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Future of Manufacturing-Additive Manufacturing

Fazeeluddin Syed[1]

[1](Mechanical Engineering Department, Muffakham Jah College of Engineering and Technology, India

ABSTRACT:- *Additive Manufacturing being the most pronounced manufacturing process in the recent times has experienced huge technological advances, and research communities of different countries are working continuously. OEM's are primarily focused towards the development of business models. This paper gives a brief comparison of Additive Manufacturing and Traditional Manufacturing highlighting the Business opportunities in Additive Manufacturing. It also throws a light on Market opportunities available and challenges faced by AM. The various AM techniques employed for different metals is also listed by giving applications for each.*

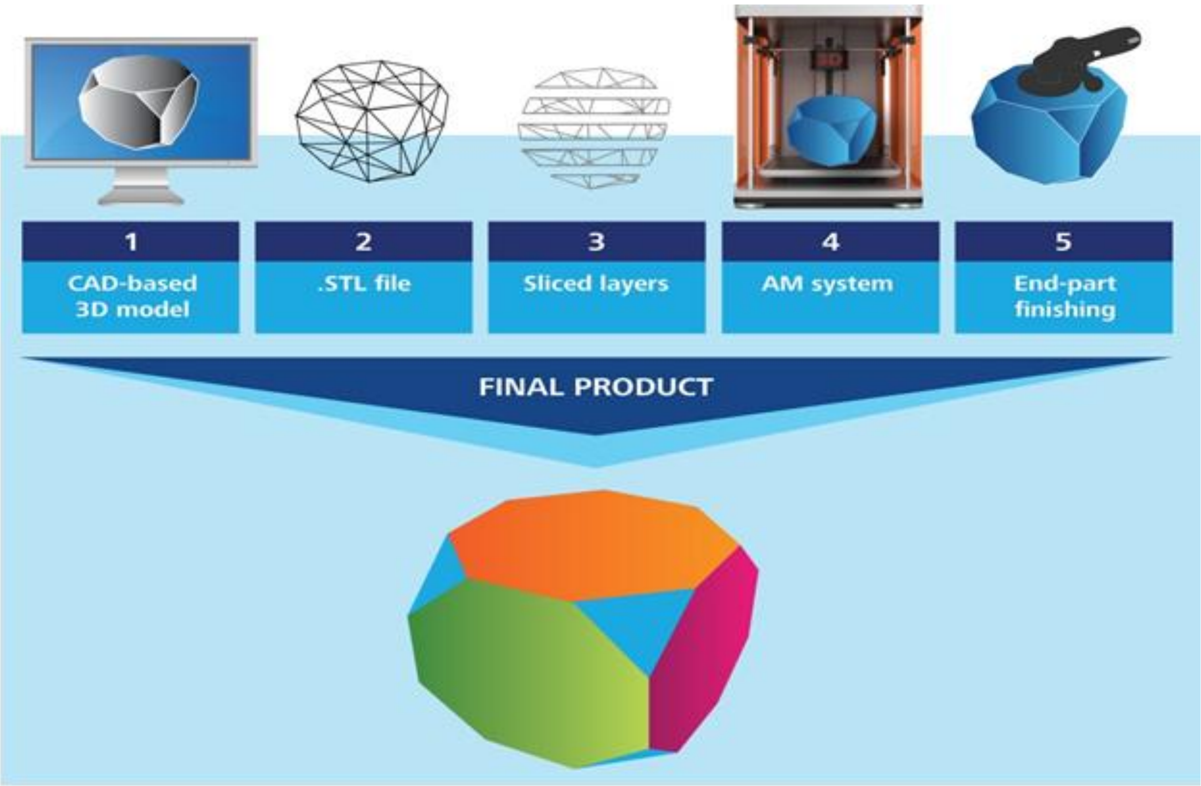
Keywords:- *Additive manufacturing, Computer Aided Manufacturing (CAM), Design, Polymers, Three Dimensional Printing*

I. INTRODUCTION

Additive Manufacturing (AM), also known as 3D printing, refers to a group of technologies that create products through the addition of materials (typically layer by layer rather than by subtraction (through machining or other types of processing). The history of AM traces back over 30 years to 1983 and the invention of stereo-lithography. Since then, the technology has evolved to include at least 13 different sub-technologies grouped into seven distinct process types. Additive Manufacturing can aid the performance, growth and innovation goals of OEM. ASTM International, a global body recognized for the development and delivery of consensus

Standards within the manufacturing industry, defines additive manufacturing as: *A process of joining materials to make objects from 3D model data, usually layer upon layer, as opposed to subtractive manufacturing methodologies.* The AM process traditionally begins with the creation of a three-dimensional (3D) model through the use of computer-aided design (CAD) software. The CAD-based 3D model is typically saved as a standard tessellation language (.STL) file, which is a triangulated representation of the model. Software then slices the data file into individual layers, which are sent as instructions to the AM device. The AM device creates the object by adding layers of material, one on top of the other, until the physical object is created.

Once the object is created, a variety of finishing activities may be required. Depending on the material used and the complexity of the product, some parts may need secondary processing, which can include sanding, filing, polishing, curing, material fill, or painting. Sophisticated 3D scanning and imaging tools are emerging as alternatives for traditional CAD programs. In addition, stylus based and other design technologies that allow consumers to modify digital models themselves—without the need for extensive CAD experience—are expected to drive growth in the personal AM systems space. New formats, such as additive manufacturing file format (AMF), are also being developed to address .STL's limitations and allow for more flexible file structures as stated by Dr. Mark Cotteleer et al. [1]



(Figure 1: shows the complete process of additive manufacturing)

II. TYPES OF ADDITIVE MANUFACTURING PROCESSES

Functional prototypes and end-use parts built through AM technologies have wide applications in industries such as industrial & consumer products, automotive, medical, and aerospace. AM technologies use a variety of materials, including plastics, metals, ceramics, and composites, and deploy multiple different processes to address issues such as design complexity, surface finish, unit cost, speed of operations, and others. To meet diverse requirements, industrial-grade AM systems are available in the market ranging in cost from $1 million—and more. AM technologies are typically based on one of the seven primary manufacturing processes described below. The major AM processes and technologies can be characterized by the materials they use and the advantages and disadvantages they offer. AM technologies use a range of materials. A classification of these materials into broad categories reveals that materials such *Vat photo-polymerization*: In vat photo-polymerization, a liquid photopolymer (i.e., plastic) in a vat is selectively cured by light-activated polymerization.

The process is also referred to as light polymerization.
Material jetting: In material jetting, a print head selectively deposits material on the build area. These droplets are most often comprised of Photopolymers with secondary materials (e.g., wax) used to create support structures during the build process. A UV light solidifies the photopolymer material to form cured parts. Support material is removed during post-build processing.
Material extrusion: In material extrusion, thermoplastic material is fed through a heated nozzle and deposited on a build platform. The nozzle melts the material and extrudes it to form each object layer. This process continues until the part is completed.
Powder bed fusion: In powder bed fusion, particles of material (e.g., plastic, metal) are selectively fused together using a thermal energy source such as a laser. Once a layer is fused, a new one is created by spreading powder over the top of the object and repeating the Process. Infused material is used to support the object being produced, thus reducing the need for support systems.

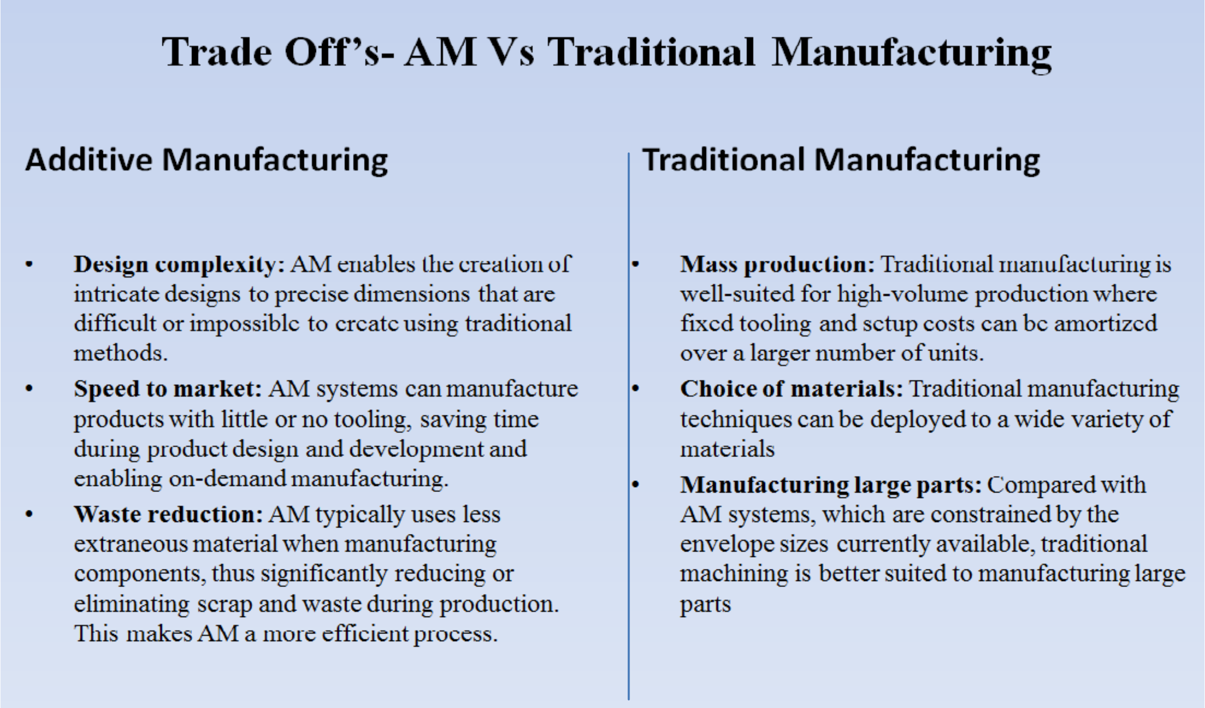
Binder jetting: In binder jetting, particles of material are selectively joined together using a liquid binding agent (e.g., glue). Inks may also be deposited in order to impart color. Once a layer is formed, a new one is created by spreading powder over the top of the object and repeating the process. This process is repeated until the object is formed. Unbound material is used to support the object being produced, thus reducing the need for support systems.

Sheet lamination: In sheet lamination, thin sheets of material (e.g., plastic or metal) are bonded together using a variety of methods (e.g., glue, ultrasonic welding) in order to form an object. Each new sheet of material is placed over previous layers. A laser or knife is used to cut a border around the desired part and unneeded material is removed. This process is repeated until the part is completed.

Directed energy deposition: In directed energy deposition, focused thermal energy is used to fuse (typically metal) material as it is being deposited. Directed energy deposition systems may employ either wire-based or powder-based approaches.

III. AM VERSUS TRADITIONAL MANUFACTURING: DISCUSSING TRADE-OFFS

AM creates 3D structures by adding materials layer upon layer. In contrast, traditional manufacturing practices (such as drilling or machining) are often “subtractive,” as they remove material from areas where it is not desired. Additive manufacturing and traditional manufacturing face different trade-offs, with each process likely to play a role in the deployment of manufacturing capabilities. Below, we list some of the respective advantages of AM and traditional manufacturing.



Trade Off’s- AM Vs Traditional Manufacturing

Additive Manufacturing

- **Design complexity:** AM enables the creation of intricate designs to precise dimensions that are difficult or impossible to create using traditional methods.
- **Speed to market:** AM systems can manufacture products with little or no tooling, saving time during product design and development and enabling on-demand manufacturing.
- **Waste reduction:** AM typically uses less extraneous material when manufacturing components, thus significantly reducing or eliminating scrap and waste during production. This makes AM a more efficient process.

Traditional Manufacturing

- **Mass production:** Traditional manufacturing is well-suited for high-volume production where fixed tooling and setup costs can be amortized over a larger number of units.
- **Choice of materials:** Traditional manufacturing techniques can be deployed to a wide variety of materials
- **Manufacturing large parts:** Compared with AM systems, which are constrained by the envelope sizes currently available, traditional machining is better suited to manufacturing large parts

(Figure 2: Tradeoff’s- AM Vs. Traditional Manufacturing)

Overall, AM offers companies an array of time efficiencies and cost reductions throughout the product lifecycle and supply chain, as well as greater flexibility in design and product customization than traditional manufacturing. These benefits will likely drive increasing levels of AM adoption going forward. The key areas of benefit include Flexible design and product customization as processes offer rapid iteration of designs and enable low volume print-on-demand applications and Workflow streamlining as we can reduce prototype development time and shorten review cycles while additive manufacturing predominantly uses a narrower range of polymers, metals, ceramics, and composites as per previous research by Dr. Mark Cotteleer et. Al [2]

IV. BUSINESS OPPORTUNITIES IN AM

The reality of AM incorporates some balance of these paths. This technology breaks existing performance trade-offs and expands the realm of possibility in two fundamental ways,

1. AM reduces capital required to achieve scale economies.
2. Its flexibility decreases the capital required to achieve scope economies.

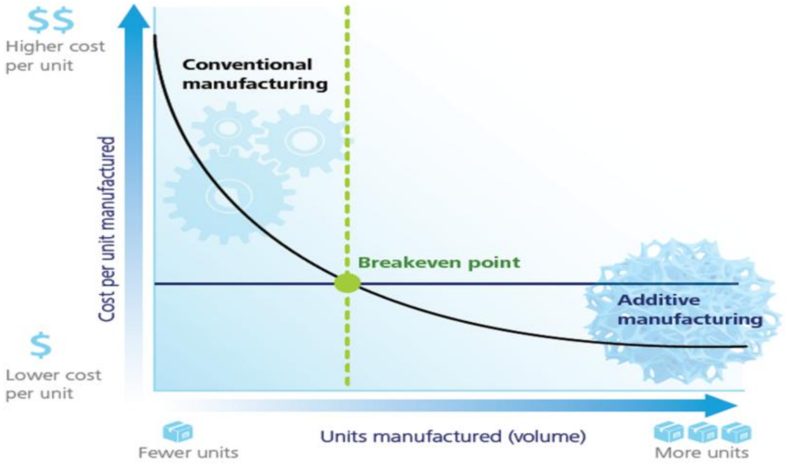
Using AM to break the constraints of these trade-offs creates opportunities for companies to improve performance, grow, and innovate. Understanding how this can be accomplished requires a review of how scale and scope economies shape the decisions that managers make about the manufacturing and distribution of their products.

Capital vs. Scale: *minimum efficient scale shapes supply chains:* AM promises to reduce —more so over time— the minimum efficient scale that gave rise to large modern industrial production facilities, lowering barriers to entry into manufacturing.

AM impacts the economics of production by reducing minimum efficient scale. In some cases, AM may allow consumers to satisfy their individual needs without the significant labor or capital investments that might have previously been required. Research supports this conclusion. Multiple economic studies illustrate that minimum efficient scale for AM can be achieved at low unit volumes—as low as one. This cost performance contrasts with that of traditional manufacturing methods that face higher initial costs for tooling and setup.

Figure below illustrates a prototypical set of cost curves for AM and traditional manufacturing methods drawn from existing studies. The cost curves illustrate the change in average cost for each incremental unit of production. Breakeven between two alternative production approaches occurs where these curves cross. Figure illustrates the achievement of minimum efficient scale for AM manufacturing, in this case, at one unit. In essence, the average cost curve is flat, suggesting that marginal cost does not change with volume. More traditional production methods may as yet yield cost advantages at higher volumes, as suggested by the declining cost curve.

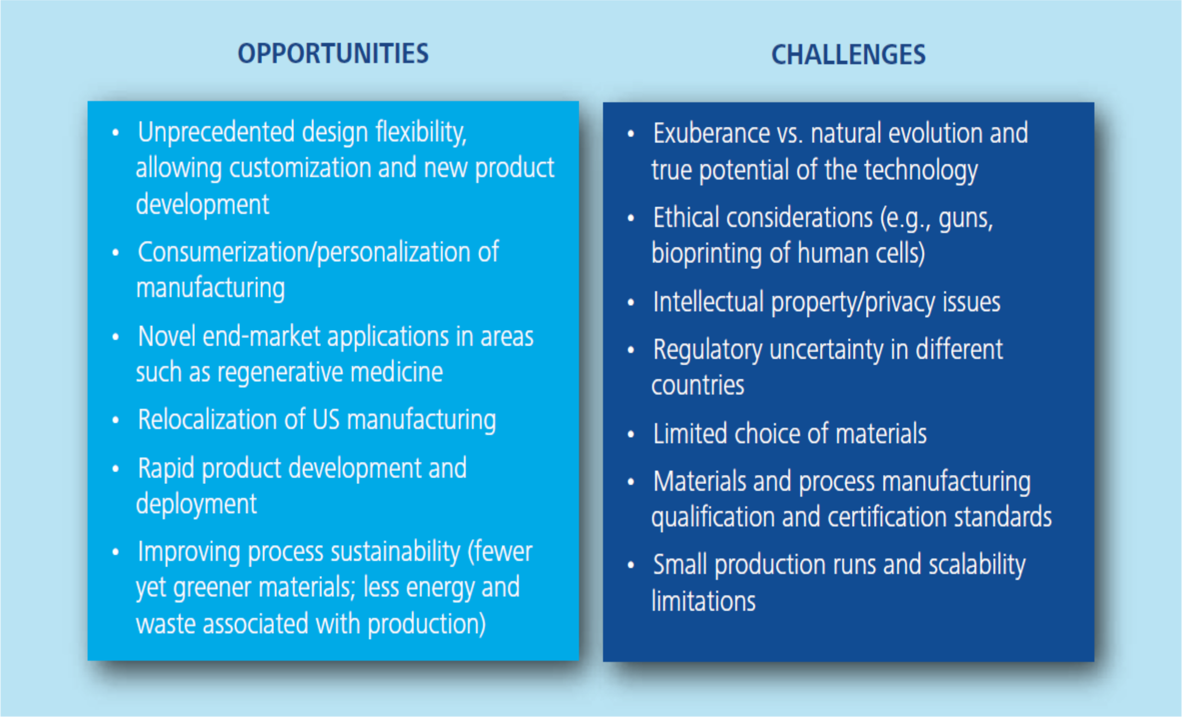
The research by Dr. Mark Cotteleer et. Al [2] concludes that AM production, using a variety of materials, can provide an efficient alternative for low-to-medium-sized production runs. Furthermore, expected reductions in material costs leave open the potential for breakeven points to substantially increase in the future. Improvements in throughput and reductions in the cost of AM equipment can only serve to further amplify these effects, increasing the production quantities at which AM might compete with more traditional manufacturing methods.



(Figure 3: AM Vs. Traditional Manufacturing Break even Analysis)

V. MARKET OPPORTUNITIES AND CHALLENGES

To understand the vitality of research & development in AM, one needs to understand the opportunities and challenges provided by Additive Manufacturing. Some experts have even heralded AM as the next great disruptive technology, similar to personal computing, giving everyone on the planet the ability to imagine, design, and create custom and personalized products. Such exuberance should be tempered. Even as AM offers great potential, it also faces an array of challenges. Figure 4 offers a snapshot of key AM market opportunities as well as challenges; although not exhaustive, this list may serve as the basis for a more thorough examination of drivers and headwinds that may impact future developments in AM.



OPPORTUNITIES

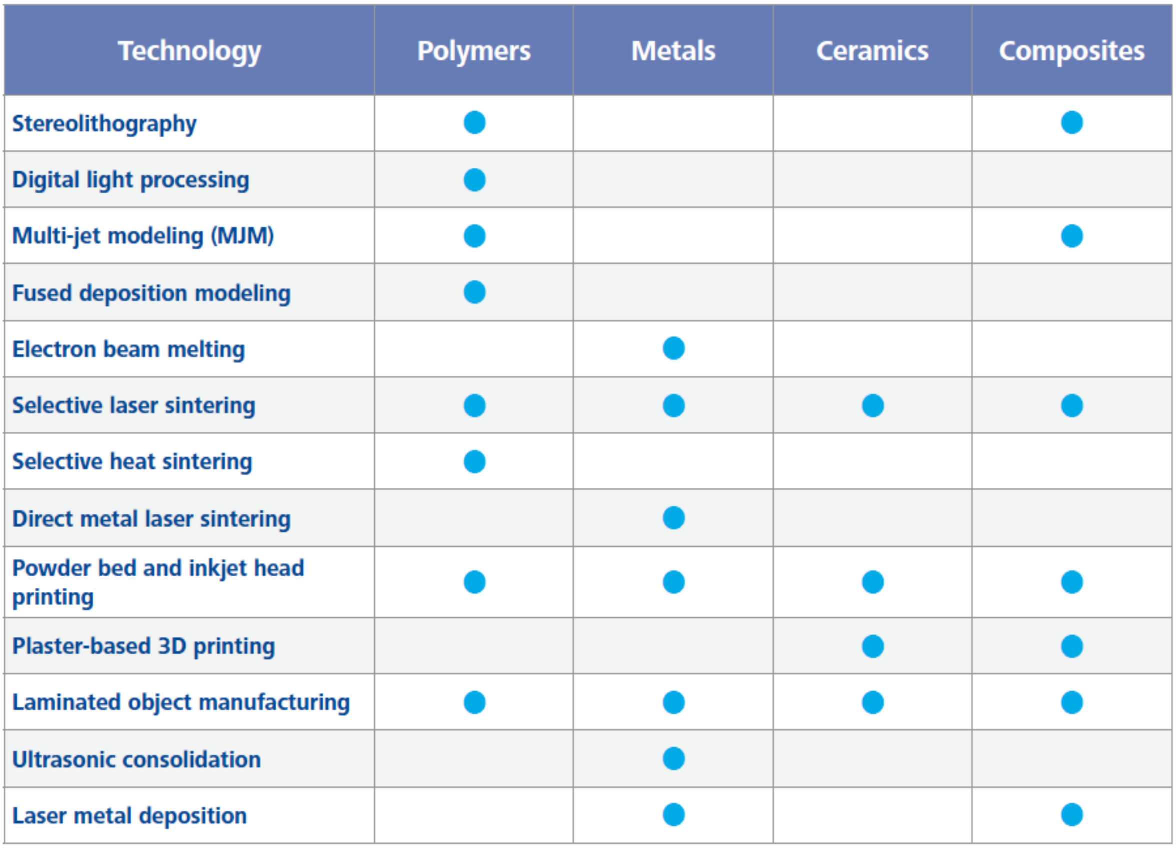
- Unprecedented design flexibility, allowing customization and new product development
- Consumerization/personalization of manufacturing
- Novel end-market applications in areas such as regenerative medicine
- Relocalization of US manufacturing
- Rapid product development and deployment
- Improving process sustainability (fewer yet greener materials; less energy and waste associated with production)

CHALLENGES

- Exuberance vs. natural evolution and true potential of the technology
- Ethical considerations (e.g., guns, bioprinting of human cells)
- Intellectual property/privacy issues
- Regulatory uncertainty in different countries
- Limited choice of materials
- Materials and process manufacturing qualification and certification standards
- Small production runs and scalability limitations

(Figure 4: AM opportunities Vs. Challenges)

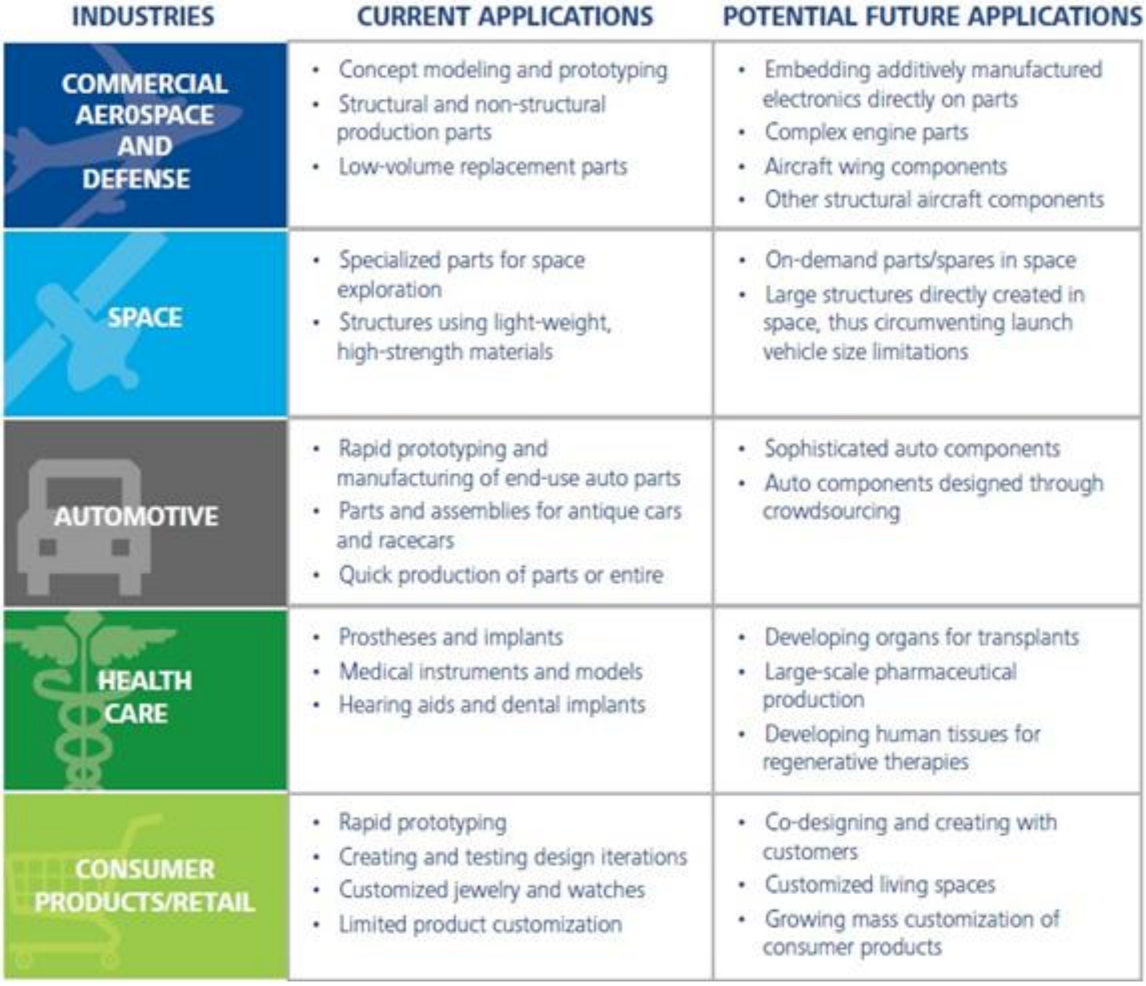
VI. Various Processes used for different Materials



Technology	Polymers	Metals	Ceramics	Composites
Stereolithography	●			●
Digital light processing	●			
Multi-jet modeling (MJM)	●			●
Fused deposition modeling	●			
Electron beam melting		●		
Selective laser sintering	●	●	●	●
Selective heat sintering	●			
Direct metal laser sintering		●		
Powder bed and inkjet head printing	●	●	●	●
Plaster-based 3D printing			●	●
Laminated object manufacturing	●	●	●	●
Ultrasonic consolidation		●		
Laser metal deposition		●		●

(Figure 5: Various AM processes used for different Materials)

VII. APPLICATIONS OF AM



INDUSTRIES	CURRENT APPLICATIONS	POTENTIAL FUTURE APPLICATIONS
COMMERCIAL AEROSPACE AND DEFENSE	• Concept modeling and prototyping • Structural and non-structural production parts • Low-volume replacement parts	• Embedding additively manufactured electronics directly on parts • Complex engine parts • Aircraft wing components • Other structural aircraft components
SPACE	• Specialized parts for space exploration • Structures using light-weight, high-strength materials	• On-demand parts/spares in space • Large structures directly created in space, thus circumventing launch vehicle size limitations
AUTOMOTIVE	• Rapid prototyping and manufacturing of end-use auto parts • Parts and assemblies for antique cars and racecars • Quick production of parts or entire	• Sophisticated auto components • Auto components designed through crowdsourcing
HEALTH CARE	• Prostheses and implants • Medical instruments and models • Hearing aids and dental implants	• Developing organs for transplants • Large-scale pharmaceutical production • Developing human tissues for regenerative therapies
CONSUMER PRODUCTS/RETAIL	• Rapid prototyping • Creating and testing design iterations • Customized jewelry and watches • Limited product customization	• Co-designing and creating with customers • Customized living spaces • Growing mass customization of consumer products

(Figure 6: Current and Potential Applications in Various Industries)

VIII. CONCLUSION

The various technologies used for additive manufacturing have been discussed. The current and potential applications of Automobile Industry are categorized. The identification and selection of the automobile parts was a cumbersome task and we focused to adapt this technology to all the automobile vehicles by this project and therefore we have selected a static component, Critical component and a component subjected to high temperatures. The design intent is to increase the durability, optimize the weight, reducing the lead time to customer etc.

Despite the challenges, the fact remains that AM is a versatile set of technologies that can support auto industry companies in their pursuit of the strategic imperatives of performance, growth, and innovation. Considering the breadth of capabilities unlocked by AM, leaders of automotive companies should consider taking advantage of AM technologies to stay ahead of competition.

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