods versus a capacity/capability shortage on the supply side, the opposite is the case for the medical industry: demand for low-quantity, highly customized goods that traditional manufacturers will hesitate to commit resources to manufacture, but which AM can produce conveniently. In a non-traditional supply chain scenario, AM has also helped reduce operating time in complex surgery cases, sometimes by as much as 50%, by allowing medical service professionals (MSPs) to visualize anatomical data in the real world through precise 3D models during pre-surgical preparations, which lowers costs for both MSPs and patients.

Market overview and trends

Medical & healthcare driving AM in Malaysia

DRIVERS

1. Strong projected growth in overall Asia Pacific healthcare additive manufacturing market
2. Advancement in materials for medical use
3. Adequate support for proliferation of technology

The growth of AM in the medical and healthcare sector in Malaysia reflects wider market trends in the region. In 2015, the Asia Pacific healthcare AM market was estimated at about USD35 million and is expected to experience a double-digit growth rate from 2016–2020. Although this growth is primarily expected to be driven by China (which has the largest market share presently, at 35%), the emergence of South Korea, Singapore, and Malaysia as medical tourism destinations is also contributing to this growth. For example, the economic region in the southern Malaysian state of Johor known as Iskandar Malaysia aims to develop itself into a medical tourism hub for ASEAN by 2025, projected to contribute MYR9.5 billion (USD2.4 billion) to the national economy, driven by a medical tourist base that has grown by as much as 35% year-over-year during the past 5 years.

As the medical market continues to grow, what makes AM exciting for MSPs is the advancement of materials. In traditional materials, MSPs often have to deal with tradeoffs between material strength/rigidity and comfort/breathability; the raw materials that have been certified for medical use in AM bypass this hurdle. The next-stage development of AM in biomedical engineering (such as the printing of live tissue, which has already made headway in the US) is expected to spur fast growth in the industry yet again once the technology reaches the Malaysian shores.

We believe that access to hardware and raw supplies is not a barrier for the Malaysian market. There are already several MNCs that have invested in Malaysia's AM market. Leading global AM hardware manufacturers such as Stratasys, TierTime, and Prodways, among a variety of other brands, have established a direct and indirect presence in the market, enabling access to the market's latest 3D printers. The same goes for human capital; Malaysia already enjoys a young, talented workforce trained in 3D software design, with more continuing to graduate from local tertiary institutions. With little reorientation, these workers should be able to quickly familiarize themselves with 3D software in the medical industry. For example, MNCs such as Materialise NV, a provider of 3D designing solutions to the medical sector, have established themselves in Malaysia and are looking to make it a regional medical AM services hub serving overseas markets as far as India.

> ***"Materialise employs a team at our Malaysian office that is dedicated to the Indian market to understand its specific needs, business culture, and to speak the same language... The focus is mainly on the various software solutions for AM [and] biomedical engineering. In recent months, there has also been a growing interest in our medical services."***
>
> – Wim Michiels, CEO Materialise Malaysia, November 2015

Overcoming regulatory barriers will be critical to improving adoption of AM in Malaysia.

Although MSPs in Malaysia are receptive to the technology, investors need to be cognizant of possible multiple regulatory requirements in the country, which have yet to be clearly formalized due to the youth of the technology. Investors should be aware that several ministries, agencies, and sub-agencies–each a stakeholder in its own right–will need to be managed (e.g. the Ministry of Health and Medical Device Authority) by new participants in the Malaysian market, and the exercise may not be as efficient compared to more developed markets.

Another challenge that may impede the industry from growing at its fastest relates to the Malaysian legal system. Given that the nature of AM technology allows for the copying and creation of existing 3D objects, the use of this technology has raised issues over the four main areas of intellectual property rights (i.e. copyright, trademark, patent, and industrial design), none of which are robustly addressed by the current intellectual property law framework in Malaysia. This could potentially deter larger investors from coming into the country, and existing players may have to spend more resources managing and mitigating the gray areas as smaller players begin to enter the industry.

Thai 3D printing industry

As one of the largest automotive and healthcare hubs in the ASEAN region, Thailand is an attractive location for application of AM solutions. However, when compared to developed countries, Thailand still lags behind significantly in the adoption of new technology.

Existing AM industries in Thailand

Thailand has a larger installed base of AM systems than either Malaysia or Singapore. These systems are primarily allocated within the following sectors:

- Education and research

  The major application of AM today is centered on R&D institutes such as the National Metal and Materials Technology Center (MTEC), National Science and Technology Development Agency (NSTDA), Thai-German Institute, King Mongkut's University of Technology North Bangkok, Chulalongkorn University Robotics Laboratory, Mahidol University, the Asian Institute of Technology (AIT), and FabLab. The technology is used for rapid prototyping and conducting research within the medical and industrial design industries. These institutions also engage in the promotion of the benefits of using AM technology to the public.

  For example, the NSTDA Academy plays an important role in promoting the benefits of AM through its annual "Value Creation by AM Technology Seminar." At the same time, desktop 3D printing has been adopted as part of the curriculum and is widely used in many international schools to expose students to the concepts and use of the technology.

- Healthcare

  AM usage in the healthcare sector is developing thanks to collaboration with national research institutions. For instance, the MTEC AIT helped to set up the Medical PR Laboratory, which showcases the use of selective laser sintering to perform rapid prototyping of human organs to aid pre-operative planning. Doctors in Ramathibodi Hospital, one of the largest state-owned hospitals, have also begun to use these AM services to manufacture prototypes of organs, such as the heart and lungs, by cooperating with local institutions or outsourcing to AM service providers in other countries such as Singapore. While the use of AM technology in healthcare is relatively basic at the moment, these institutions have expressed optimism that interest in the technology will grow rapidly in the near future.

- Aerospace and automotive

  While AM is not commonly adopted in mass manufacturing similar to the rest of ASEAN – it seems to have gained some traction in the automotive sector, especially in the rapid prototyping of parts by OEMs. However, it is rare to find AM adoption in tier 1 and tier 2 manufacturers. As Japan is one of the key adopters of AM technology within Asia, Japanese companies with subsidiaries or partners in Thailand have been more receptive to modifying their production lines to incorporate AM technology. One such example would be the tooling industry for aerospace applications.

Opportunities in Thailand

Advanced and innovative manufacturing technology is also a major area of interest for the Thai government. The government has initiated a plan to stimulate investment through incentives such as exemptions from import taxes for AM machinery, exemptions of the operating tax for R&D centers involving advanced manufacturing technologies, as well as favorable tax relief and foreign land ownership policies. Major industry players, such as Stratasys, have established their presence in Thailand and are focusing on the industrial design, automotive, and medical sectors.

3D PRINTING INDUSTRY IN CHINA

Government policy initiatives are key drivers for 3D industry development in China.

Development of the 3D industry has been a topic of conversation within the Chinese government for a long time, but progress has been limited due to the unfavorable macro- and micro- environment through the years. With the 3D industry developing in the global context at the same time that China has moved to increase its value added manufacturing, the industry began to gain enormous attention about four years ago from both the central and provincial governments, for a number of reasons:

- The technology would help manufacturers reduce the R&D cycle and lower costs, as well as improve their design abilities, contributing to Chinese industrial improvements.
- It could create new industries, coupled with new avenues for economic growth.
- It could solve manufacturing challenges in certain industries to benefit the public (e.g. in the healthcare industry to produce human organs).
- It could help entrepreneurs produce innovative products, helping more individuals start their own businesses and create more job opportunities.

At the moment, China's 3D printing industry is still at an initial stage, with barriers and challenges to be overcome and improvements to be made across the industry value chain. It is clear, however, that the Chinese government is determined to develop China's 3D printing industry by initiating a series of policies to provide support to the industry.

Two of these policies are proving to be the most influential:

National Additive Manufacturing Industry Development Promotion Plan (2015-2016).

Chinese government policies released in February 2015 for the first time include 3D printing industry development as a part of the national development strategy, showing the government's commitment to developing the industry.

Key highlights of this plan include:

a) The AM industry in China is anticipated to achieve approximately 30% annual growth of sales revenue by the end of 2016, and two to three companies are expected to be established and competitive in a global context.

b) A number of positive initiatives are encouraged by the government, such as providing a favorable tax rate and encouraging banks to provide loans to AM-related players (e.g. academic institutions, science and research centers as well as manufacturing enterprises).

c) The plan greatly emphasizes the usage of metal AM in aerospace and defense industries.

Made in China 2025

This plan is believed to be China's most comprehensive industrial plan to upgrade China's manufacturing and to move manufacturing up the value chain. In the plan, new materials (including 3D printing) have been prioritized as one of the strategic sectors in the next few years.

Priority sectors identified in the plan:

- New information technology
- Numerical control tools and robotics
- Aerospace equipment
- Ocean engineering equipment and high-tech ships
- Railway equipment
- Energy-saving vehicles and new energy vehicles
- Power equipment
- New materials
- Biological medicine and medical devices
- Agricultural machinery

There is limited information available on how the initiative will be implemented at the moment. However, it is clear that the government is going to use mandates / subsidies and other methods to encourage manufacturers to upgrade their factories and manufacturing processes.

Following the central government's initiatives, a number of local governments are also actively engaging with the 3D printing industry. One of initiatives involves building 3D printing industrial parks to attract and unite 3D printing related companies by providing favorable policy support, such as tax reduction, low rental costs and more. For example, first Zhejiang 3D printing national park opened at the end of May 2016, and Chengdu is planning to build an industrial cluster by leveraging on the presence of potential downstream end-user companies within the aerospace and defense industries.

Currently in China, key industries that adopt 3D printing technology are largely driven by government action.

It is clear that 3D printing technology in the aviation and national defense industries has developed more quickly than in other industries due to the push from the Chinese government.

Aviation

Globally, 3D printing technology has been employed in the production of titanium alloy airframes, landing gear and engine parts (e.g. turbine blades and disks). In China, the central government encourages the relevant institutes, universities, and companies to actively explore the possibilities of applying 3D technology in airplane manufacturing since 2001. Beihang University and Northwestern Polytechnical University are the leading universities in researching 3D printing usage in aviation.

Industry experts believe that 3D technology could significantly speed up the R&D process as well as reduce waste in manufacturing. One outstanding example comes from the C919, China's first domestically designed commercial aircraft. The titanium central wing spar of the C919 weighs about 140kg when manufactured using 3D technology, saving more than 90% in material utilization compared to that required by the traditional forging method. Another example is of the double-curved surface window frame, which could be produced by a foreign company at a cost of about USD2 million and a delivery time of around two years. In contrast, a domestic Chinese firm using 3D printing technology manufactured the window frame in about 55 days and at a lower cost.

The Chinese commercial aviation market is expected to experience positive growth moving forward. According to the plans from the Aviation Industry Corporation of China, mainland China will experience an increase of 5,378 civilian airliners, including 4,580 jumbo jets and 942 regional aircraft between 2015 and 2034. This increase in domestic demand, coupled with the development of domestically produced commercial aircraft, will bring promising market potential for 3D technology adoption in the long term.

Defense

3D printing technology has been adopted by the Chinese defense industry as well. For example, titanium alloy primary-load-carry components made by 3D printing technology are already being incorporated in J-15 fighter jets.

The technology could significantly shorten the R&D cycle to produce weapons. For example, it could produce fighter prototypes in the R&D stage, which may greatly reduce the R&D cycle from between ten and twenty years to as low as three years.

Moreover, the technology could also provide considerable support to military logistics, considering different types of products could be produced by 3D printing on the battlefield, from food and medical supplies to military equipment.

Outside of government-driven sectors, 3D printing technology in commercial use is still in an early stage.

Despite great promise, the main use of 3D printers for commercial use at the moment is in producing prototypes to test and amend designs for downstream customers, while the low adoption rate of 3D printing technology results from a number of reasons. Current obstacles in the adoption of 3D printing in China includes the speed of printing as well as the printing accuracy relative to the price of the printer. Furthermore, industry stakeholders have cited the lack of professionals trained to design components using 3D printing as one of the key barriers for progression of 3D printing in China.

Other issues still need to be addressed in connection with the adoption of 3D printing technology. For example:

- Intellectual property (IP) protection: 3D printing technology obviously opens the possibility for others to copy products. At the same time, it might be challenging for IP owners to identify infringers and infringements, as products manufactured by 3D printers are indistinguishable from originals. Thus, it is important to have effective methods to protect original manufacturers' IP.

- Industry standards: It is important to set industry standards for manufacturing and maintaining products produced by 3D printing technology. This will regulate the market and align manufacturers and customers' expectations.

- Roles and responsibilities of different parties: A number of parties are involved in 3D printing technology (e.g. 3D printer manufacturers, 3D printing software suppliers, OEMs, 3D printer operators, and customers using products made with 3D printing technology). It is necessary to clearly define the roles and responsibilities of each party to protect each player's benefits, especially when product problems occur.

- Safety issues: Individuals can easily print products based on available stereolithography files. Thus, it is vital to form regulations and policies to prevent customers from printing items that might be harmful to the public, such as weapons.

At the moment, industries that showcase slightly higher levels of adoption of 3D printing technology are dentistry and education.

Healthcare

3D printing technology has been broadly adopted by the dentistry industry in China. According to an expert from Peking University Stomatological Hospital, it takes about a week to produce a denture using traditional methods, and patients need to undergo a complex process and multiple trials, while the whole process may take less than half an hour with the application of 3D printing technology.

There are other reasons why 3D printing technology is popular in the dentistry industry. First, dentistry requires extreme personalization and customization of consumer products, which is a particular strength of 3D printing technology. Furthermore, the product size is small and the materials are widely available in the market, which provides a significant opportunity for 3D printing technology adoption.

Besides dentistry, a number of Chinese medical professors are working with different institutes to develop 3D printed organ prototypes to be used as surgical guides, or joint prostheses to be used for implants. In particular, bone prototypes are believed to be very helpful in preoperative diagnosis or surgery rehearsal. An expert from a local leading life sciences company states that by using bones printed by 3D printers for surgery rehearsal, in some cases surgery time may be reduced by 30% to 50%, while the success rate could increase greatly.

However, most remaining sectors of the healthcare industry hold a conservative attitude towards 3D printing technologies and are staying at the stage of “trial and testing.” A number of reasons contribute to this attitude; for instance, industry experts often cite the high price of 3D printers as well as printing materials. Moreover, government supervisory bodies and sanitary bureaus have not formulated market access mechanisms or clear regulations to supervise the quality of products produced or services provided by 3D printing technology. Furthermore, setting the price for services and products provided by 3D printing is a challenge, as there is no standardized pricing strategy or policy available.

At the same time, the medical expense products made with 3D printing technology may not be covered by the government under China’s health insurance system, as 3D printing related products and services have not been included in the Chinese medical system yet, necessitating personal expenditures by Chinese patients.

Education

The Chinese government is highly engaged in developing public understanding and awareness of 3D printing technology, aiming to improve market acceptance and adoption. The central government has been planning to invest in 3D printing education, and one government initiative calls for installing 3D printers for personal and consumer use in ~400,000 elementary schools by 2016/2017, allowing students to use 3D printers in daily study and to improve students’ understanding of 3D printing technology.

In response to the central government initiatives, local government and education institutes are actively engaging in 3D printing technology education. Some schools and universities are installing printers for trial use by students, not only to improve their understanding of 3D printing technology, but also to stimulate the younger generation’s passion for this technology. For instance, more than 5,000 schools in Yunnan province will provide 3D printing related classes beginning this year, focusing on the use of 3D printers to make products. Moreover, a number of schools in Zhejiang province purchased 3D printers for students to learn from and gain experience with the technology. Some schools and universities also teach basic knowledge of 3D printing, such as setting parameters, choosing printing materials, and polishing finished products.

Besides installing 3D printers for trial purposes, a small number of universities and research institutions also provide courses to teach the application of 3D printing technology to current manufacturing processes, as well as how to improve or amend 3D printing technology to better fit current applications. This practice is expected to gradually ease the 3D-related talent constraints situation in the long term.

On the other hand, 3D printer manufacturers as well as third parties understand the importance of engaging younger generations. Thus, some of them are cooperating with schools and universities by providing free or low cost 3D printers, as well as courses to teach them how to use 3D printers. For example, Tiertime, the largest table 3D printer manufacturer in Asia, has selected 50 schools in Beijing to provide 3D printers and courses to teachers.

Existing challenges and potential long-term growth.

In the long term, despite some challenges in the market, 3D printing has the potential to be adopted on a large scale in China, with growth mainly driven by the following factors:

- Government support, covering policies as well as funding
- The influence of pioneer companies in different industries

3D PRINTING INDUSTRY IN INDIA

Market potential of 3D printing in India and key drivers

According to 6W Research, India's 3D printing prototyping and materials market is projected to reach USD79 million by 2021. The rapid increase in domestic production, demand for lean manufacturing, and increasing penetration across various applications is kindling demand in the 3D printer market in India. With initiatives like "Make in India," the domestic manufacturing sector is being supported by the national government, which will play a pivotal role in the growth of the local 3D printing industry.

Major users of 3D printing in India

In the past year, automotive applications have accounted for the highest revenue share of the Indian 3D printer market, followed by industrial prototyping and education applications. Besides these, applications related to architecture, aerospace, and defense also witnessed growth. Medical applications will continue to innovate and contribute to growth in the 3D printer market. Other niche applications include arts and crafts, interior decoration, fashion accessories, footwear designs, jewelry designs, animation and gaming, furniture, and modeling.

3D printing technology evolution in India

The growing 3D printing trend of industrial manufacturing in India is largely due to the decreasing prices of state-of-the-art industrial 3D printers as well as a strong demand for the technology. In terms of materials used for 3D printing in India, the highest demand is for Polyactic Acid, better known as PLA, and Acrylonitrile Butadiene Styrene (ABS) – two of the most standard plastic 3D printing materials. In line with this, the most popular 3D printing technology used in India is fused deposition modeling.

The rapidly growing adoption and increasing user base of professional CAD/CAM design software like Autodesk, Solidworks, and Rhino have further proliferated engineering designs to be made in the form of software models that can be directly used as inputs by the CNC and 3D printing industry. The adoption of digital CAD processes in many of the traditional manufacturing sectors has opened up opportunities to introduce more product lines, enabling rapid prototyping and fast manufacturing processes even for products and components with small production volumes.

Players shaping the 3D printing market in India

At present, India primarily imports 3D printers from countries such as China, the US, and Germany. However, with government initiatives to boost domestic manufacturing, many local players are expected to emerge. India's market leaders in the 3D printing prototyping industry include small and medium tech firms like Altem Technologies, Imaginarium, Novabeans Prototyping, Think3D, MyObjectify, Stanley 3D Tech, 3D Spectra Technologies, and LBD Makers Technology. The trend is now rapidly shifting towards industrial & manufacturing applications, owing to growing awareness and declining prices for industrial 3D printers.

Adoption of 3D printing in India – Case studies

As one good example, GE's USD200 million, multi-modal advanced manufacturing facility in Pune, India, could revolutionize 3D printing and cause a ripple effect in the country's manufacturing industry. The giant facility is located in Pune, near Mumbai, and covers 67 acres. Dubbed a "brilliant factory" by its creators, the facility was established to produce jet engine parts, locomotive components, wind turbines, and a host of other additively and traditionally manufactured components for a number of GE companies. The facility now employs around 1,500 workers who are responsible for operating 3D printers and other machinery. The facility is helping to bring plastic and metal AM technology to GE's India operations, an advancement which offers the company huge flexibility and cost-saving potential.

Along with producing critical end-use components such as the jet engine fuel nozzle, the facility will also service a more urgent need: 3D printing replacement parts for broken machinery—parts that would otherwise have to be made in bulk and stored, or else sourced from an external supplier. Replacement parts, especially for older appliances, can be incredibly difficult to source when those appliances are discontinued or simply made in small quantities. 3D printing these replacement parts is much faster than producing them using traditional manufacturing techniques, with previous timescales of three to five months reduced to around one week with the use of AM.

The Pune AM facility will undoubtedly heighten the company's potential to produce high-quality 3D printed products all across the globe. The facility will also help to create jobs and spark technological developments in India, both within GE and for suppliers and connected businesses.

In 2015, Hindustan Aeronautics (HAL), India's sole manufacturer of military aircraft, used 3D printing technology to manufacture components for its 25-kN aircraft engine project. HAL plans to develop most of the components and assemble the new engine in next two years.

HAL is also ready to adopt 3D printing technology and acquire the technology used to print ABS plastic quality "Kaveri" engine components.

3D printing technology allowed engineers to print thousands of components for installation into the Kaveri engine in just 4 weeks, and assembly of the engine was completed in another two weeks, meaning a complete model of the Kaveri engine was manufactured in six weeks, which allowed HAL to study the engine in detail, including specific components that demonstrated technical anomalies or flaws that could not have been found by using only computer aided design. Before 3D printing, an engineering model of the Kaveri engine could have been developed only after up to a year of manufacture and assembly, meaning HAL saved nearly 40% of cost and nearly 10 months in preparation and assembly by using 3D printing.

Apart from industrial products and the educational sector, 3D printing in India is finding greater adoption in the healthcare industry, where research labs and hospitals are not only using the technology to bio-print tissues, but also using 3D printed cardiovascular models for pre-surgical planning. Dr. Kappanayil Mahesh, of the Amrita Institute of Medical Sciences and Research Centre Kochi, is well known internationally for his success in handling clinical cases using 3D mockups of real organs. One of the most common applications in healthcare is making custom implants, and Indian firms like Stryker have extensively used 3D printing for standard implant manufacturing. For example, 98% of hearing aids worldwide are manufactured using 3D printing, and this transformation has happened less than two years after the first adoption of the technology. 3D printing in the medical sector in India is expected to grow exponentially, not just for custom but also for standard devices.

Some big businesses and the government realize that India's small scale enterprises are a huge underutilized asset. The government estimates that India has 48 million small-scale enterprises, which account for 45% of its manufacturing output. However, these companies lack access to advanced manufacturing technologies as these small and medium enterprises are disorganized and poorly positioned to take advantage of new technology.

Notwithstanding this, India has a thriving outsourced engineering services industry that works alongside global companies that specialize in 3D modeling and other skills required for 3D printing. When these skills in 3D modeling and printing are imparted to engineers working in India's small and medium enterprises, they can rapidly develop samples and prototypes for their own customers. The industry, however, should not view these technologies as simply a replacement for manual labor in a country where job-creation is a priority. The trick lies in using 3D printing technology to make Indian workers more productive and the production processes safer, faster, and better.

In the past two years, a significant number of companies in India have been coming forward to explore this segment. People are getting easy access to 3D printing and market expectations are very high. Globally established players, such as Stratasys, 3D Systems and Optomec, are gradually establishing their footprints in India through partnerships and alliances with India-based technology firms. Other major global players in the 3D printing market include Sintermask (Fabbster), 3D Systems, Leapfrog, and Flashforge, along with a wide range of Chinese made printers that have flooded the Indian market recently. Major players active in India's 3D printing market (including manufacturers and distributors) include Altem Technologies, Brahma 3, Design Tech Systems Ltd., Imaginarium, JGroup Robotics, KCbots, and REDD Robotics (3Ding).

As with other young technologies, the 3D printing landscape of the future is still being shaped by key players within the industry. Ipsos Business Consulting will continue to carefully monitor new developments and opportunities, and an in-depth focus on 3D printing in Korea and Japan is already slated for early 2017.

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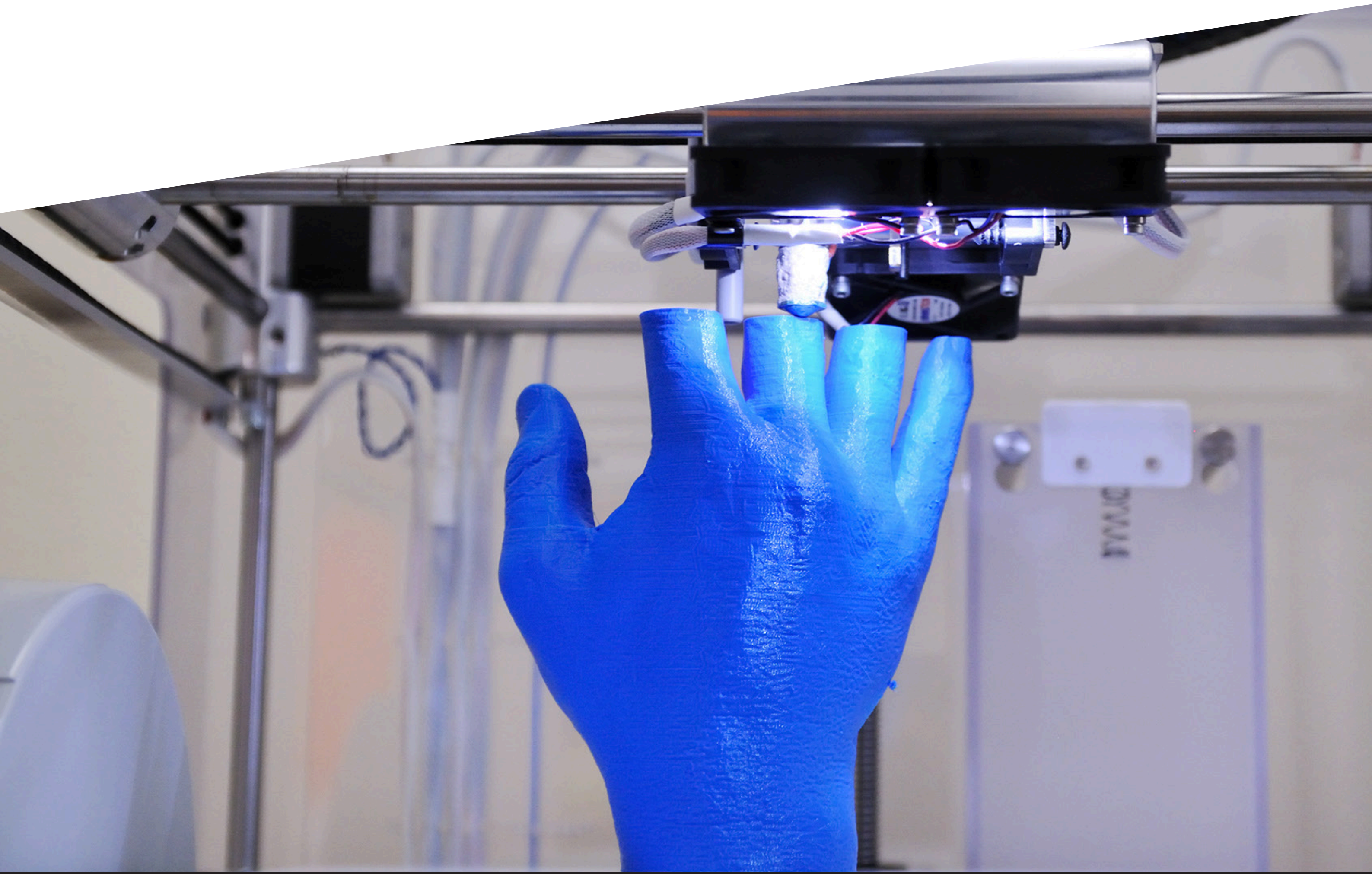

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