3D PRINTED AIRCRAFT, SPACECRAFT AND DRONES

THE FUTURE OF INDUSTRIAL PRODUCTION TAKES OFF WITH ADDITIVE MANUFACTURING

SMARTECHMARKETS
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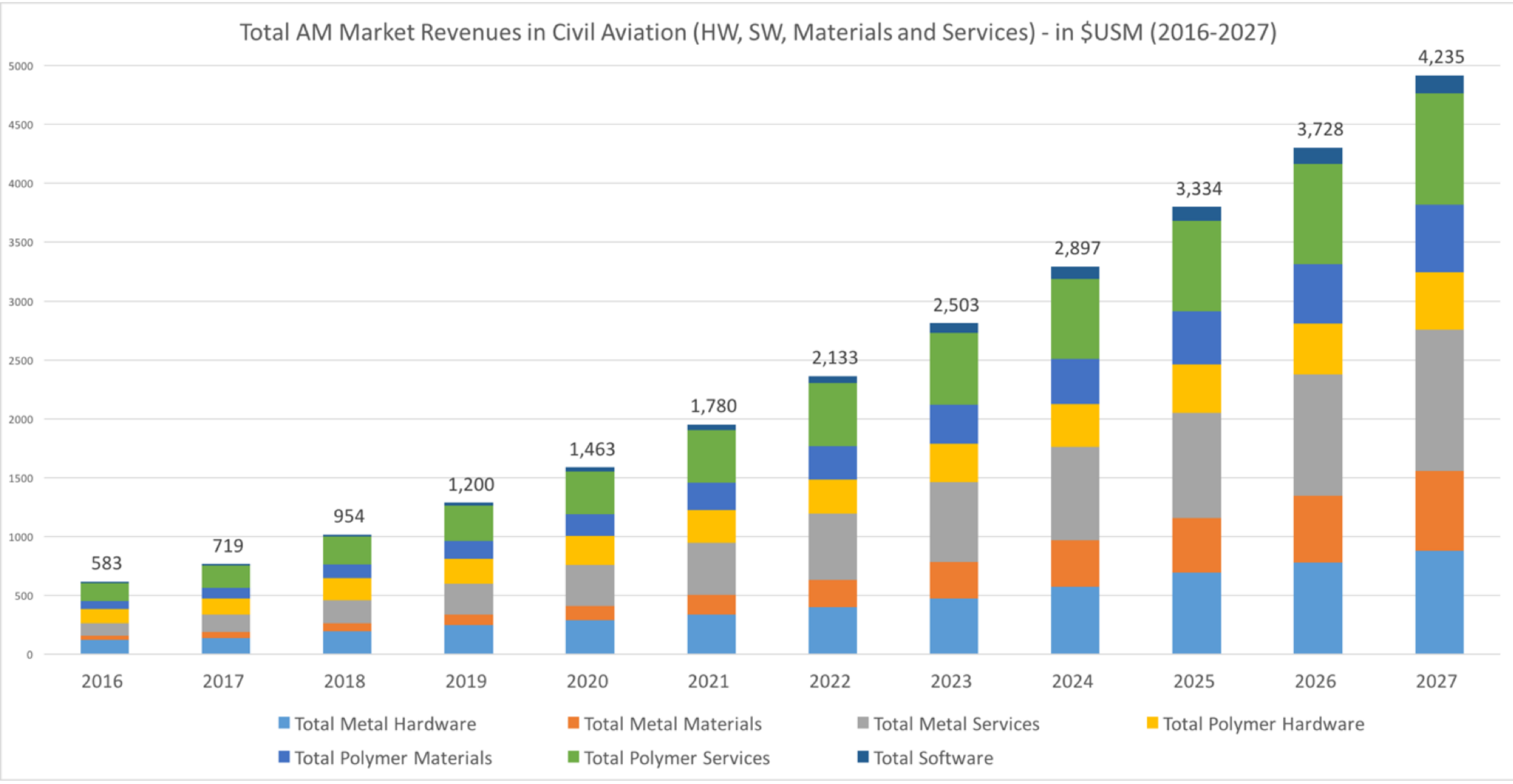
Contact Robert Nolan (rob@smartechpublishing.com)for details on SmarTech's aerospace and aviation AM market research and advisory services.

AM IN THE AEROSPACE INDUSTRY IS EXPECTED TO GROW TO BETWEEN 1% AND 2% OF THE OVERALL MARKET BY 2030

A $25+ BILLION OPPORTUNITY

CIVIL AVIATION

- YEARLY VALUE GENERATED BY AM OF FINAL AIRCRAFT PARTS: BETWEEN $20 AND $25 BILLION YEARLY BY 2027
- INCLUDING AND DRIVING A $4.2 BILLION YEARLY OPPORTUNITY FROM AM HARDWARE, AM MATERIALS, AM SOFTWARE AND AM SERVICES.



- RECENT EVOLUTIONS INDICATE SUSTAINED GROWTH IN ADOPTION OF METAL 3D PRINTING
- TECHNOLOGICAL EVOLUTIONS IN SPEED, SIZE AND PROCESS AUTOMATION.
- THE NUMBER OF HARDWARE SYSTEM SUPPLIERS HAS ALSO INCREASED DRAMATICALLY
- THE NUMBER OF ADOPTERS FOR END-USE PART PRODUCTION REMAINS LOW.

CIVIL AVIATION

LIMITATION: LIMITED MARKET AWARENESS AND ADOPTION OF SOFTWARE TO FULLY SUPPORT ALL PHASES OF THE AM PROCESS

CAD, CAE, CAM, GENERATIVE LATTICE DESIGN, TOPOLOGY OPTIMIZATION (DASSAULT, AUTODESK)

PLM (SIEMENS)

ENTERPRISE INFRASTRUCTURE (SAP)

SOME ADOPTION HIGHLIGHTS FOR CIVIL AVIATION

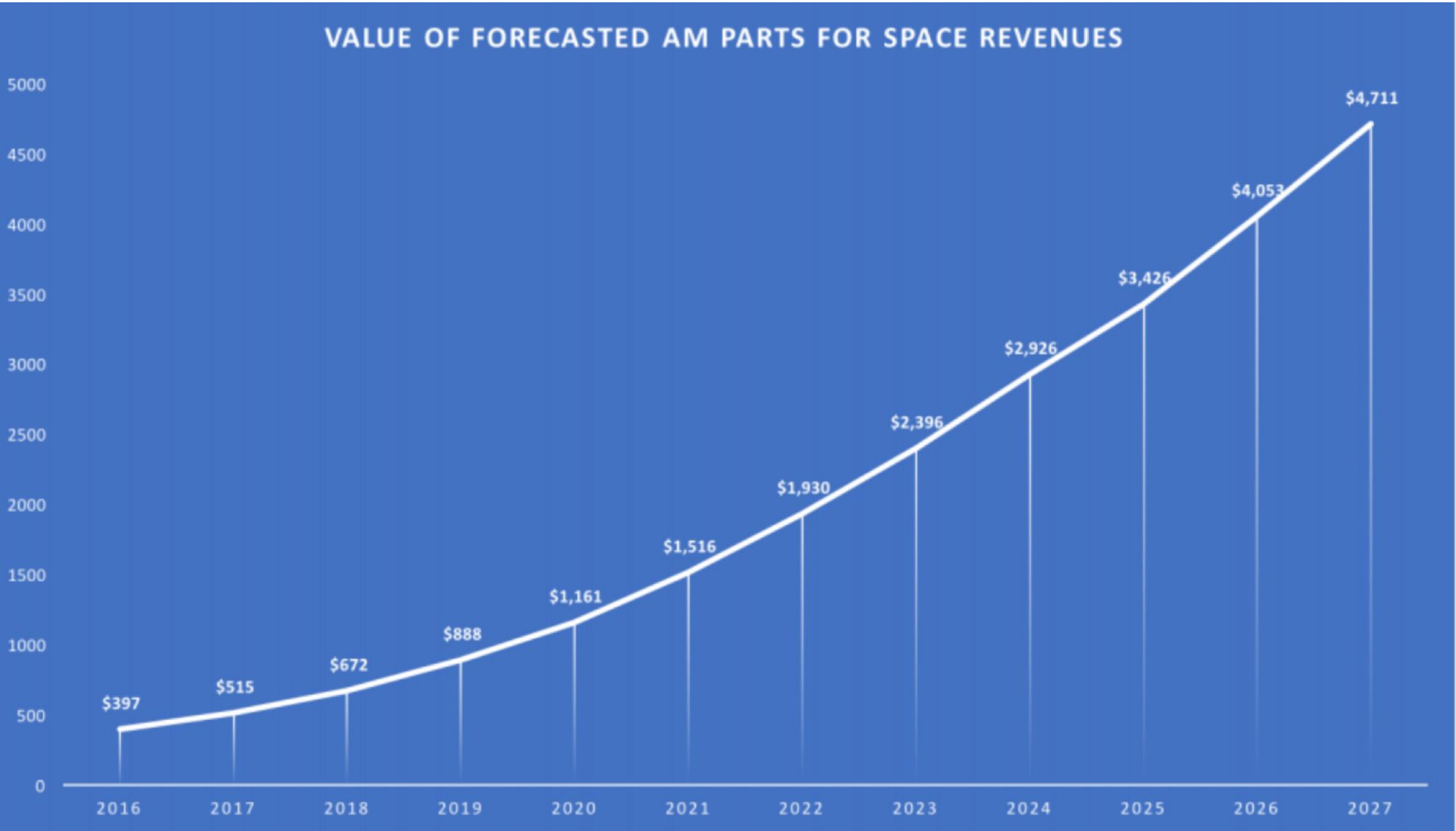
1. GE Aviation completed testing a 35 percent additive manufactured demonstrator engine designed to validate additive parts in its clean-sheet-design Advanced Turboprop (ATP), which will power the all-new Cessna Denali single-engine turboprop aircraft.
2. Since 2015 GE has been testing the next-generation 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 MARKET FOR SPACE

- US GOVERNMENT REPORTED THAT GLOBAL SPENDING ON SPACE REACHED $323 BILLION IN 2015.
- OF THIS, NEARLY 40% WAS GENERATED BY COMMERCIAL SPACE PRODUCTS AND SERVICES.
- 37% ($120 BILLION) IS FOR THE COMMERCIAL INFRASTRUCTURE AND SUPPORT INDUSTRIES.
- U.S. GOVERNMENT (AERONAUTICS AND NASA)—ACCOUNTED FOR ABOUT 14%
- 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.

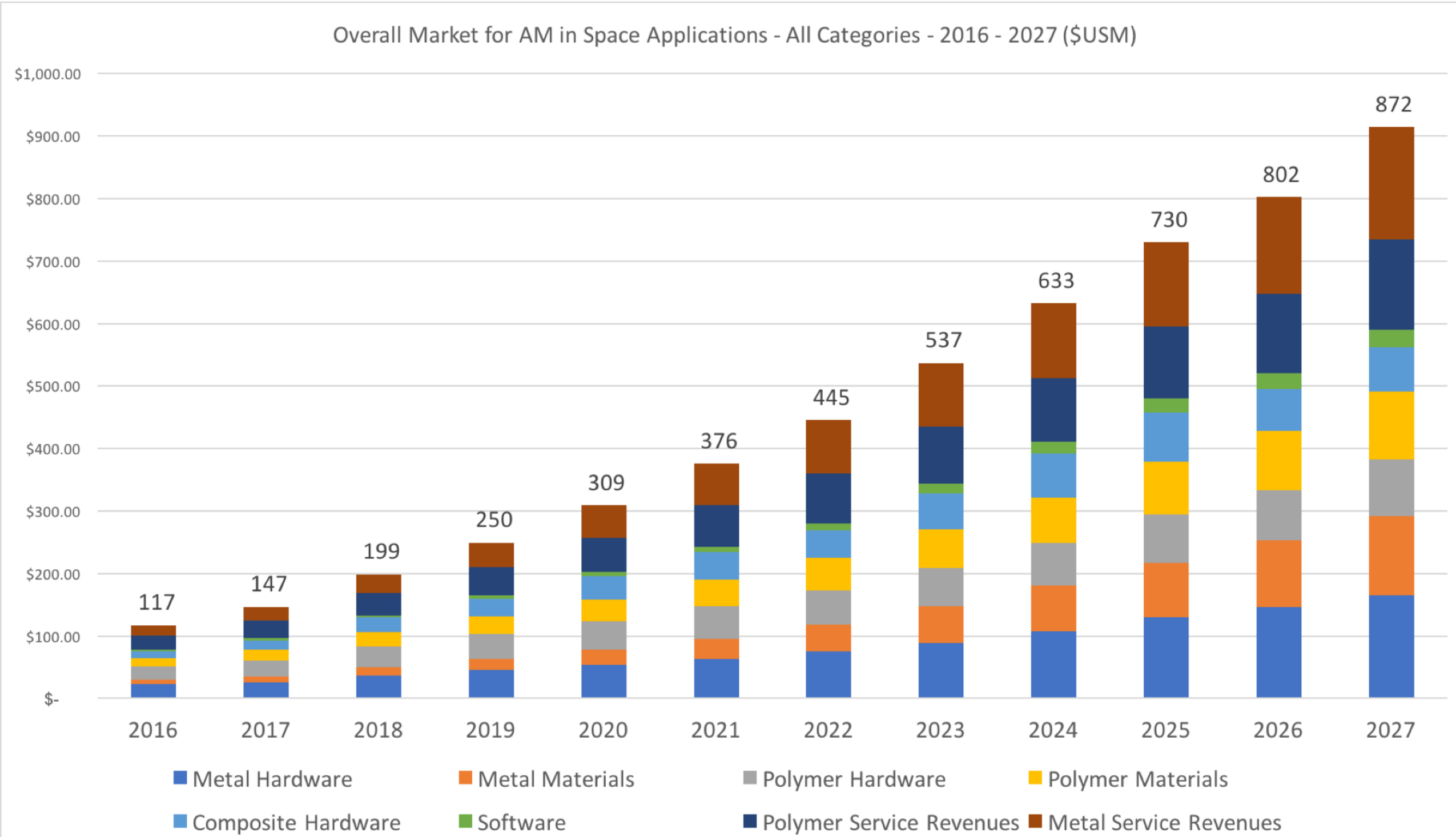
SPACE

- SMARTECH 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



SPACE

- 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



KEY POINTS ON SPACE AM ADOPTION

- 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 - and the significant economic benefits from weight optimization.
- 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.
- Additive manufacturing *IN space (for space borne structures) is one of the most interesting long term applications but it remains limited as a revenue opportunity for the duration of this forecast.*

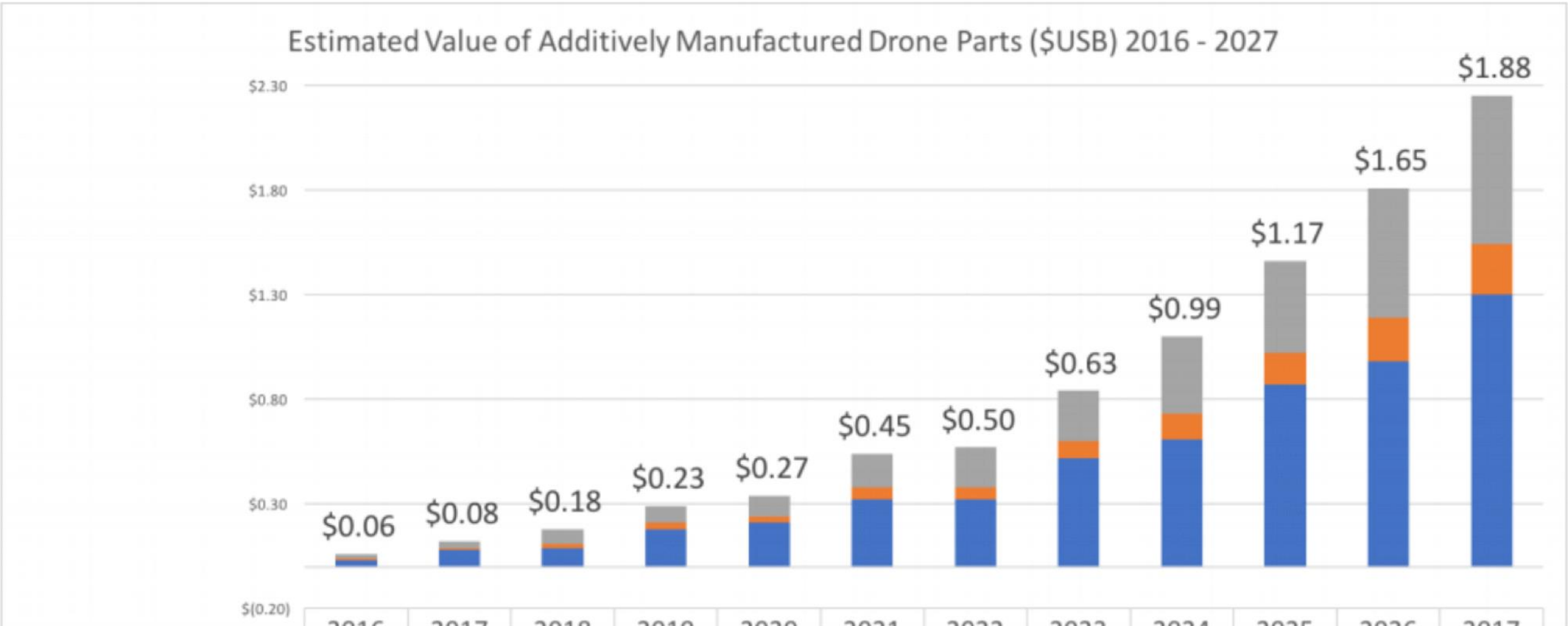
AM & DRONES: A MATCH MADE IN HEAVEN

- 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.
- Both are discovering new applications, while introducing new systems, almost daily.
- They are currently about the same size in terms of overall global revenues—less than 10 billion dollars — with similar overall growth forecasts on the horizon.
- The combination of two high-growth industries clearly makes for potential exponential growth over the next decade
- No major study has been conducted on the use of AM for drone manufacturing

DRONES

SMARTECH EXPECTS THE OVERALL VALUE GENERATED BY 3D PRINTING OF DRONE PARTS TO REACH 1.88 BILLION BY 2027.

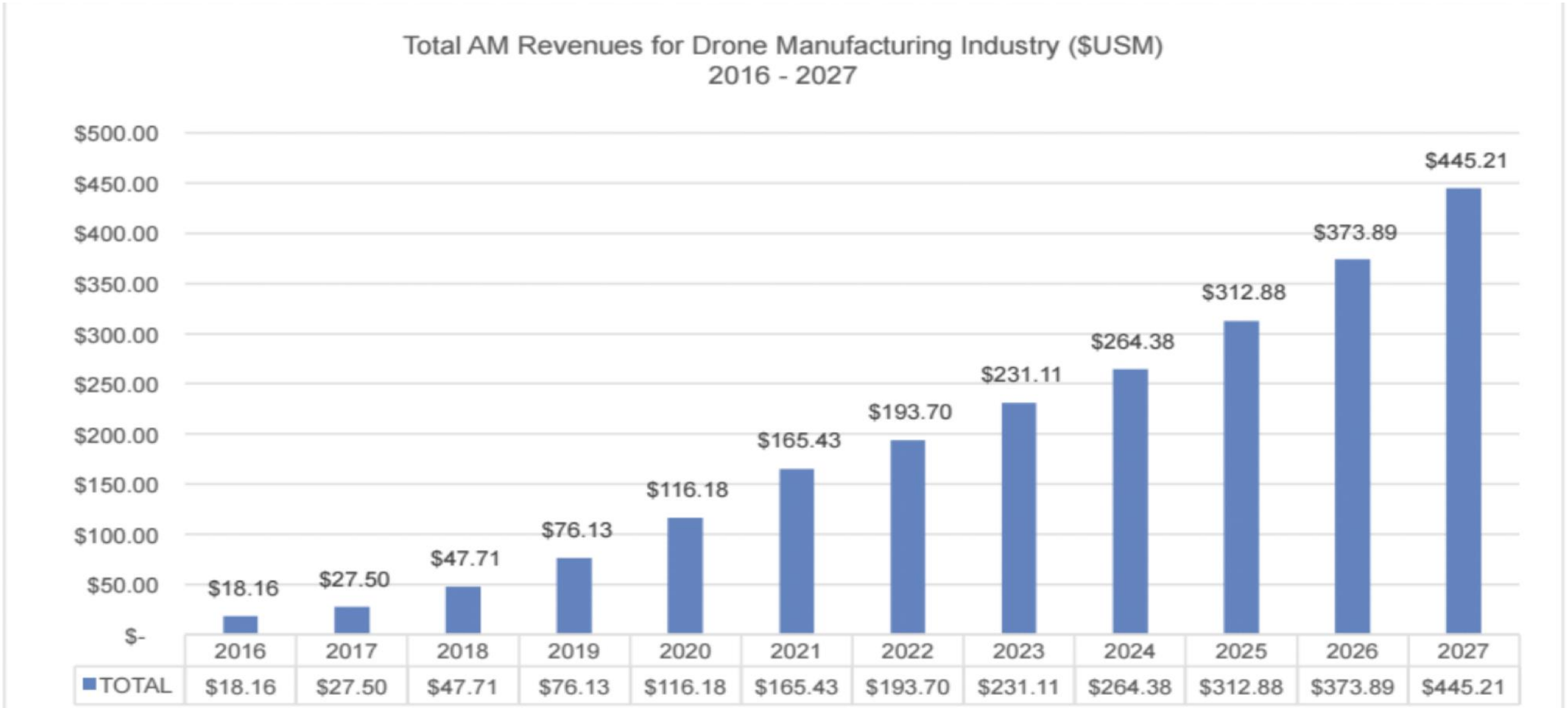
DRONE MARKET INCLUDES DEFENSE, COMMERCIAL AND PERSONAL DRONES



	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

DRONES

- DEMAND FOR AM DRONE PARTS IS EXPECTED TO DRIVE REVENUES FOR $445 MILLION IN MAJOR AM SEGMENTS.
- DEFENSE DRONE SEGMENT FOLLOWS SIMILAR TRENDS AS THE GENERAL AEROSPACE INDUSTRY -> FOCUS ON METAL PBF/DED
- COMMERCIAL DRONE INDUSTRY FOLLOWS 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 FIT FOR END PART PRODUCTION AS WELL AS RAPID PROTOTYPING ACTIVITIES.



SMARTECH PUBLISHING

- SmarTech Markets 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 Markets Publishing is the leading provider of market research and industry analysis in the 3D printing/additive manufacturing sector.

DAVIDE SHER

- Davide Sher is a journalist and industry analyst covering the 3D printing/additive manufacturing industry. He was was born in Milan, Italy and spent 12 years in the United States, where he graduated from SUNY USB. He now lives in Milan.
- Since 2016 he is Senior Analyst, Europe at SmarTech Markets Publishing, where he has conducted extensive market research in several rapidly evolving vertical AM segments. Reports published have ranged from vertical application segments such as the Jewelry and Aerospace industries to advanced materials such as Ceramics and Composites.
- He has participated as keynote speaker at several 3DP/AM industry events in Europe and Asia and held a number of webinars contributing to raise awareness on the opportunities offers by AM and its market potential.
- Since 2013 he has been covering the additive manufacturing industry daily through 3D Printing Media, ltd, the UK-based company he co-founded. The company runs several media properties all focusing on AM, including 3D Printing Business Directory (www.3dprintingbusiness.directory), currently the largest directory of 3DP/AM related companies in the world; 3D Printing Media Network (www.3dprintingmedia.network), leading global resource for 3DP/AM industry news, and Replicatore.it, the leading Italian 3DP and AM news portal.

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