AMFG / Autonomous Manufacturing

THE ADDITIVE MANUFACTURING LANDSCAPE 2019

ESSENTIAL INSIGHTS INTO THE ADDITIVE MANUFACTURING MARKET, KEY TRENDS AND ANALYSES

TABLE OF CONTENTS

EXECUTIVE SUMMARY

Additive manufacturing (AM) is experiencing a renaissance. No longer solely a tool for rapid prototyping, the technology is finding a new lease of life in industrial applications like tooling and end parts.

2019 is, therefore, an exciting time for the additive manufacturing industry. The landscape is evolving rapidly as companies begin to adopt AM in-house and new technologies emerge, fuelled by application-driven demands from the market.

New players, offering innovative solutions, continue to enter the market, and partnerships and acquisitions continue to proliferate.

With these constant shifts in the market landscape, it can be difficult for manufacturers **to keep track of the key companies offering solutions across the spectrum of AM.**

For this reason, in February 2019, AMFG published the industry's first **Additive Manufacturing Landscape**. The purpose of this landscape was to provide manufacturers across industries with a better understanding of the current AM market, and use this to benchmark the evolution of the industry in the future.

From the outset, we knew that a high-level overview of some of the main categories within AM was sorely needed. However, the response to our first infographic was more than we anticipated. We've since received a multitude of suggestions for additional companies to be included in the revised edition of the landscape.

Having taken this feedback on board, we've now updated the infographic to include **171 companies and institutions that are actively helping to shape the future of additive manufacturing.**

This whitepaper is an analysis of the key trends taken from our research. With this report, we hope to provide a clear overview of the AM market landscape and the major trends to watch out for in 2019.

We hope you find this whitepaper a valuable resource, and we look forward to revisiting the landscape in 2020.

Victoria Akinsowon
Senior Marketing Manager, AMFG

ADDITIVE MANUFACTURING IN 2019

By the end of 2018, the global additive manufacturing market was estimated to have reached **$9.3 billion** [1]. This figure, which encompasses hardware, software, materials and services, represented an impressive 18% growth from the previous year.

A key factor driving this growth is the advancement of new applications for 3D printing, as companies continue to find areas where the technology adds value alongside traditional manufacturing methods.

Additionally, large companies and corporations are entering the market, bringing with them added investment and research.

Then there are the industries where adoption of 3D printing is continuing to increase. Unsurprisingly, the key industries at the forefront of adoption remain aerospace, medical and automotive. However, there are also emerging opportunities in sectors like consumer goods, energy and construction.

For companies within the AM ecosystem, these trends are a renewed source of excitement, offering significant opportunities to bring new technologies and innovations to market. Each of the companies included in this report are doing just that.

WHICH COMPANIES ARE INCLUDED IN THE LANDSCAPE?

For the purposes of this report, we've divided the Additive Manufacturing Landscape into six main categories:

- HARDWARE MANUFACTURERS
- SOFTWARE VENDORS
- MATERIALS SUPPLIERS
- POST-PROCESSING SYSTEMS
- QA AND PROCESS INSPECTION PROVIDERS
- RESEARCH INSTITUTIONS

WHICH COMPANIES AREN'T INCLUDED?

The scope of this landscape focuses exclusively on i**ndustrial 3D printing**. Therefore, we've only included companies that provide **B2B products and services**.

Companies with a primarily consumer focus are outside the scope of this report.

The service provider market is an important category that also hasn't been included in this landscape. Due to the large scope of this category, this will be the subject of a future report.

BREAKING DOWN THE ADDITIVE MANUFACTURING LANDSCAPE

Of the **171 organisations** featured in the AM landscape, there are:

92 Hardware manufacturers

32 Software vendors

29 Material developers and suppliers

11 Research institutions

5 Post-processing system manufacturers

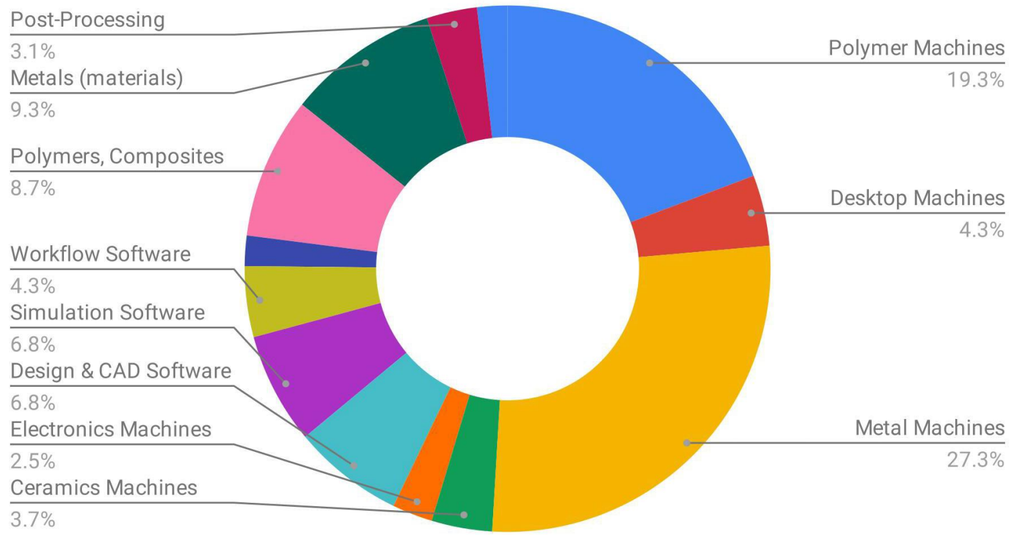
3 QA and process inspection companies


3D PRINTER MANUFACTURERS
Polymer Machines
31
Desktop Machines
7
Metal Machines
44
Ceramics
6
Electronics
4
SOFTWARE VENDORS
Design and CAD Software
11
Simulation Software
11
Workflow Software
7
Security/IP
3
MATERIAL SUPPLIERS
Polymers and composites
14
Metals
15
POST-PROCESSING
Post-Processing Systems
5
QUALITY ASSURANCE
Quality assurance & Process Inspection
3
RESEARCH
Research Centres & Institutions
11

METAL MACHINES ARE THE LARGEST SEGMENT

Metal machine manufacturers make up **47.8%** of the hardware category and **27.3%** of the overall landscape. These figures also exclude research institutions.

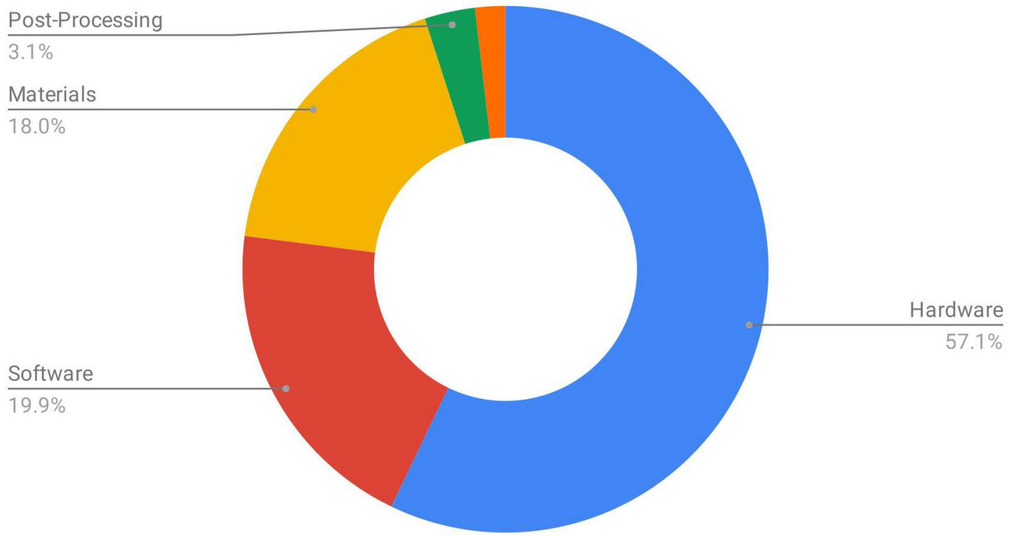
This finding is supported by the wider growth of the metal 3D printing market, as well as the influx of startups like **Desktop Metal, Digital Alloys**, **Velo3D** and **Markforged** entering the market with their own, proprietary 3D printing technologies.



Above: A breakdown of the AM landscape, featuring the hardware, software, materials, post-processing systems, QA & process inspection categories. Source: AMFG

HARDWARE IS THE LARGEST CATEGORY

Hardware manufacturers make up **57.1%** of the overall AM landscape, excluding the research institutions. This is a category that is becoming increasingly competitive, as companies launch new technologies to meet the demand for industrial solutions.



HARDWARE COMPANIES CROSS MULTIPLE CATEGORIES

In addition to the hardware category, a significant number of machine manufacturers occupy multiple categories. For example, almost all of the hardware manufacturers featured also offer materials that are compatible with their technologies. Examples include **3D Systems** (metals, thermoplastics, elastomers), **Carbon** (resins), **Markforged** (carbon fiber, fiberglass, kevlar, onyx), **Rize** (thermoplastics), **Roboze** (high-performance polymers) and **Stratasys** (thermoplastics, elastomers).

Others also provide software, such as **Ultimaker's** open source slicing software, Ultimaker Cura. Clearly, in what has become an increasingly competitive landscape for manufacturers, creating diverse revenue streams has become a strategic imperative.

NON-AM COMPANIES EYE NEW OPPORTUNITIES

Companies outside of the manufacturing industry are recognising the commercial benefits of 3D printing. One recent example is **Xerox**, which in February 2019 acquired **Vader Systems**, a manufacturer of liquid metal jet 3D printers.

As a direct result of this acquisition, Xerox has been added to our landscape. A broader example is the influx of global materials suppliers, like **BASF**, **Solvay**, **Arkema**, **Mitsubishi Chemical** and **SABIC**, all of whom are increasing efforts to develop AM-specific materials.

THE UNICORN TRIFECTA

As of 2019, three 3D printing companies have reached unicorn status — a valuation of over $1 billion. To put this into context, there are 326 unicorn companies in the world at the time of writing [2].

Notably, the three 3D printing companies are all hardware manufacturers: **Desktop Metal** ($1.5bn), **Carbon** ($1.7bn) and **Formlabs** ($1.06bn). All three mentioned have developed and commercialised their own 3D printing technologies.

THERE ARE MORE PRIVATELY-FUNDED AM COMPANIES

When it comes to sheer numbers, it's not necessarily a question of the larger, public companies leading the way.

A defining feature of the AM industry is the number of privately-funded or venture-backed startups that are populating the landscape. This landscape shows that **74%** of the companies fall into this category, while **26%** are public companies.

Admittedly, most of the public companies are either established industry players like **3D Systems**, **Materialise** and **Stratasys**, or well-established chemical or engineering corporations like **DSM** and **Siemens**. However, we also see some newer players becoming public, including hardware manufacturers, **Nano Dimension** and **Titomic**, and **Sigma Labs** (QA).

KEY TRENDS

TREND #1 METAL 3D PRINTERS: COMPETITION IS INCREASING

Metal 3D printing is continuing on its growth trajectory, with the creation of entirely new processes and advancements being made in existing technologies. A number of technologies are also due for commercialisation over the next two years: for example, both Digital Alloys and HP have slated 2020 for the commercial release of their metal 3D printing technologies.

On the one hand, this growth is tremendously exciting. The growing number of active companies within this segment illustrates the rapid pace of innovation that is happening in this sphere. On the other hand, with competition increasing in this category, the coming months and years will determine which metal AM technologies and manufacturers will ultimately dominate.

TREND #2 POLYMER 3D PRINTING CONTINUES TO MATURE

While metal 3D printing has received a great deal of press attention over the last couple of years, the steady growth of the polymer market has almost gone under the radar. **The increasing number of industrial applications being found** is one of the key reasons behind the growth of the polymer segment.

Another important factor is that materials suppliers are developing high-performance polymers, such as PEEK and ULTEM, that retain their mechanical strength even in highly demanding, industrial environments. These developments have the additional benefit of broadening the portfolio of materials that can be used for 3D printing.

There have also been developments on the polymer hardware side. At Formnext 2018, EOS announced its LaserProFusion system, developed specifically for polymers.

With one million diode lasers melting the polymer material, the LaserProFusion machine promises speeds ten times the rate of existing systems — and a potential alternative to injection moulding processes. This is yet another sign of strides being made to ensure polymer 3D printing can meet the demands of industrial manufacturing.

TREND #3 SOFTWARE IS BECOMING CRITICAL FOR INDUSTRIALISATION

As additive manufacturing industrialises, software is playing an increasingly significant role across all areas of the AM workflow. While design, CAD and simulation have always been a requirement, the production of industrial-grade and lightweight parts requires software that can adequately cope with the specific requirements of the additive manufacturing process.

As a result, software used for design and product development is becoming more advanced out of necessity, leveraging technologies like generative design and topology optimisation.

But it's not only design and simulation solutions that are dominating the software space. Workflow software is a subcategory that has emerged over the last five years - but only in the last two has it seen greater interest outside of a core client base of service providers. As manufacturing departments look to manage and scale their 3D printing efforts, workflow software that can manage the production process is becoming a vital component.

The market for workflow software will, therefore, continue to grow as the need for greater visibility, centralisation and automation is increasingly felt by service providers and OEMs alike.

TREND #4 AUTOMATION IS A KEY FOCUS ACROSS SEGMENTS

While additive manufacturing offers game-changing benefits for production, the reality is that many areas of the production process itself remain manual.

This lack of automation is a key source of frustration among many manufacturers. As a result, companies within the AM landscape are increasingly **offering automated solutions to reduce the time needed to perform key tasks**.

For example, post-processing, known for its labour-intensive and manual processes, is one area that can greatly benefit from automation. It's no coincidence, therefore, that 3 of the companies in this category offer **automated post-processing systems.** A similar trend can be seen on the software side, where automating manual tasks along the AM workflow is a key imperative. Software vendors are therefore offering solutions to automate repetitive, manual tasks, like production scheduling and file repair.

TREND #5 COLLABORATIONS, PARTNERSHIPS AND ACQUISITIONS ABOUND

The additive manufacturing industry is still relatively small, particularly when compared to the wider $12 trillion manufacturing market.

As a result, many companies have recognised that collaboration and, in some cases, acquisitions, will be key to accelerating the adoption of the technology. Such examples are apparent across all categories.

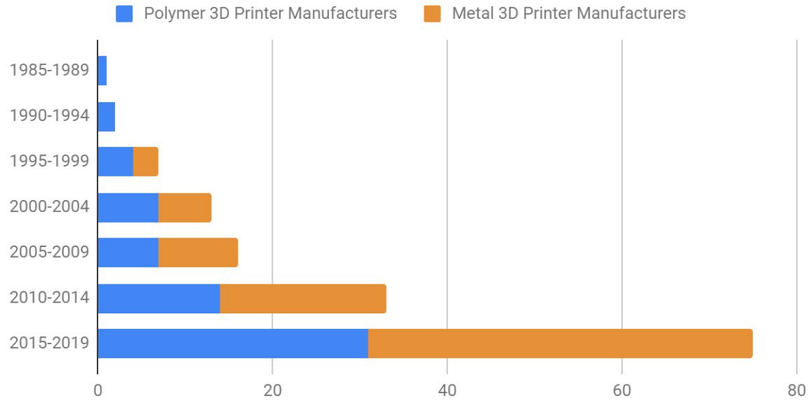
Take, for example, GE's acquisitions of Concept Laser and Arcam (2017), ANSYS' acquisitions of 3DSIM (2017) and material company, Granta Design (2019), and Carpenter Technology Corporation's acquisition of UK-based metal supplier, LPW (2018).

HARDWARE

Industrial 3D printers are continuing to advance on all fronts: print speeds are increasing, part quality and accuracy are improving, and costs of the machines are continuing to decrease. Across the spectrum, companies are also developing their own technologies in a bid to differentiate themselves from the competition.

The industry's shift towards manufacturing is a key driving force in the evolution of the hardware landscape. As OEMs look to adopt 3D printing for manufacturing applications, hardware vendors are aiming to meet this demand by developing more sophisticated industrial-grade systems.

It's worth noting the dramatic increase in the number of hardware manufacturers over the last decade, as show in the graph. In the last 10 years, new players like **Desktop Metal, Markforged** and **Carbon** entered the market, as well as well-established names like **HP**, **GE Additive** and **Lincoln Electric**.

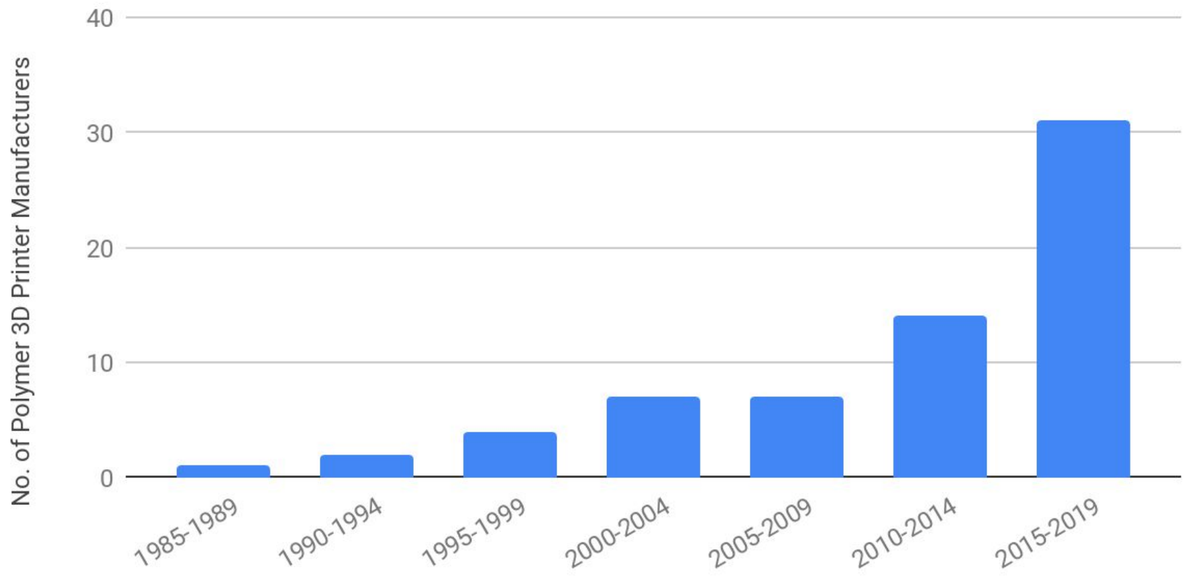


Above: The number of polymer and metal 3D printer manufacturers has risen significantly in the last 5-10 years. Source: AMFG

POLYMER MACHINES

Additive manufacturing truly began with polymer 3D printing, when the first commercial SLA machine was released by 3D Systems in 1987. The 1990s saw **EOS** and **Stratasys** joining the landscape — and for about a decade, the hardware market for 3D printing was dominated by the three key players.

Of course, the market has evolved significantly since then. Since the late 2000s, there has been a sharp increase in the number of companies offering machines that produce high-quality polymer parts — helped, in part, by the expiration of key patents around the same time.



Above: The number of manufacturers of industrial polymer AM systems from 1985 to now. Source: AMFG

DEVELOPING NEW TECHNOLOGIES: CARBON AND NEXA3D

Two examples of companies developing their own technologies are **Carbon** and **Nexa3D**.

Carbon, founded in 2013, has its eye set on high-volume production. Its proprietary Digital Light Synthesis™ (DLS) technology is used by the likes of Adidas, Ford Motor company and Riddell to produce high-quality polymer parts.

DLS is a photochemical process that works by fusing together light and oxygen to produce parts from a pool of programmable liquid resins. For the company's customers, the technology offers a number of benefits, not least the ability to 3D print high-performance, durable parts with an excellent surface finish and isotropic mechanical properties.

Perhaps a less well-known name, US startup, Nexa3D, is a manufacturer of high-speed, industrial-grade SLA printers.

Its 3D printers are based on the company's proprietary Lubricant Sublayer Photo-curing (LSPc) technology, which is said to offer faster print speeds and greater accuracy than any other industrial SLA system on the market.

METAL MACHINES

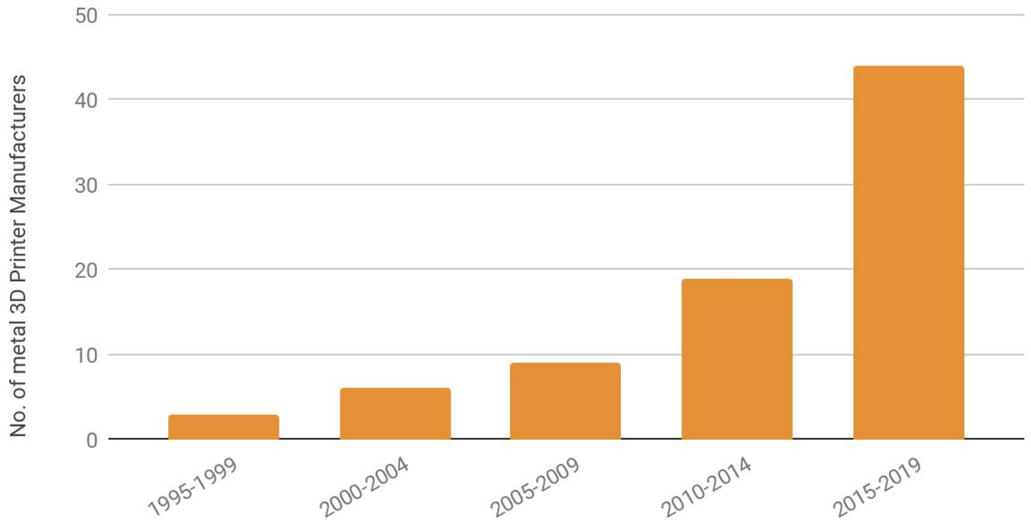
Arguably, the metal 3D printing market is evolving more rapidly than any other segment. Overall, the market has seen continued growth over the last few years — the period 2017-2018 alone saw an 80% growth in the sales of metal AM systems [3].

The number of companies offering metal Powder Bed Fusion technologies has increased over the last decade, with companies like **Renishaw**, **AddUp**, **Farsoon**, **Trumpf** and **DMG Mori** moving into the space to challenge established incumbents like **EOS** and **SLM solutions**.

However, with competition increasing in this space, manufacturers will need to determine which technology will best suit their needs. On the flip side, vendors will need to differentiate their offerings and continue to improve the technical capabilities of their systems to ensure a continued advantage.

There has also been an increase in the number of manufacturers now offering metal binder jetting technologies, with **Desktop Metal**, **HP**, **Stratasys** and **GE Additive** all throwing their hat into the ring with technologies set to be fully commercialised in the coming months.

The graph below shows that the number of metal 3D printer manufacturers on the market has seen a sharp increase, particularly in the years 2015-17. This period saw an influx of companies like AddUp, **BeAM**, **Digital Meta**l, **Spee3D** and **Velo3D** entering the market.



Above: The period 2015-2019 has seen a significant increase in the number of manufacturers offering metal 3D printing systems. Source: AMFG

NEW PLAYERS: DESKTOP METAL AND DIGITAL ALLOYS

Further driving the excitement within the metal AM sector is the development of new processes. **Desktop Metal** is one example — the company is targeting two segments with its Studio System (desktop) and Production System (large-scale manufacturing).

The Production System uses a reinvented binder jetting process, called Single Pass Jetting™ (SPJ), which is said to be faster than comparable laser-based systems. It is also said to be able to compete with traditional manufacturing methods, like casting.

Another US-based company, **Digital Alloys**, has developed its patented Joule Printing technology for metal 3D printing. Set for commercial release in 2020, Joule Printing is a high-speed technology that uses metal wire instead of powder as its raw material. The metal wire is fed into a precision motion system with a precision wire feed and is melted by a current as the print head moves, with the droplets of metal fused together to form the final part.

Having secured a $12.9 million Series B funding round in 2018, Digital Alloys says that its technology will help to address the issues of speed, quality and cost for metal additive manufacturing.

MOVING FROM POLYMERS TO METALS: HP AND MARKFORGED

A few manufacturers of polymers machines have also made the move into metal 3D printing, having spotted a strategic opportunity to straddle the two categories.

Take **HP** as an example. After the successful release of its Multi Jet Fusion (MJF) technology in 2016, the company announced its Metal Jet system in 2018.

Like MJF, HP's Metal Jet has been developed with an eye on high-volume manufacturing. Metal Jet's binder jetting technology uses metal injection moulding (MIM) powders and is said to be up to 50 times more productive than comparable binder and laser sintering technologies on the market.

Markforged's development tells a similar tale. Following the release of its composite Mark One 3D printer in 2013, the company expanded its scope to metals in 2018, with the release of the Metal X desktop 3D printer.

The Metal X uses Atomic Diffusion Additive Manufacturing (ADAM) technology, whereby metal powder, encased in a plastic binder, is printed layer by layer before being sintered and fused into a solid metal part.

With a price point under $100,000, the system offers in-house metal 3D printing at a fraction of the cost of industrial metal systems that can typically cost upwards of $1 million.

DESKTOP MACHINES

The landscape for desktop 3D printing has undergone a significant transformation over the last five years, largely driven by the burst of the consumer 3D printing hype.

A number of desktop manufacturers saw a decline as a result of the collapse — but others have successfully made the transition from consumer to professional and enterprise markets.

This shift is indicative of the broader need for industrial systems that are smaller and a fraction of the cost of their larger counterparts.

Desktop 3D printers are becoming a vital part of the industrial landscape, and product development in particular, offering a means of rapid prototyping and, increasing, tooling and end part applications.

FROM CONSUMER TO ENTERPRISE: FORMLABS AND ULTIMAKER

Two defining examples of the shifts in desktop 3D printing are **Formlabs** and **Ultimaker**.

In 2011, Formlabs was founded with a mission to make professional SLA 3D printing more accessible. At the time, the market for SLA systems consisted of large, expensive industrial 3D printers, inaccessible to many smaller companies and AM departments.

Formlabs' desktop SLA systems have helped to transform the status quo, offering industrial machines that are not only smaller, but also more affordable — its Form 2 3D printer retails for around $3,500. This, in turn, has helped to make SLA machines more accessible to a wider range of companies.

The company is now perhaps the industry's biggest seller of SLA 3D printers, with over 40,000 systems sold as of December 2018 [4]. Formlabs has also expanded its scope to SLS in 2017, having released its first desktop SLS system, the Fuse 1.

In less than a decade, Formlabs has established itself as one of the leading companies in desktop SLA 3D printing, thanks to a combination of technological innovation and astute strategic thinking.

On the FFF/FDM side of the industrial desktop equation is Ultimaker. Founded on a similar premise of making 3D printing accessible to all, Ultimaker offers a range of open-source desktop 3D printers in addition to materials and software. Its strategic decision to focus on enterprise has proven to be the right bet, offering an alternative to established players like Stratasys' industrial FDM machines.

For example, Volkswagen Autoeuropa is successfully using Ultimaker's desktop machines to 3D print tooling, jigs and fixtures, reportedly achieving $200,000 in savings in 2018 [5]. Similarly, Jabil is using Ultimaker's desktop printers to produce tooling, fixtures and jigs in-house — and its Jabil's Auburn Hills facility has seen an 80% reduction in the time needed to produce tooling and fixtures [6].

CERAMICS

Compared to polymers and metals, ceramic 3D printing is still in the very early stages of development. The technology is still relatively immature, and high material costs and challenges associated with the printing process are currently barriers to widespread adoption.

That said, the potential of ceramic 3D printing is exciting. One report estimates that the segment will generate $3.6 billion in revenues by 2028 [7]. The same report predicts an inflection point for the technology after 2025, helped the development of ceramic injection moulding (CIM) processes in much the same way that metal injection moulding-based AM processes have helped the adoption of metal 3D printing.

The ability to 3D print complex ceramics parts could be transformative. High-performance ceramic parts are used in industries like aerospace, dental, electronics, biomedical and jewellery. Applications include bearings, semiconductors, restoration of veneers and crowns, as well as prosthetic limbs.

Currently, there are a handful of companies offering 3D printing systems for 3D printing ceramics. This small number is indicative of the challenges of 3D printing ceramics: the materials have very high melting points, for example. High porosity and a propensity for micro-defects are also additional challenges, as is the need for extensive post-processing (including debinding and sintering) to achieve the required mechanical and chemical properties.

In addition to these challenges, companies will need to develop the applications to truly take advantage of the technology and make adoption viable.

SPOTLIGHT: NANOE AND LITHOZ

Founded in 2008, Nanoe offers industrial-grade technical ceramics. Nanoe was the first company to offer technical ceramic filaments — Zetamix — and has adapted its ceramic materials to the FDM 3D printing process.

Lithoz, based in Austria, provides materials and 3D printers for high-performance ceramics. The company has developed a technique called lithography-based ceramic manufacturing (LCM), based on DLP photopolymerisation methods. Its CeraFab systems and ceramic-based materials have been used in applications within the dental and aerospace industries.

ELECTRONICS

Like the ceramics market, the market for 3D-printed electronics is still relatively young, but is one that holds great promise for the sector.

From drones and satellites to consumer devices like smartphones, the use of electronics in today's landscape is ubiquitous.

Such devices require electronic components like printed circuit boards (PCBs) to function. 3D printing has the potential to redefine traditional design approaches for these components by providing greater design complexity (particularly in the case of non-planar, or non-flat, geometries) and accelerating the product development phase.

With 3D printing, companies can create complex electronic components with intricate shapes - giving designers and engineers the freedom to produce electronic objects that couldn't have been created with any other means. Additionally, the ability to 3D print prototypes in-house can help to eliminate the costs and delays associated with outsourcing to third parties.

PIONEERING ELECTRONICS 3D PRINTING: NANO DIMENSION AND OPTOMEC

Nano Dimension is one of the leading companies within the field of electronics 3D printing. Its DragonFly Pro System simultaneously 3D prints metals and dielectrics polymers in a complex process that requires multi-material 3D printing capabilities. The company's technology is enabling companies to 3D print electronic prototypes in-house, faster and cheaper.

In addition to metal 3D printing, US-based Optomec offers solutions for additively manufacturing electronic components. Its Aerosol Jet technology offers a multi-material approach, as multiple ink input devices allow materials to be switched and blended during the printing process.

SOFTWARE

As additive manufacturing continues to industrialise, software will play an increasingly critical role in managing all elements of the additive workflow.

While design and simulation software have received the majority of press attention in recent years, growing segments to keep note of are workflow and security software solutions. As companies look to scale and expand their AM facilities, workflow software that can efficiently manage and coordinate each part of the production process will be vital for greater efficiency, traceability and repeatability.

Similarly, the gradual move towards distributed manufacturing models will require the transfer of digital assets between parties and, therefore, security will become a growing concern. A small number of startups in this segment have emerged to address this issue head on.

DESIGN/CAD

Additive manufacturing offers the benefits of greater design complexity and freedom. However, design software is key to unlocking this geometrical freedom.

The rapid evolution in 3D printing technologies has meant that design tools have had to play catch up to the advancements made.

Design for additive manufacturing (DfAM) has become a talking point within the industry, as AM requires an approach to design that differs from traditional manufacturing methods. Accompanying

this are trends like generative design and topology optimisation, tools developed to give engineers new opportunities to create innovate, complex designs that would otherwise be impossible to produce.

AUTODESK

Products: Netfabb, Fusion 360

The design and CAD software landscape for additive manufacturing is dominated by well-established names within the field of engineering software.

Autodesk, for example, offers a range of software products, including print preparation software, Netfabb, used to prepare STL files for 3D printing.

Autodesk also has a strategic focus on generative design, with the release of its Fusion 360 software.

PARAMATTERS

Product: CogniCAD

The field of design and CAD software also contains a handful of startups hoping to transform the market. Paramatters, founded in 2016, has developed generative design software, CogniCAD.

The California-based company's software platform offers a range of tools, including topology optimisation, high-res finite element analysis (FEA) and computational geometry. The software's scope carries positive implications for industries such as automotive, aerospace and medical.

NTOPOLOGY

Products: Element, nTop

Founded in 2015, nTopology offers design software. In 2017, the company released its generative design software, Element, which provides lattice design and optimisation tools. Engineers have the ability to create complex structures such as lattices and cellular objects. The company has a goal to become a key player within the design and CAD realm, with generative design technology being a key strategic element of its value proposition.

SIMULATION

Advancements in simulation software go hand-in-hand with the growth of the metal 3D printing market.

Currently, the metal 3D printing process can still be unpredictable at times, with issues like warping and distortion inherent in the process. Consequently, trial and error remains a common issue for many companies.

Simulation software can help to minimise the risk of build failures by simulating and predicting the behaviour of a part before a file is even sent to print.

ANSYS

Product: Additive Suite

ANSYS' is looking to dominate the sphere of simulation solutions for metal 3D printing. The company has recognised the potential of additive, siand has expanded its software offerings to cover metal AM with Additive Suite, a series of metal simulation and advanced design tools.

To this effect, its Additive Suite software provides both part and process simulation, and is increasingly moving into the realm of designing for additive.

ANSYS has also made a couple of acquisitions, including metal simulation company, 3DSIM, and materials company, Granta Design – all an effort to expand its simulation capabilities for metal 3D printing.

Additive Works

Product: Amphyon

Founded in 2016, Additive Works' Amphyon software has been developed to enable a "first-time-right" additive process for metal 3D printing technologies. With analysis, simulation and other tools within its product scope, Additive Works aims to bring greater simulation to the metal AM process.

WORKFLOW SOFTWARE

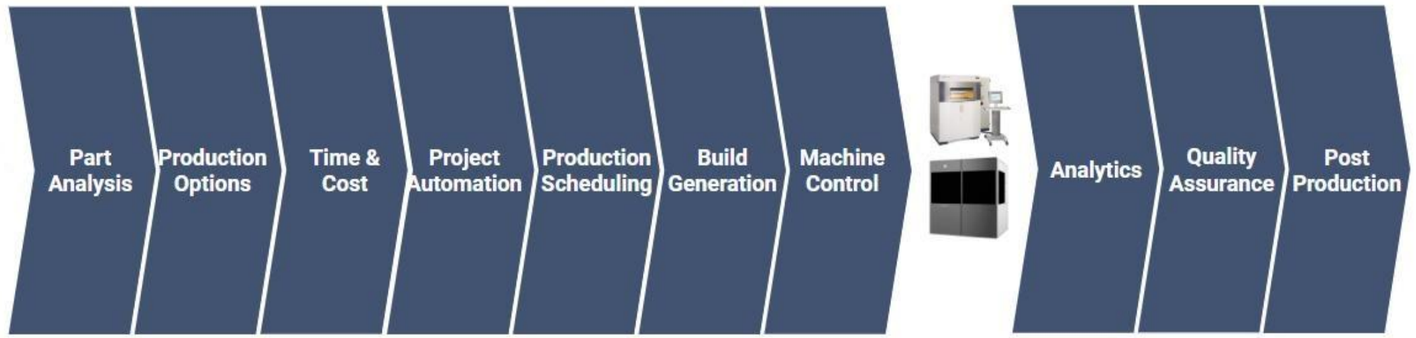
The industry's move from prototyping to production has led to the increasing need for workflow software.

Workflow software aims to provide a complete system to manage and coordinate all of the processes involved in additive production. This can include, but isn't limited to, standardising requests, conducting printability analyses and scheduling production.

Key trends driving the growth of this segment are the need for an end-to-end platform, flexible enough to be customised to the individual requirements of additive manufacturing departments. Currently, only very few companies currently offering such a solution.

Machine connectivity will also play a bigger role, as users begin to demand more 'plug and play' solutions and the ability to connect their entire network of machines.

The need for workflow software is ultimately a volume question, and will become increasingly pertinent as companies look to scale their additive manufacturing activities.



Above: the scope of AMFG's workflow software platform

SECURITY

The market for security software for additive manufacturing is small, occupied by less than a handful of providers. A key reason for this is maturity: the majority of OEMs have not yet reached a point in their AM adoption whereby the need for security solutions has become imperative.

That said, trends that will likely drive the growth of the software security segment include the potential of distributed manufacturing. Distributed manufacturing refers to the ability to produce parts on-demand, close to or at the point of need. This model will enable companies to streamline their supply chains and reduce costs associated with logistics and inventory maintenance.

Of course, this also requires the transfer of data and digital assets between parties. As the rate of AM adoption increases, companies will need to consider how they control their assets and secure the transfer of design files and other digital assets along the supply chain.

LEO Lane
Founded: 2013

LEO Lane provides a cloud-based Saas solution to encrypt files when they are sent between two parties. Its “Limited Edition Object” (LEO) files replace the full digital file when the transfer takes place. The LEO includes a modified from of the STL format (LSTL), which can determine the design. An IP owner can build instructions into the LSTL file, for example specifying the type of machine a part is to be printed on, the material that is to be used, and the authorised number of prints. LEO Lane has also recently partnered with AMFG to provide secure, end-to-end workflow solutions.

GROW
Founded: 2014

GROW offers secure distributed manufacturing solutions enabling designers and service bureaus to protect their IP. Users can, for example, lock down instructions for an additive manufacturing process to a 3D printer ID number.

Identify3D
Founded: 2014

Identify3D offers IP protection, quality assurance and data security for digital manufacturing. This includes the authentication of devices and settings. With the software, users can track the movement of parts, secure files against counterfeits and prevent files from being modified so that unauthorised or uncertified parts can’t be produced and pollute the supply chain.

MATERIALS

Big names dominate the category of AM materials. Looking to stake their claim in the market, global materials suppliers like DSM, SABIC, BASF, Arkema and Solvay are heavily investing into materials research and development specifically for additive manufacturing.

This increase in competition will go a long way to tackling two of the key challenges facing additive manufacturing: 1) the cost of materials and 2) the variety of materials. The more players that are active in this category, the greater the likelihood that material costs will be driven down and a broader range of materials will ultimately be developed.

The demand for industrial-grade materials will also drive growth, particularly across critical industries like automotive and aerospace. Hence the rise in materials like high-performance thermoplastics, composite materials like carbon fibre, ceramics and, of course, metal alloys.

There are also 3D printer manufacturers that are also investing in materials development to secure long-term revenue streams. **Carbon**, for example is diversifying its portfolio of polymer materials, while on the metal side, companies like **Desktop Metal** and **Markforged** have developed new metal feedstocks to rival loose metal powders.

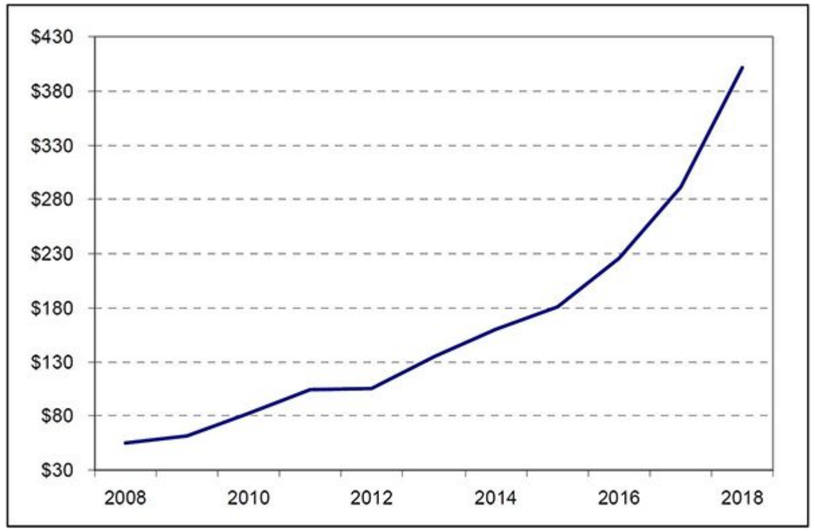
The Additive Manufacturing Landscape 2019

POLYMERS

In terms of revenue, the largest materials segment for additive manufacturing is polymers.
In 2018, the polymer AM segment grew to nearly $5.5 billion, according to one report [8].

The 2019 edition of the Wohlers Report shows a similar tale: sales of materials for polymer powder bed fusion in 2018 were at an all-time high see graph).

A key trend to note is the rise of high-performance polymers, materials that can withstand demanding, stressful environments. These include materials like PEEK and PPSU, both known for their high heat and chemical resistance. In some applications, high-performance thermoplastics can provide an alternative to metal, matching the strength of metal parts, but at a fraction of the weight.



Above: Sales of materials for polymer PBF reached an all-time high in 2018. Source: Wohlers Report 2019

Aiding this development is the emergence of 3D printers that can process these high-temperature materials.

METALS

For a fifth consecutive year, **the metal materials market saw strong growth in 2018 — 41.9%** [9].

With metal 3D printing gearing up for production applications, metal powder manufacturers and suppliers are investing to meet rising demand from customers.

Additionally, the cost of materials will be paramount. Here, trends include the proliferation of metal injection moulding (MIM) based metal powders and filaments. These are ideal for low cost, high-speed metal additive manufacturing. Interestingly, Desktop Metal, HP and Stratasys are among the well-known names currently targeting MIM for their new metal systems.

Metal alloys and metals like titanium can be prohibitively expensive to use with conventional methods. For this reason, currently, one of the most popular materials for 3D printing is titanium, driven by applications within the medical, dental and aerospace industries. For example, titanium can be used for implants, with additive manufacturing providing a cost-effective means to produce customised implants for patients.

Titanium is also seeing an upswing in adoption for 3D printing within aerospace, as titanium-based alloys have a high melting point and are resistant to oxidation and acids — ideal for critical aircraft parts like brackets and housings in aircraft engines [10].

POST-PROCESSING SYSTEMS

For a long time, post-processing has been referred to as additive manufacturing's 'dirty secret'. This is because post-processing, a necessary step in any AM workflow, has typically been highly manual and labour-intensive.

Simplifying the process of going from a print to a finished part that is ready to use has, therefore, been a key imperative for the industry.

An imperative that is being driven by automation.

The ability to automate the post-processing stage comes with a number of benefits, not least being able to significantly reduce overall production times.

AUTOMATED POST-PROCESSING SOLUTIONS

Currently, there are three key companies globally offering automated post-processing solutions: **PostProcess Technologies** (US), **Additive Manufacturing Technologies** (UK) and **Dyemansion** (Germany).

While a small category, there is still a lot of activity in this segment. For example, PostProcess Technologies has recently announced plans to expand into Europe with its partnership with Rösler Oberflächentechnik GmbH, a manufacturer of finishing systems for traditional manufacturing.

DyeMansion, which offers systems for the automated cleaning, finishing and colouring of 3D-printed parts, is also looking towards expansion. The company received a $5 million Series A investment in 2018, to be used to develop a finishing technology that can achieve injection moulded surface quality with 3D-printed polymers.

Additive Manufacturing Technologies (AMT) currently offers its PostPro3D system, a vapour smoothing system designed to smooth and finish thermoplastic polymer parts.

The technology, which is based on the company's proprietary BLAST™ process (Boundary Layer Automated Smoothing Technology), is said to rival injection moulding finishing. AMT is gearing up to release its PostPro3D Mini, a scaled-down version of the PostPro3D system.

CONCLUSION

This year's Additive Manufacturing Landscape illustrates the diverse set of companies within the industry, as well as the fast-paced nature of the industry itself.

Through this whitepaper, we aim to have provided a clearer picture of the AM landscape, particularly for manufacturers seeking more knowledge about the industry and its key players.

The coming months will see a greater interplay between each of the major segments, particularly hardware, software and materials, as manufacturers demand seamless workflows and systems that work harmoniously with each other.

All of these elements will therefore need to come together to ensure an end-to-end seamless additive manufacturing workflow.

For manufacturers looking to adopt additive manufacturing, it is vital to consider all of the options available before opting for a solution.

A key takeaway, therefore, is to use this landscape as a starting point to research which vendor(s) best meet your needs, so you can ensure that you're able to unlock the full benefit of additive manufacturing.

REFERENCES

[1] *2019 Additive Manufacturing Market Outlook And Summary Of Opportunities*, SmarTech Publishing

[2] '$1B+ Market Map: The World's 326 Unicorn Companies In One Infographic' CB Insights

[3] *Wohlers Report 2019,* Wohlers Associates

[4] 'From startup to unicorn, an inside look at Formlabs' metamorphosis', 3D Printing Media Network

[5] 'Can you jig it? 3D printing inside Volkswagen Autoeuropa', TCT Magazine,

[6] 'Jabil Auburn Hills sees 80% reduction in production time with Ultimaker', Ultimaker.com

[7] *Ceramics Additive Manufacturing Markets 2017-2028*, SmarTech Publishing

[8] 'The global additive manufacturing market 2018 is worth $9.3 billion', SmarTech Publishing

[9] *Wohlers Report 2019,* Wohlers Associates

[10] *Revenues From 3D-Printed Titanium To Reach Almost $520 Million By 2022*, SmarTech Publishing

AMFG Autonomous Manufacturing

About AMFG

AMFG provides an AI-powered workflow software platform that enables manufacturers to streamline and manage their entire additive manufacturing workflows.

AMFG offers flexible, customisable workflow solutions to ensure a seamless production workflow, from request management to production scheduling and post-processing management.

With offices in four global locations and customers in 19 countries, AMFG has expertise in working with enterprise companies to help them scale their workflows and successfully integrate additive manufacturing into their wider manufacturing processes.

For more information, contact: **info@amfg.ai** or visit: **www.amfg.ai.**