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# 6 Key Insights about Additive Manufacturing

White Paper

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# 6 Key Insights about Additive Manufacturing

## Executive Summary

Additive Manufacturing (AM) is 30 years old, but is very much an emerging technology that is gaining acceptance worldwide in the aerospace, automotive, medical, and consumer products arenas. It is currently on track to triple in market penetration over the next five years.

Since AM is dependent upon the use of 3D CAD models, AM will be a driving force in the transition of industries to model based enterprises, which will mutually accelerate the ease of use and speed of adoption of both.

AM growth into the mainstream will be inexorably linked to the growth of web-based and computer-based design tools leading to a large scale shift in the way parts are designed, produced, and distributed.

AM has the potential to grow to 100 times its current size over the next 20 years, reaching $200 billion by 2035.

AM will define the next major wave in manufacturing for large enterprises. It will also be the basis for the creation of new entrepreneurial businesses that capitalize on the emerging technologies.

The positive impact on the bottom line of manufacturing enterprises will be far greater than most current estimates, at a minimum doubling the profit on parts made either by direct manufacture or assisted by AM-created tooling.

# Introduction

Additive Manufacturing (AM), commonly referred to as 3D Printing, has been in existence for about thirty years. Akin to the early VHS/Betamax or CD/DVD wars, no clear category or technology has yet emerged as dominant, nor is one likely to in the near term as significant investments are now pouring in to advance the technology. This white paper addresses some of the key concepts in understanding the issues that are moving AM forward as a viable business opportunity.

## 1. Additive Manufacturing is More than Manufacturing

Until recently, AM has been the exclusive purview of R&D or manufacturing. AM as an alternative manufacturing method will have a profound effect on the extended enterprise – encompassing the entire value chain and amplifying the advantages of the model based enterprise (MBE). For this reason it is necessary to widen the scope of involvement, encompassing multiple disciplines in the development of an AM mindset, gaining support for its adoption by more effectively communicating its considerable benefits at multiple levels. The expansion of AM is in some ways analogous to the growth of composite materials. Composites grew from a novelty to primary structural application through a systematic evolution of design philosophy, manufacturing processes, quality methods, and supply chain involvement. Likewise, it is clear that large scale commercialization of AM for mainstream uses will require rethinking the infrastructure of the extended enterprise to hasten the shift from prototyping to high value manufacturing and realization of the shorter product development and introduction cycles that are implicit in the AM promise.

Much of the current surge in use of AM comes from companies who understand that AM has to be treated as more than a discrete curiosity. Planning for AM is an early global decision that has to be made, impacting basic make/buy decisions. That is, do we go to the vendor base to acquire our AM parts, or do we bring more manufacturing back in house, enabled by the lower cost and faster time to market it allows. For the supplier community, do we start to offer AM, or just prepare for its arrival?

The first impacts will be felt at the supply chain level where communication will be enhanced by concise and complete technical data packages. Other immediate impacts will come from radical changes to what is acquired, how it is acquired, and equally radical shifts will occur in inventory levels. The AM supply chain doesn't really exist today in any robust form, and will have to be created and nurtured. Of course all these changes to the supply chain will have a radical impact on costs and how they are managed. Compared to "subtractive manufacturing" (e.g., machining), AM provides for freeing up capital, reducing work in process, reducing material costs, and improving amortization of new product costs.

## 2. Additive Manufacturing is Software Intensive, but Complexity is Free

Additive manufacturing, by being based on 3D models, allows for creation of more complex parts that could not otherwise be created. In theory, if you can model something in CAD, you can make it using AM. Designs that reduce part count by an order of magnitude have already been created in a production environment by GE Aviation. A fuel nozzle, previously manufactured and assembled from twenty parts is now being produced by AM as a single complete part. GE has reduced the weight by 50% for parts that have complex internal structures by using interior lattice structures that would otherwise be impossible using conventional manufacturing techniques.

The typical software front end of AM consists of taking a 3D CAD model, saving it in STL format, taking the data into a "slicing program" that outputs the model as layers ready for printing by the AM technology. Since we are starting with a 3D model that is further defined as 80 micron slices there is, for all practical purposes, no limit to the complexity of the part being produced.

## 3. Which AM are We Talking About?

The reality is that there are many forms of AM methods available. AM is a rapidly evolving approach that currently embodies 6 different processes and 11 different technologies, each creating parts from specific materials or material groups. Some of the materials available today for AM are metal alloys, thermoplastic, photopolymers, porcelain, metal clay, metal powders, stainless steel, titanium, and aluminum.

The processes are generally categorized as extrusion, wire, granular, powder bed, laminated, and light polymerization.

The technologies currently in use are Fused Deposition, Electron Beam Freeform Fabrication, Electron Beam Melting, Direct Metal Laser Sintering, Selective Laser Melting, Selective Heat Sintering, Selective Laser Sintering, Plaster-based 3D Printing, Laminated Object Manufacturing, Stereolithography, and Digital Light Processing. In a nutshell, some of the more popular categories are described below.

Extrusion deposition uses a plastic filament or metal wire to supply material to an extrusion nozzle, which turns the flow on and off. The nozzle melts the material and can be moved in both horizontal and vertical directions by a software package. The model or part is produced by extruding small beads of thermoplastic material to form layers as the material hardens immediately after extrusion from the nozzle.

Granular materials binding uses selective fusing of materials in a granular bed. The category fuses parts of the layer, and then moves the working area downwards, adding another layer of granules and repeating the process until the piece has built up. This process uses the unfused media to support overhangs and thin walls in the part being produced. A laser is typically used to sinter the media into a solid.

In photopolymerization a vat of liquid polymer is exposed to light from ultraviolet lasers, LEDs or through DLP. The exposed liquid polymer hardens. The build plate then moves down in small increments and the liquid polymer is again exposed to light. The process repeats until the model has been built. The liquid polymer is then drained from the vat, leaving the solid model. The first commercialized AM machine was the vat polymerization process known as stereolithography.

## 4. AM for Tooling Eliminates Cost and Constraints

Tooling has, more often than not, been the long pole in the tent in manufacturing a new or redesigned product. AM is in the unique position of creating two completely different substantial approaches to reductions in tooling time and cost.

The first and most obvious way is to eliminate tooling altogether by using AM to directly manufacture the product. This, of course, eliminates 100% of the tooling cost and accelerates time to market by as much as 18 months. According to Dr. Henner Wapenhans, the Rolls-Royce head of technology strategy, "One of the great advantages in the aerospace world is that some of these parts that we make have very long lead times, because of the tooling process that's got to [happen], and then it takes potentially 18 months to get the first part after placing an order – versus printing it, which could be done quite rapidly."

The second way AM can decrease the long tool lead time is to use it for the direct manufacture of tools, inserts, jigs, and fixtures – reducing dramatically the long lead time involved in designing, manufacturing, and testing a new tool. Moreover, rather than constantly refurbishing and recalibrating tools, they can simply be replaced at predetermined intervals. Similar to the benefits reaped by direct manufacture of parts, AM of tooling can bring a 95% reduction in tooling cost.

## 5. AM Market Size is Still Small But Growing Rapidly

AM articles, surveys, and forecasts have been touting a compound annual growth rate of anywhere from 25% to 39% for the market for Additive Manufacturing. Although these numbers are mathematically accurate, they overstate the growth in absolute terms.

While some forecasts postulate that the market for AM will triple over the next five years, that still only amounts to a growth from $2 billion to $6 billion dollars. Matched against the $340 billion dollar aerospace market, we are still talking about a relatively small number.

The good news, of course, is that means there is huge room for growth. Industry sources indicate that the current utilization of AM is about 30% for direct manufacture of parts, 15% for tooling and tooling patterns, 20% for fit and assembly and 10% for patterns for metal casting, to name the largest categories.

Estimates of growth vary widely, so we approach our estimate of size from a market potential calculation. It is our belief that based on a world-wide manufacturing market size of about $10 trillion a conservative 2% market penetration gives a potential for a $200 billion dollar market for AM parts, materials, and services. We further estimate that this level can be reached in 20 years.

What could potentially limit this growth picture? One consideration raised by some industry experts is the capacity for high-grade powder materials required for production of primary components using AM. This could be a chicken-and-egg situation that might inhibit AM growth—at least in the near term. Another consideration is whether or not AM-produced components will be robust enough to provide a one-for-one replacement for existing designs. Expressed differently—and back to the composites reference—will a whole new approach to component design be required to realize AM's full potential? Finally, for build-to-print members of the supply chain, the cost to receive approvals and perform qualification tests in order to change a form/fit/function part from conventional processes to AM could be prohibitive (although these limitations are much less likely to affect AM for tooling).

## 6. How Do You Measure the Cost Effectiveness of AM?

Depending on which side of the issue you're standing on and how global your view is, AM is both too expensive and too slow, or a huge savings and lightning fast. It is typical that opponents and proponents of the AM issue use a narrowly construed view of what goes into cost and what resulting benefits are derived from changing to AM. From the outside vendor point of view, the cost is easier to define – amounting to the purchase price plus an amortized realization of the additional engineering and design costs of the newly created part. The benefit side has to include all the savings created by reduced demand on internal resources like assembly and even as far as what the additionally available time available on those resources can now be used to generate.

From an internal manufacturing point of view the costs have to include the capital costs amortized over what is likely a relatively short time period and the operating costs. Savings include significantly reduced material costs (AM produces far less waste than SM), shorter cycles times (TTM), reduced labor costs of manufacturing and assembly, reduced inventory and WIP, and the huge potential of increased plant capacity resulting from all of the above. The issue of speed is a bit more complicated. While it is true that currently technology is relatively slow – with many machine runs taking 24 hours or more – the overall time as measured by concept to delivery is remarkably fast – eliminating as much as 18 months from the cycle. Quantifying the dollar value of such a time to market saving will add an order of magnitude growth to profitability.

## Conclusion

Renaissance Services is working with numerous aerospace companies and suppliers to help upgrade their additive manufacturing and design systems to span the value chain from customers to suppliers. We are currently helping define standards of AM and hands-on applying AM to both direct manufacture of parts and creation of tools and process aids.

To learn more about how it can work for you, contact:

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