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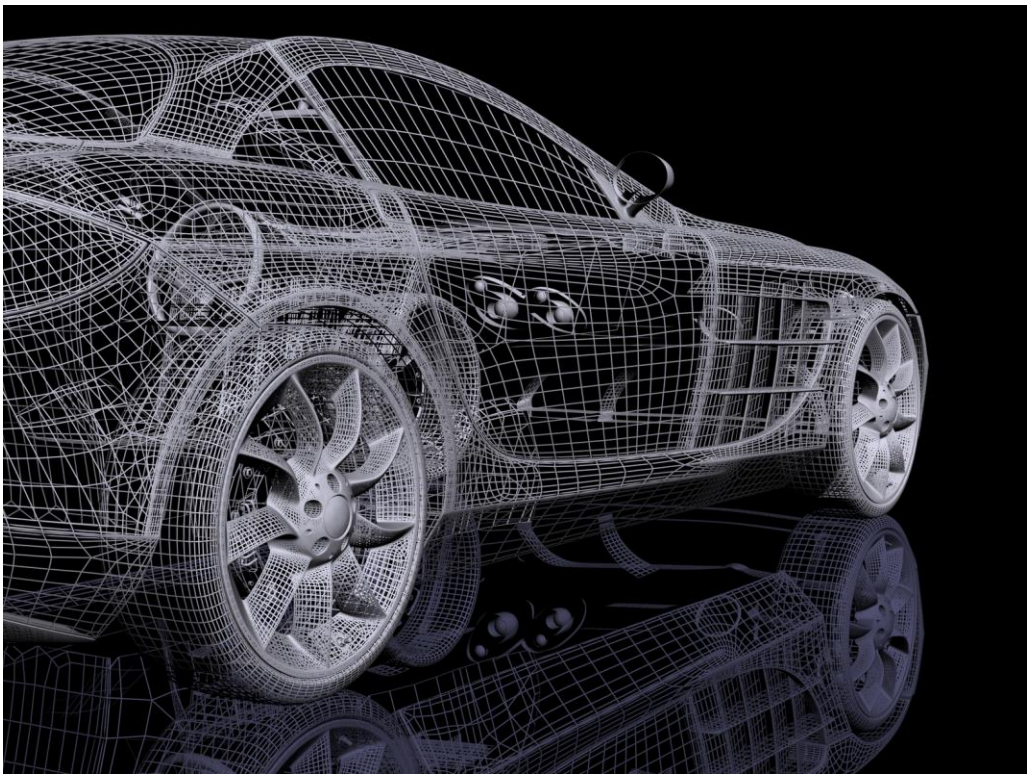

Additive Automotive: Advancing 3D Printing Adoption In the Automotive Industry

A SMARTECH WHITE PAPER

PUBLISHED JANUARY 2015

This White Paper is based on market research and industry analysis carried out for ***SmarTech's*** *report "Additive Manufacturing Opportunities in the Automotive Industry: A Ten-Year Forecast." More information on this report can be found at:* http://smartechpublishing.com/reports/additive-manufacturing-opportunities-in-the-automotive-industry-a-ten-year

The SmarTech Adoption Model for 3D Printing in the Automotive Market

Automotive companies have been utilizing 3D printing techniques for decades. However, as the 3D printing industry has evolved quite rapidly in the last ten years, use of the technology by automotive companies has remained focused on rapid prototyping. Only within the last three years has the automotive industry—particularly major auto manufacturers—begun to utilize the technology in more advanced applications which include functional prototype parts, 3D-printed tooling, sand molds for casting, and in some unique cases, end use parts.

SmarTech Markets Publishing *has created the only industry-specific adoption model for 3D printing, as a way to depict a roadmap for past, present, and future use of 3D printing technology in the automotive industry. In this White Paper, we outline what our model says about where the opportunities will be found in "additive automotive."*

SmarTech believes that, in the context of the automotive industry, a clear adoption trend for 3D printing can be identified for automotive manufacturers. This adoption trend happens in four distinct phases, and various segments or even companies within the automotive industry can be placed at different points along the adoption model. Exhibit I outlines the adoption model for 3D printing within the automotive industry, as we currently see it.

Stage #1: Basic Rapid Prototyping: In the first stage of the adoption model, referred to as the "Basic Rapid Prototyping" stage, users typically possess a single 3D printer, purchased to produce a specific prototype part identified pre-purchase.

Many automotive manufacturers began at this stage a decade or more ago, and there are some that remain in this early phase. Alternatively, users in this stage may rely on 3D printing services exclusively for the creation of prototypes.

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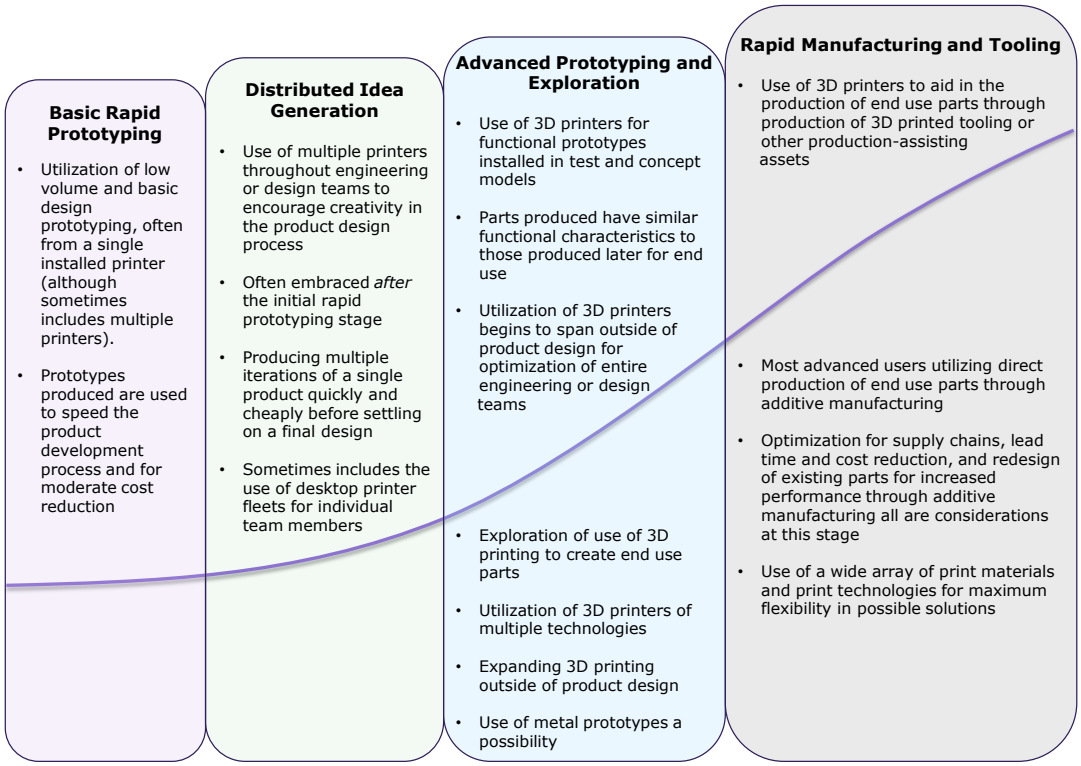
Moving out of this stage into more widespread rapid prototyping in the distributed idea generation stage is becoming easier now that awareness around the benefits of 3D printing is growing rapidly.

Exhibit I: Automotive Industry Adoption Model for 3D Printing



Source: SmarTech Markets Publishing

Stage #2: Distributed Idea Generation: During the second stage, referred to as "Distributed Idea Generation," users have amassed a small fleet of 3D printers, sometimes of different technologies, in order to expand prototyping activities to beyond what might be feasible utilizing other methods or with a single printer. As an alternative they may have a *contract* arrangement with a service house.

Users in this stage of adoption can utilize the higher print volume capacity when designing new parts in order to maximize creativity and see multiple

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iterations of an idea all the way through to a physical prototype. These prototypes can be utilized for fit and finish capability.

An alternative or sometimes complementary portion of this stage is characterized by the purchase of numerous desktop 3D printers of lower cost, which are sometimes given to entire teams of engineers or designers who are then free to utilize them as they please to bring early ideas into physical concepts before a more precise prototype part is necessary.

Stage #3: Advanced Prototyping and Exploration: In the "Advanced Prototyping and Exploration" phase, users have begun to employ their 3D printers or 3D printing services to produce functional prototypes that will be installed in concept models or test projects and vehicles.

These parts may have similar characteristics to final production parts, but are not considered end-use appropriate. Metal prototypes may become popular or useful during this stage. Additionally, users in this phase of adoption have begun to utilize 3D printing to optimize beyond just product development and design and into other areas of the business now that capabilities of printers are better understood.

Some supply chain considerations may also come into the picture, as well as utilizing printers for difficult-to-source or costly replacements in less critical environments.

Stage #4: Rapid Manufacturing and Tooling: The final stage of adoption is in rapid manufacturing and tooling. In this phase, use of 3D printers may aid in the production of end-use parts through creation of molds, fixtures, jigs, or other tooling that directly contributes to an end-use part.

The most advanced users in this stage also may be producing end-usable parts directly from a 3D printer with additive manufacturing. All of the major value enhancements for additive fabrication begin to be considered in this stage including supply chain optimization, cost and lead-time reduction, and redesign of existing components to be enhanced through additive manufacturing.

It is also important to note that in the SmarTech adoption model, a company utilizing rapid tooling or manufacturing for a single part, or in a single instance, does not necessarily place them into the most advanced stage of the adoption model. Rather, a consistent use of 3D printing technologies in

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these advanced capacities is required to truly be considered in the most advanced stages of adoption.

Thus far, in **SmarTech's** opinion, few entities within the automotive industry truly qualify for this stage. However, there are a few examples that are rapidly progressing towards advanced usage, including BMW Group and Ford Motor Company.

In Exhibit II, **SmarTech** has estimated based on collected data where various segments and players of the automotive industry fall on the adoption curve. Individual manufacturers in the commercial automotive sector may fall at various points along the adoption curve. However in general these companies can be divided into laggards and more advanced adopters (although note that at present few manufacturers have adopted what would be characterized as truly advanced uses of additive manufacturing which includes printing end-use parts and tooling).

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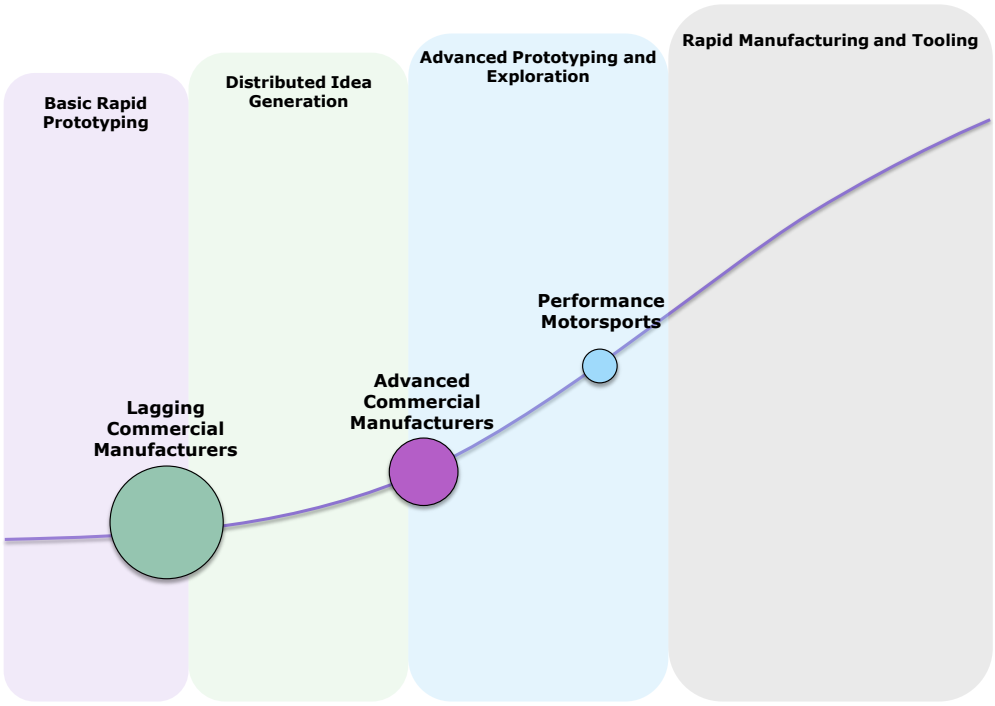
Exhibit II: Automotive Industry Adoption Model for 3D Printing



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Key Drivers for the Future of Automobile Design Using 3DP

The use of 3D printing technology within the automotive sector will naturally also be influenced heavily by the overall goals driving automobile design for the future. Use of automobiles around the world dictate how the automotive industry will evolve their products to meet future requirements.

SmarTech has identified three major influencers of the future of automobile design. These are profiled in Exhibit III.

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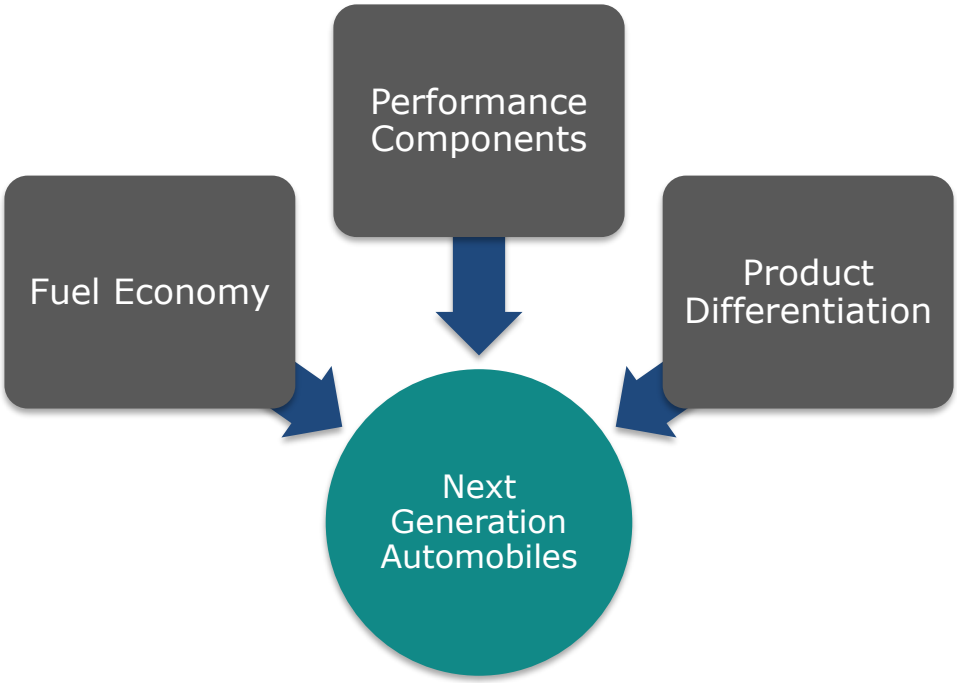
Exhibit III: Automotive Manufacturing Requirements Influencing Next-Generation Vehicles



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These trends are very important to the future of 3D printing adoption in the automotive industry. Developers of 3D printing technology must demonstrate that their products have the ability to influence one or more of these drivers in a positive manner in order to be incorporated into any relevant automobile manufacturing process today, or in the future.

Overcoming Challenges in Advancing Automotive Industry Adoption of 3D Printing

In order to continue to move the overall industry forward along the adoption curve, there are a variety of challenges that must be overcome. The most important of these challenges in our opinion, however, is a combination of communication and education. This is not to say that 3D printing technologies available today do not also have *technical* limitations for

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automotive applications. There certainly is a good deal of evolving left to do for the technology of today to become ubiquitous across the automotive industry.

But unlike users in the aerospace industry, for example, who understand the capabilities of additive manufacturing very well but are hindered by a long and arduous process to qualify 3D printed parts for high-value aerospace applications, relatively few automotive industry engineers are thinking in terms of how 3D printing can change the way mass produced automobiles and their components can be designed.

Interestingly, in some ways it appears as if the automotive industry's lengthy history with earlier forms of rapid prototyping equipment has influenced the perception of what today's technology is (and is not) capable of.

For example, it is a fairly commonly held belief in many industries (not just automotive) that 3D printers cannot compete with traditional manufacturing methods for manufacture of products that need to be produced in volumes of hundreds of thousands, or millions of parts per year. Nonetheless, **SmarTech** believes this may not be a significant barrier to adoption of 3D printing in automotive for two reasons:

- There are already multiple examples of automotive manufacturers producing over a hundred thousand 3D printed parts per year *today* with relatively small amounts of equipment
- Mass produced automobile design does not currently put importance on designing parts for high performance, but rather on economics of production

Although exceptions exist in every case, engineers and automobile designers are simply not trained to design components with additive manufacturing in mind, free of traditional constraints.

In order to overcome this, a combination of educational curriculum development for additive manufacturing, and activity from manufacturers targeting advanced applications in automotive is needed to better communicate value of current technology needs.

For makers of 3D printing systems, the majority of current engagement is based around established prototyping applications. While this area has grown rapidly in recent years with automotive manufacturers, there has not been

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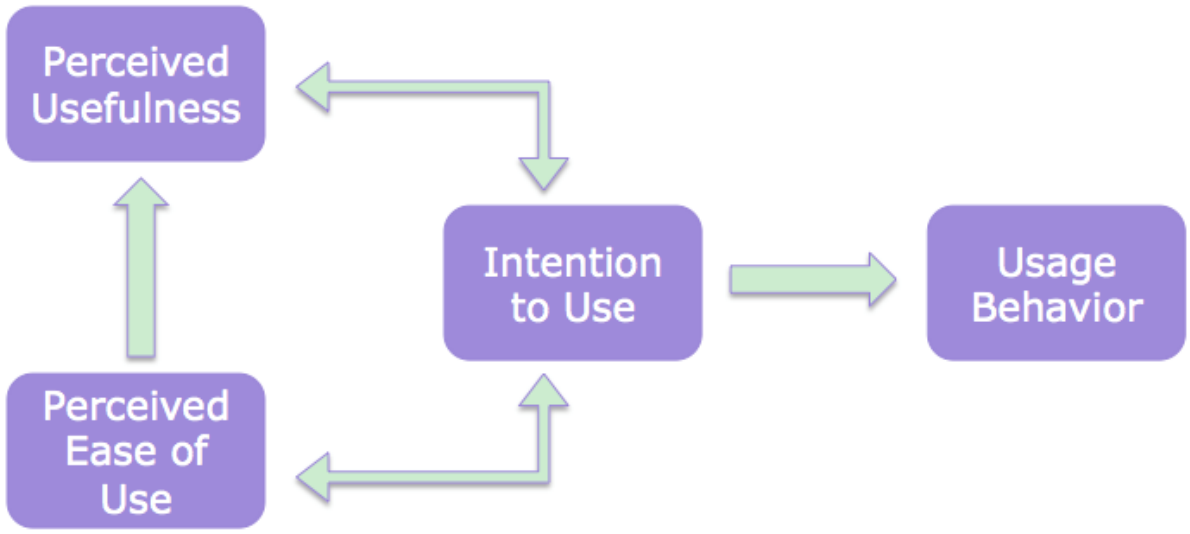
enough focus from 3D OEMs on automotive applications based around higher-value parts.

3D printing OEMs are beginning to combat this gap in communication of value by partnering with service bureaus that serve automotive customers, and engaging in end-user consulting services.

If the theory of technology acceptance developed by Davis in 1989[1] is applied to this context (Exhibit IV below), it appears that 3D OEMs that targeted automotive manufacturers very early have succeeded in creating intention for use of 3D printing among automotive manufacturers by influencing perceived usefulness and ease of use of rapid prototyping equipment of the last 20 years.

Exhibit IV: Theory of Technology Acceptance



[1] Davis, F. D. (1989), "Perceived usefulness, perceived ease of use, and user acceptance of information technology", *MIS Quarterly*, 13(3): 319–340

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Source: SmarTech Markets Publishing

However, at the same time this may have created usage behavior of 3D printing equipment that is driven by fundamental principles of 3D printing that are becoming outdated as 3D printing technology has advanced rapidly in the last ten years.

Additive Automotive: The Road Ahead

SmarTech fully expects the automotive industry to grow its position within the overall group of industries leading 3D printing adoption. While automotive certainly gained some advantage by being an early adopter, it now is playing a bit of catch-up in terms of outdated value propositions for 3D printing in manufacturing. There is certainly much more value not being capitalized on from automotive manufacturers as a whole—even with today's 3D printing technology.

Still, the future of "additive automotive" looks very bright, as visionary leaders in the automotive industry are rapidly exploring new ways of utilizing 3D printing technology, which when combined with the boom in awareness of overall 3D printing value, seems to have lit a spark under the automotive industry. A rapid expansion in more advanced usage of 3D printers in the short term will drive rapid growth in the total value of 3D printing in automotive, as detailed in SmarTech's projections in Exhibit V.

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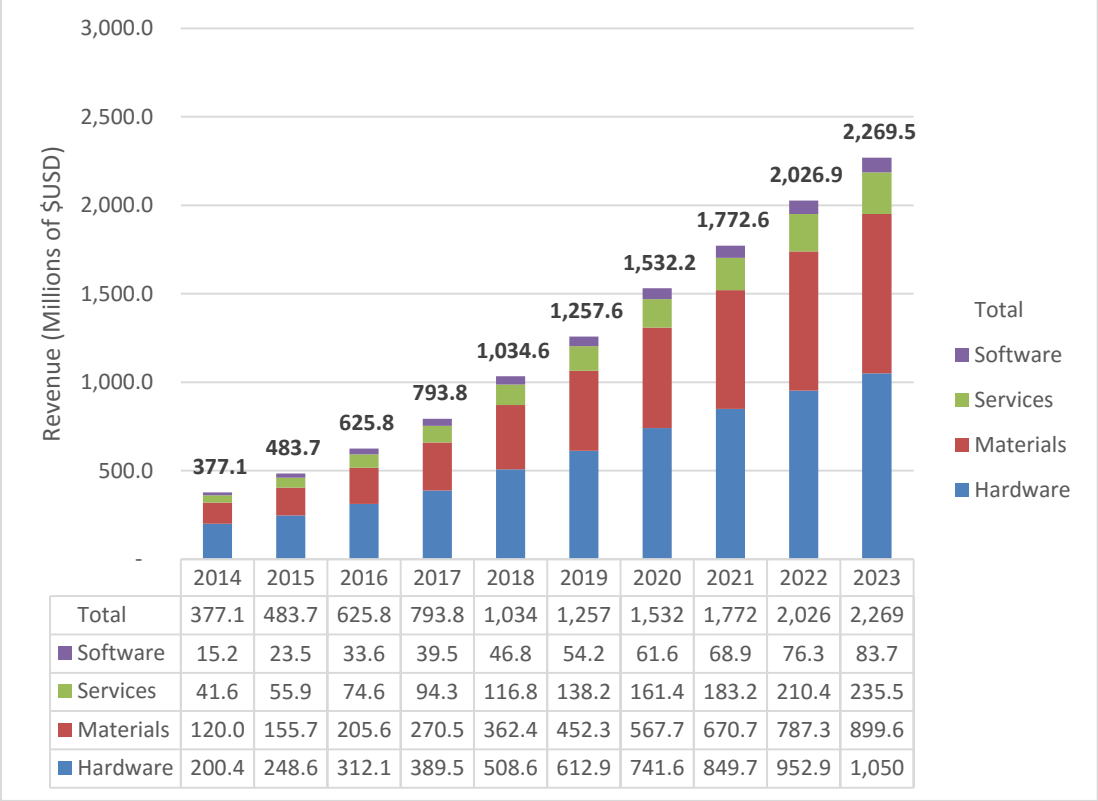
Exhibit V: Total 3D Printing Automotive Market Revenues



	2014	2015	2016	2017	2018	2019	2020	2021	2022	2023
Total	377.1	483.7	625.8	793.8	1,034	1,257	1,532	1,772	2,026	2,269
Software	15.2	23.5	33.6	39.5	46.8	54.2	61.6	68.9	76.3	83.7
Services	41.6	55.9	74.6	94.3	116.8	138.2	161.4	183.2	210.4	235.5
Materials	120.0	155.7	205.6	270.5	362.4	452.3	567.7	670.7	787.3	899.6
Hardware	200.4	248.6	312.1	389.5	508.6	612.9	741.6	849.7	952.9	1,050

Source: SmarTech Markets Publishing

*In **SmarTech's** report "Additive Manufacturing Opportunities in the Automotive Industry: A Ten-Year Forecast" we further break down AM in automotive into its most basic elements. Available equipment, industry makeup, component supply chain, key players, benefits, applications, and processes are all explored to arm our clients with the information needed to drive meaningful business decisions.*

About SmarTech Markets Publishing

SmarTech Markets Publishing delivers industry analysis and market forecasts for the 3D printing industry. Our coverage provides insight for those companies offering 3D printing equipment, materials, services, and software, as well as companies who operate in industries where 3D printing will begin to play a role in the near future.

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When a company purchases a report from SmarTech Markets Publishing or engages us for custom consulting, it receives:

- Comprehensive analysis that reflects today's 3D printing market realities and tomorrow's profitable possibilities
- Detailed forecasts that provide our clients with compelling evidence to support important strategic decisions and give them an edge over the competition.
- Actionable recommendations identifying where money will be made and where it will be lost.
- Candid market assessments based on today's best strategic thinking, not just data dumps from the Internet.

SmarTech offerings complement internal product planning technology road-mapping, as well as provide low-cost knowledge enhancement for firms in the 3D printing industry.

Our mission is to identify business opportunities in the areas of Additive Manufacturing (AM)/3D printing and other advanced manufacturing technologies.

We use a proven market analysis process with roots that stretch back 30 years in the telecommunications industry.

Our reports are focused on providing granular, comprehensive ten-year forecasts of revenue generation and market size for sectors of the AM industry. Our reports include forecasts of hardware, software, services, and materials, along with market size for potential applications.

SmarTech Markets Publishing's reports are intended as key strategic inputs for all senior executives planning 3D printing product/market strategies and for investors who are looking to take equity positions in 3D printing firms

SmarTech also offers customized consulting and due diligence analysis.

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