Aircraft, Spacecraft and Drones:
The Future of Industrial Production Takes Off with Additive Manufacturing

A SMARTECH PUBLISHING RESEARCH NOTE

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Aircraft, Spacecraft and Drones: the Future of Industrial Production Takes Off with Additive Manufacturing

Of all the industrial sectors that are bound to benefit from the transition to additive manufacturing production, the aerospace industry is where the most significant revenue opportunities are arising and will continue to arise in the foreseeable future. SmarTech Publishing provides and in-depth analysis of the specific opportunities in major aerospace segments in three new reports which focus on civil aviation, space-borne parts and UAVs (drones).

The combined, overall revenue opportunity for AM hardware, software, materials, services and parts in these three booming industry segments is expected to grow to over $20 billion by 2027. This conclusion is in line with overall expectations for the AM industry, which sees AM representing between 1% and 2% of the $12 trillion manufacturing industry by 2030.

Buckle Up

In the civil aviation manufacturing industry, which includes both private and commercial aircraft, AM is expected to represent at least 1% of the overall $1.8 trillion generated yearly by 2027. The market for AM technologies and materials in civil aviation is set to grow steadily, driven by record demand for new aircraft over the forecast period. It is expected that more parts will be produced by AM in a market segment which is expected to continue experiencing record growth through 2027.

The yearly value generated by AM of final aircraft parts is expected to be between $20 and $25 billion, and is expected to drive a $4.2 billion yearly opportunity from AM hardware, AM materials, AM software and AM services.

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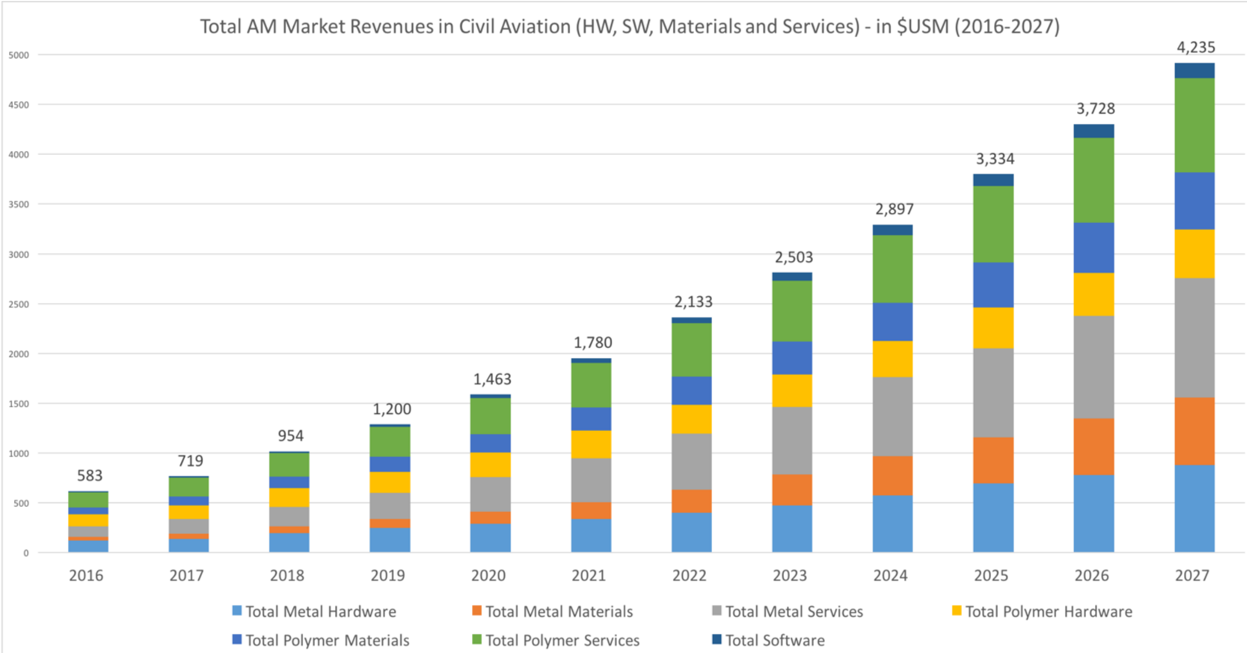

SmarTech expects the overall value generated by 3D printing for civil parts to reach $4.2 billion by 2027, driven by expected value of AM aircraft parts of $20-$25 billion.

The market for AM in the general and commercial aerospace industry has undergone several radical changes over the past two years, all targeted toward implementing the AM process in part manufacturing. Although following very different dynamics, these changes concern both the metal AM and the polymer AM (metal replacement and composite) segments.

Most of the new evolutions in the AM market indicate a continued and sustained growth in the adoption of metal 3D printing systems, along with rapid technological evolutions primarily on three fronts: speed, size and process automation.

The number of hardware system suppliers has also increased dramatically; however, the number of adopters for end-use part production (while also increasing) remains low. The last two years have demonstrated that one very significant limitation to the AM market's growth in terms of production output is the availability and—still limited market awareness and adoption—of software to fully support all phases of the AM process, from CAD to PLM to enterprise infrastructure. This market segment has undergone a very significant evolution in terms of the size of the investments made specifically toward AM by the largest software providers operating in this segment.

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AM for Civil Aviation Production

AM for civil aviation is moving closer to serial part production for both polymers and metals. While actual serial production by AM is still limited in size, several processes have been implemented to industrialize, understand and optimize the process.

Advancements in CAD, CAE, CAM and PLM software are driving the need for AM in general and commercial aviation manufacturing. More optimized, complex shapes and the need for a more automated production process make AM ideal for a growing number of production requirements. AM technologies are continuing to prove key for weight optimization and production automation. Topology optimization is now starting to be an integral part of part design in civil aviation.

Several challenges still need to be overcome in terms of AM process industrialization, standardization and certification. Major civil aviation OEMs and tier 1 manufacturers have completed extensive research cycles and the process for validating and certifying a safety-critical part is expected to shorten significantly. Very significant new investments in AM for aviation manufacturing are coming from large companies. OEMs such as Airbus and Boeing are leading, along with engine manufacturers such as GE and Safran. Tier 1 suppliers are also conducting AM process optimization and industrialization research.

Process and system industrialization still need to advance for serial part production in civil aviation to really take off. Both powder bed and powder fed technologies still have limitations in terms of process efficiency and reliability. Industrial FDM systems are taking front seat in non-safety critical interior part production. The use of high performance (flame retardant) materials such as ULTEM and—eventually—PEEK is already providing a solution for production of parts for aircraft cabin's interiors.

Demand for metal- and polymer-based hardware in civil aviation is expected to increase significantly, due to increased efficiency of the validation and certification processes. This trend is expected to drive the establishment of "AM Factories" for civil aviation part production with full production process capabilities and multiple production systems installed.

After engine parts, metal AM processes are now moving toward safety-critical and major structural components. Metal DED- and plastic extrusion-based technologies already enable production of very large parts with no molds required. Several successful test cases, detailed in the report support this trend.

The most notable recent applications for AM in Civil Aviation include:

1. GE Aviation completed testing a 35 percent additive manufactured demonstrator engine designed to validate additive parts in its clean-sheet-design Advanced Turboprop (ATP), which will power the all-new Cessna Denali single-engine turboprop aircraft.

2. Since 2015 GE has been testing the next-generation LEAP jet engine, which holds 19 3D-printed fuel nozzles

3. In March 2017, Airbus flew the first fully 3D printed hydraulic manifold on board its Airbus A380 number 1 aircraft. This was the first time a highly safety-critical structural complex component was flew on board a commercial aircraft.

4. In April 2016, Arconic—now a standalone company of the Alcoa group—signed an agreement with Airbus to provide 3D printed titanium fuselage and engine pylon parts.

5. Norsk Titanium, one of the two global suppliers of structural titanium components produced using wire-based DED technology, announced in mid-2017 that it has received a production purchase order for 3D printed structural titanium components from aviation aerospace giant Boeing.

6. In 2015 EasyJet reportedly tested 3D printing technology to make 5,000 replacement armrests in about two weeks' time.

7. KLM also reportedly used 3D printing to make a custom trolley for in-flight draught beer. This was used as a case study to research the use of 3D printing for production of custom parts in its aircrafts.

8. In early 2017 a pilot project between Siemens, Strata and Etihad Airways Engineering led to the successful development of the first aircraft interior part (a plastic frame which surrounds media screens) to be designed, certified and manufactured with 3D printing technology in the Middle East.
9. Air New Zealand is also using 3D printers (FDM) to build parts of its long-haul planes. The airline hopes to soon start rolling out 3D printed components for its Business Premier cabins.

10. In 2017, Stratasys signed an official agreement with SIAEC (Singapore Airlines Engineering Company) to explore establishing a Singapore-based additive manufacturing center with the goal of providing design, engineering, certification support and part production to SIAEC's network of partners and customers.

The commercial and general aviation market is set to continue on its booming growth path over the next twenty years, driven by factors such as rapidly expanding middle classes in emerging economies, urbanization, increased liberalization of travel, overall simplification of immigration procedures (in spite of some recent, generally isolated, cases) and increasing tourism. All these elements will drive significant growth in aircraft demand. Of the estimated global civil aerospace industry revenues of around $200 billion a year, the majority are associated with North America and Europe, which remains a close second, with China dominating the Asia Pacific region—which is expected to become the largest region in driving aerospace demand—in third place.

Taking AM to Space

Whether it will take another 10, 50 or 100 years for commercial space-based ventures to grow into one of the largest—if not the largest—manufacturing segments, we are already living well past the dawn of the commercial space age. Commercial space exploration or commercial planetary colonization may not yet be at hand but, driven by the satellite and communication industries, several companies of various sizes are now creating short to medium term viable business opportunities in space. For all intents and purposes, "space" as we discuss here, is generally intended as Earth's orbit which includes Low Earth Orbit (LEO), Medium Earth Orbit, Geosynchronous Earth Orbit (GSO), and High Earth Orbit.

One of the most significant challenges that all these space ventures need to overcome in order to place satellites, probes, landers, telescopes or even spacecraft in orbit is the high per kilogram cost required to break free of the Earth's gravitational pull.

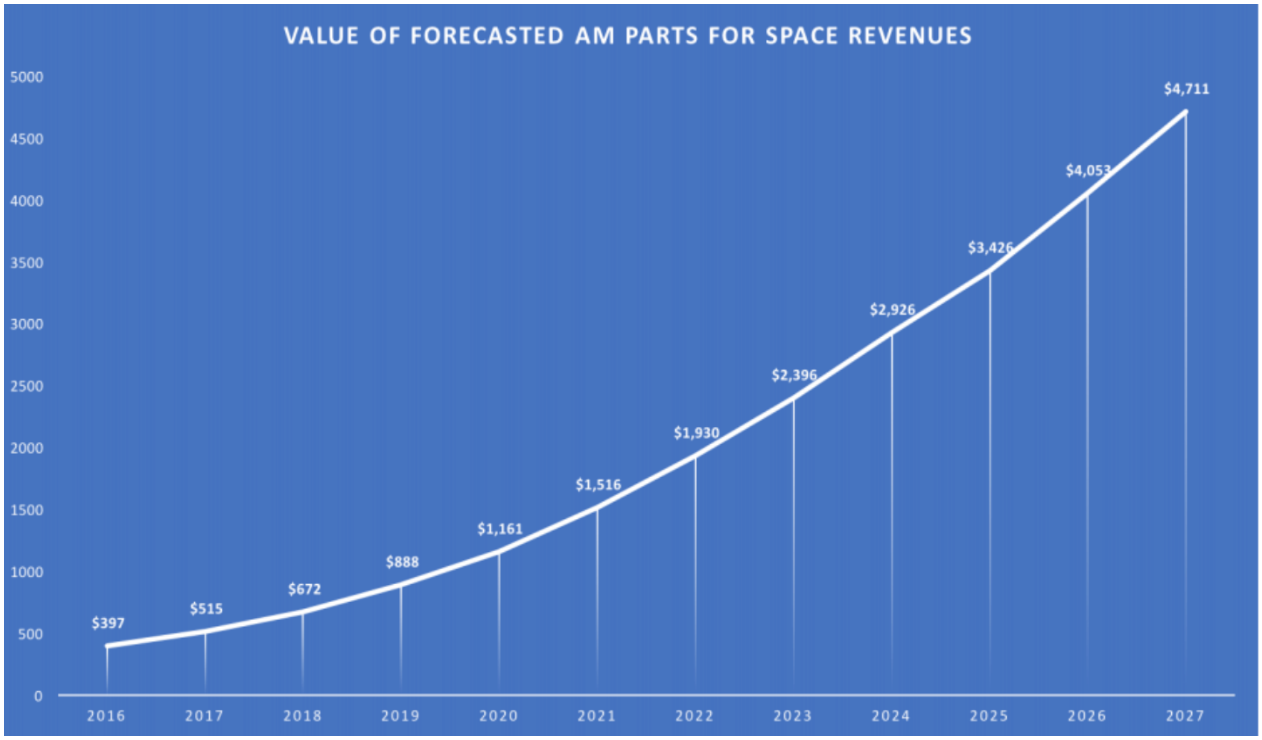
Even more so than for the aviation industry, additive manufacturing provides the most effective tool to optimize weight in systems built to reach space. This is true both for launch vehicles and—until the time when resources are gathered in space—for space borne systems and devices. Together with weight optimized geometries, AM can contribute to greatly lower cost of commercial space activities by continuing to drive development of advanced materials, including metal replacement high-performance polymers and composites. Additional direct advantages can be derived from increased process automation for small batch series or single item production—which is a more relevant issue in rocketry and satellite manufacturing than in any manufacturing segment. SmarTech Publishing expects AM to play a very significant role in the future development of the $330-billion space industry.

This is especially true within the $120 billion commercial infrastructure and support segments—including the manufacture of spacecraft, in-space platforms, and ground equipment, as well as launch services, independent research and development. While the overall revenues will continue to represent only a minimal part of the overall space manufacturing industry, AM has the potential to be one of the key elements that will help the commercial space industry grow into maturity.

The Market for Space

Official U.S. government estimates reported that global spending on space activity reached an estimated $323 billion in 2015. Of this amount, nearly 40% was generated by commercial space products and services. The rest, as show in Exhibit 1-1 below, is represented as 37% ($120 billion) by the commercial infrastructure and support industries. The U.S. government—including national security agencies and the National Aeronautics and Space Administration (NASA)—accounted for about 14% of global spending; government spending by other countries was responsible for the remaining 10%. This makes the total value of space industry segments that may benefit from AM equal to roughly $200 billion.

One of the segments where AM processes could see the highest adoption, the commercial infrastructure and support industries—including the manufacture of spacecraft, in-space platforms, and ground equipment, as well as launch services, independent research and development—represented $120.88 billion out of the 2015 total.



SmarTech expects the overall value generated by 3D printing of space-borne parts to reach $4.7 billion by 2027.

SmarTech Publishing expects AM to grow to represent 1.78% of the total yearly value of space infrastructure manufacturing at the end of the forecast period, for a global turnover of **$4.7 billion** derived from the value of additively manufactured parts alone.

This opportunity is expected to drive the overall revenues generated yearly in additive manufacturing segments for the space industry from $117 million in 2016 to **$872** million by the end of the forecast period in 2027. This number includes revenues generated by AM hardware, AM materials, AM software and AM services.

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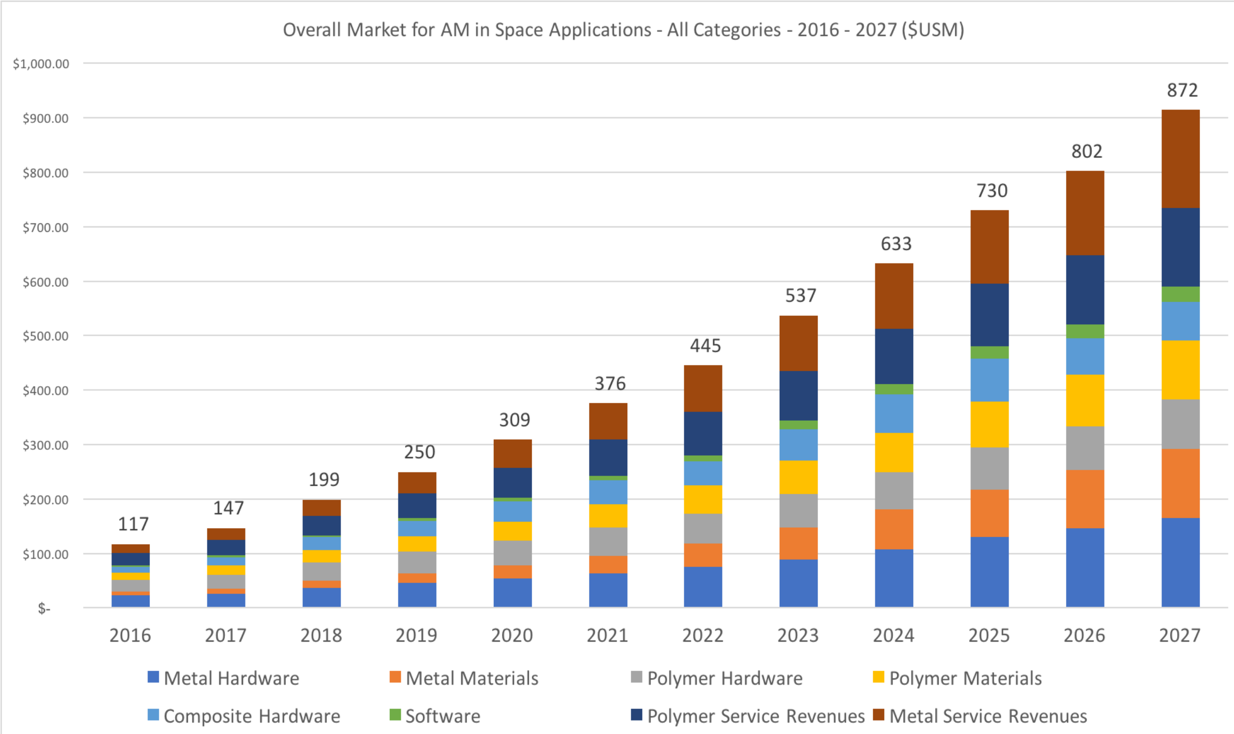

Demand for additively manufactured space-borne parts is expected to drive revenues of $872 million in major AM segments by 2027.

The renewed interest in low-cost satellites, some of which are small enough to be held in one hand, is prompting a range of start-ups and providing new accessibility to space by educational institutions, small businesses, and individual researchers. This trend favors adoption of AM technologies to reduce costs.

SmarTech Publishing is also expecting spacecraft and rocket parts to represent the largest opportunity segments due to the generally much higher cost of the parts and systems involved. While satellites today represent the area where AM has been used most intensively, the emergence of low-cost CubeSat and NanoSat systems makes this a less valuable opportunity overall.

A Match Made in the Heavens

Although they are based on entirely different core products, there are many similarities between the additive manufacturing industry and the drone industry: for one, both are extremely fragmented, very young industries with a high potential for future applications but still at the very early stages of their growth and technological evolution curve. Both industries make intensive use of 3D data and both are

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discovering new applications, while introducing new systems, almost daily. Last but not least, they are currently about the same size in terms of overall global revenues—less than $10 billion (if we exclude drone services revenues and AM part value) with similar overall growth forecasts on the horizon.

Drones, intended only as aerial vehicles in the SmarTech Publishing report, include a large family of different products that are generally characterized by the acronym UAV (unmanned aerial vehicles). UAVs can be large flying objects used primarily for defense purposes, as well as medium size objects used for commercial purposes and services, as well as small machines (usually quadcopters or multicopters) used primarily for recreational purposes.

The combination of two high-growth industries clearly makes for potential exponential growth over the next decade and beyond; however, at this time, no major study has been conducted on the use of AM in drone manufacturing. SmarTech's is the first report that we are aware of that focuses exclusively on the potential for implementing additive manufacturing processes, materials and technologies in drone manufacturing. As such, the information and the forecasts presented in this report contain estimates that may need to be reviewed in future versions to take into consideration the evolutionary paths of both drone and additive manufacturing technologies.

AM for UAV's

SmarTech Publishing projects the yearly value of AM manufactured parts in the drone industry will reach $1.9 billion, driving over $400 million in yearly sales of AM equipment, software, materials and services. Thus, SmarTech's analysis indicates that the yearly investments in AM technologies, materials, software and services will both fuel and be driven by an overall value of additively manufactured drone parts and components set to grow from $60 million in 2016 to $2.2 billion in 2027, at a CAGR of 38.7%.

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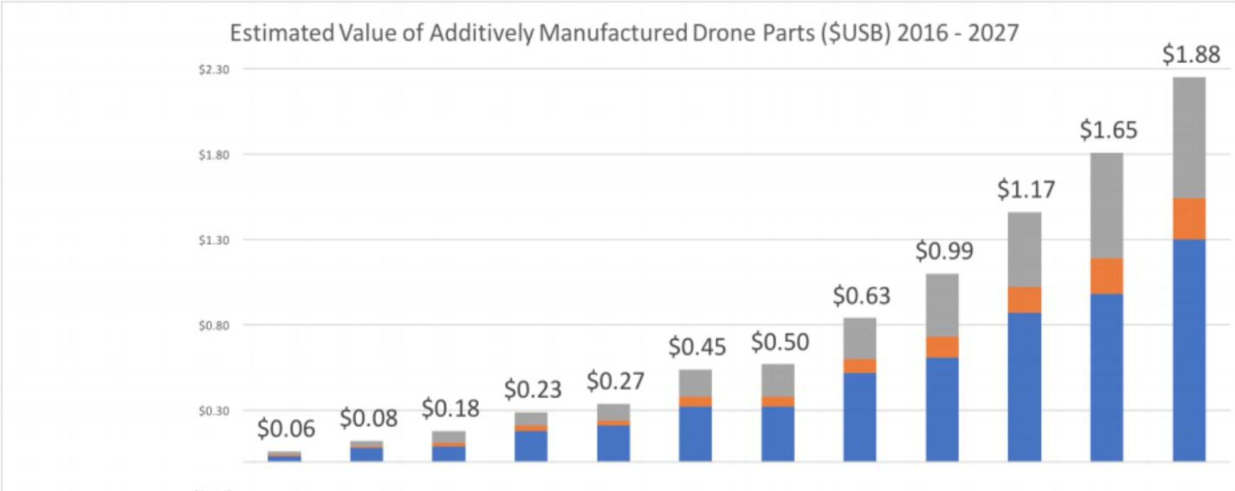
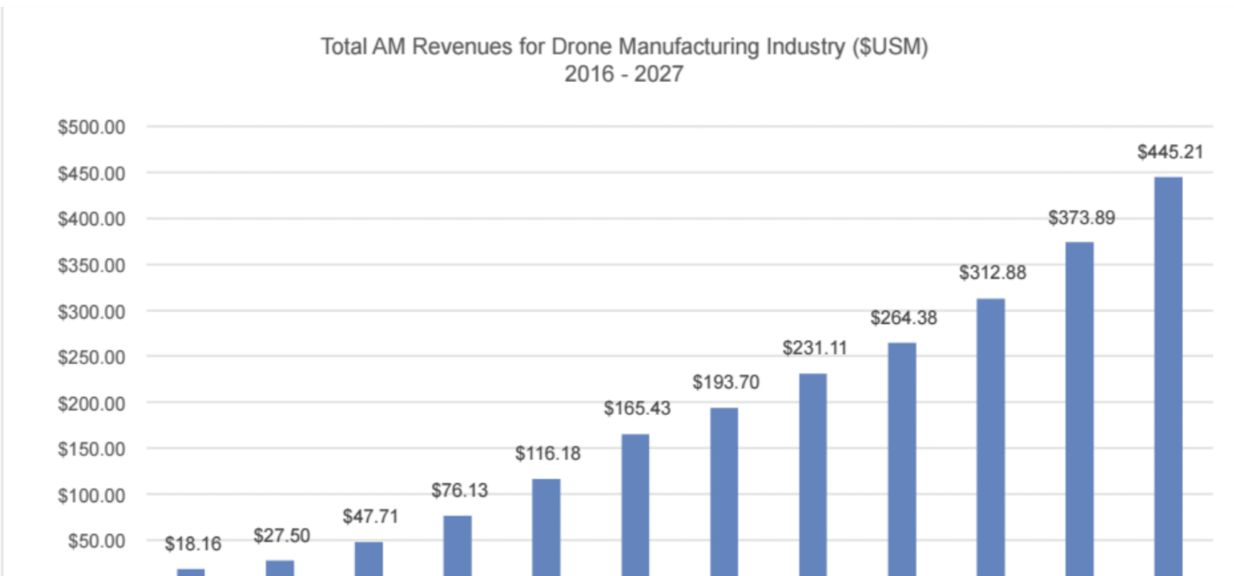


	2016	2017	2018	2019	2020	2021	2022	2023	2024	2025	2026	2017
Total	$0.06	$0.08	$0.18	$0.23	$0.27	$0.45	$0.50	$0.63	$0.99	$1.17	$1.65	$1.88
Commercial Drones	$0.02	$0.03	$0.07	$0.08	$0.10	$0.16	$0.19	$0.24	$0.37	$0.44	$0.62	$0.71
Personal Drones	$0.01	$0.01	$0.02	$0.03	$0.03	$0.06	$0.06	$0.08	$0.12	$0.15	$0.21	$0.24
Defense Drones	$0.03	$0.08	$0.09	$0.18	$0.21	$0.32	$0.32	$0.52	$0.61	$0.87	$0.98	$1.30

SmarTech expects the overall value generated by 3D printing of drone parts to reach 1.88 billion by 2027.



	2016	2017	2018	2019	2020	2021	2022	2023	2024	2025	2026	2027
TOTAL	$18.16	$27.50	$47.71	$76.13	$116.18	$165.43	$193.70	$231.11	$264.38	$312.88	$373.89	$445.21

Demand for additively manufactured drone parts is expected to drive revenues to $445 million in major AM segments by 2027.

While the defense drone segment will follow similar guidelines as the general aerospace industry—with a greater focus on metal technologies—the commercial drone industry is likely to follow a similar evolutionary trend as the automotive industry, with a greater focus on prototyping and, eventually, on the use of production-grade polymer technologies. Polymer extrusion and polymer powder bed fusion are expected to be the most widely adopted technologies in the drone industry because they are—as of today—the only ones fit for end-part production as well as rapid prototyping activities.

About SmarTech:

SmarTech Publishing delivers industry analysis and market forecasts for the 3D printing/additive manufacturing industry. Our coverage provides insight for those companies offering 3D printing services, materials and software sectors, as well as those that make the 3D printers themselves. SmarTech Publishing is the leading provider of market research and industry analysis in the 3D printing/additive manufacturing sector.

About the Author:

Davide Sher is Senior Analyst, Europe, at SmarTech Publishing and has built an extensive experience as an analyst and technology journalist for additive manufacturing. He is the author of three recent reports related to additive manufacturing in civil aviation, space and UAVs. He has also authored reports on composites and ceramics in 3D printing. Prior to his time at SmarTech, he founded the London-based company 3D Printing Business Media Ltd, which includes several 3D printing industry related online media outlets. Among these, the 3D Printing Business Directory (www.3dprintingbusiness.directory) is currently the largest global directory of companies related to the 3D printing and additive manufacturing supply chain. The international news portal 3D Printing Media Network (www.3dprintingmedia.network) and the leading Italian 3DP news portal Replicatore.it are a global reference for updated and verified global 3D printing market news and editorials.

Related studies:

- Additive Manufacturing for the Drone/UAV Industry
- Additive Manufacturing for Space Industry Applications
- Opportunities for Additive Manufacturing in Aerospace 2017 - Civil Aviation

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