REGIONAL AEROSPACE CLUSTER DEVELOPMENT BUSINESS PLAN: ADDITIVE MANUFACTURING

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I. PROJECT HISTORY

What is now called the "I-41 Corridor Region" of Wisconsin spans from Green Bay at its northern edge to Fond du Lac on its southern and includes the additional communities of Neenah, Menasha, Appleton and Oshkosh (Region). As the state's third largest population center, it is an important part of Wisconsin's economy. The Region has a long history of industrial activity and still ranks at the top of the country in terms of manufacturing jobs per capita. (Source: EMSI: "The states where manufacturing jobs matter the most", September 2, 2013). More than 20% of the Region's workers are employed in manufacturing, the most of any industry, and the industry has also reported the largest gains in job growth over the past five years. (Source: Economic Overview I-41 Corridor, July 2015).

The area has been historically known as the "Paper Valley" because of the location of many paper and pulp mills in the Region. This industry provided many needed jobs over the years, but that industry has changed considerably in the last two decades with consolidation driving much of this industry overseas. (Source: World Pulp and Paper "Consolidation in the Paper Industry" 2015).

The Region's past is in paper and lumber, but the strong manufacturing economy can serve as the base of a future in high tech industry – in particular aviation and aerospace. The idea of fostering the development of aerospace and aviation businesses in the Region is not a new one. Many have long believed the Region is uniquely positioned to foster business in this industry, due to incredible assets such as the world headquarters of the Experimental Aircraft Association (EAA) and the annual AirVenture fly-in, a network of four airports with a wide array of services and facilities, aviation education programming at Fox Valley Technical College (FVTC) and the University of Wisconsin Oshkosh (UW Oshkosh), a strong workforce and established supply chain - and an already existing aviation business cluster.

Beginning in 2009, an Oshkosh-based economic development organization, Chamco, recognized the need to diversify the local economy and began efforts to establish an aviation-focused business park at Wittman Regional Airport in Oshkosh and develop an aviation/aerospace focused business cluster. The Chamco Aviation Development Committee was active in furthering the aviation cluster initiative until December 2014, when Chamco transferred its economic development responsibilities to a new economic development organization serving the Oshkosh area – the Greater Oshkosh Economic Development Corporation (Greater Oshkosh EDC). The Greater Oshkosh EDC Aviation Development Committee (Aviation Development Committee) took over Chamco's responsibilities to provide oversight, direction and leadership to the aerospace cluster development project.

The wisdom of the idea of advancing the development of aviation/aerospace businesses was also embraced by UW Oshkosh as it founded the AeroInnovate program in 2008 to foster innovation in aerospace and aviation. Further bolstering the idea of fostering aviation/aerospace business development came from several economic development studies conducted in the Region over the past five years which concluded that aviation should be an industry of focus (summary of these studies is found at **Exhibit A**).

The state of Wisconsin has also been supportive of the development of an aviation/aerospace business cluster as one of four priority cluster industries promoted by the Wisconsin Economic Development Corporation (WEDC). WEDC is also working with industry to establish the Wisconsin Aerospace Partners (WAP), an industry-led organization with a mission to foster growth in the Wisconsin aviation/aerospace industry. Wisconsin's Lieutenant Governor, Rebecca Kleefisch, chairs the Manufacturing Committee of the Aerospace States Association and has been a strong advocate for the industry.

Grants from the U.S. Economic Development Administration (EDA) and the Department of Defense, Office of Economic Adjustment (DoD-OEA) have provided funding support for advancement of the aerospace cluster initiative. East Central Wisconsin Regional Planning Commission (ECWRPC), with Chamco, the City of Oshkosh and UW Oshkosh, successfully applied in 2012 for the City of Oshkosh to receive a $2,000,000 grant from the EDA to provide funding assistance to put in necessary infrastructure at the Oshkosh Aviation Business Park. In 2013, following cuts in defense spending which resulted in the loss of more than 2,000 direct jobs at Oshkosh-based Department of Defense contractor Oshkosh Corporation and hundreds more in the regional economy, the region was awarded a planning grant from the Department of Defense Office of Adjustment's ORDIDI grant. ORDIDI stands for 'Oshkosh Regional Defense Industry Diversification Initiative.' The purpose of the grant was twofold: One, to provide direct assistance to suppliers and employees in Oshkosh and other impacted communities in the surrounding area; and, two, to assist with economic diversification efforts already underway. One such diversification effort was the aerospace development cluster project. A portion of the ORDIDI grant was allocated to provide funding to conduct an aerospace cluster study in Oshkosh (and develop this associated business plan). Supplemental funding was secured in 2014 from DoD-OEA to expand the study to include the communities of Green Bay, Appleton and Fond du Lac – the four communities in the region with airports, aviation-focused business parks and a desire to build an aerospace business cluster (Project Partners). The aerospace cluster study's objective was to assist the Region with determining which areas of the aerospace/aviation industry to focus efforts, based on industry trends, market opportunities and assets in the Region to support the cluster development.

Explorer Solutions, an aerospace consultant based in Quebec, Canada, was chosen following an RFP process to conduct the aerospace cluster study for the City of Oshkosh. Explorer Solutions' work provided much of the background industry research that supports this business plan. Mid-way through the ORDIDI grant period, the Aviation Development Committee and the City of Oshkosh determined Explorer Solutions had provided all that was needed for the local project partners to take ownership of the creation of the cluster development strategy and business plan. Greater Oshkosh EDC was hired to complete the study process, which in turn hired NextJen Studios to provide additional industry specific research to supplement the Explorer Solutions work. The City of Oshkosh also contracted with Elizabeth Hartman, former CEO of Chamco, who has been engaged in the aerospace cluster development project since 2009, to coordinate completion of this business plan.

Throughout the study process, the Aviation Development Committee has provided oversight, direction and leadership to the cluster development plan. A listing of the members of the Aviation Development Committee is found at **Exhibit B**.

Based on the research provided by Explorer Solutions, the Aviation Development Committee concluded that the I-41 Corridor Region was well positioned to focus on fostering growth in Maintenance, Repair and Overhaul (MRO) in the short term (the subject of a separate business plan) and Aerospace Additive Manufacturing (Cluster), as a long term strategy for the Region. The background research provided by Explorer Solutions supporting the Committee's conclusion is attached at **Exhibit C.**

Below sets forth information on aerospace industry trends in aerospace additive manufacturing, local research, regional assets, Cluster development strategy and Cluster operations.

II. INDUSTRY TRENDS IN AEROSPACE ADDITIVE MANUFACTURING

Additive manufacturing (AM) is a manufacturing technique that builds three dimensional objects from an electronic data source layer by layer using materials such as polymers, metals and composites. There are several different techniques including:

- Direct metal laser sintering – AM technique that uses laser as the power source to sinter powdered material;
- Electronic beam melting – AM technique that fully melts the metals using an electronic beam as the power source; and
- Fused deposition modeling – FDM machines deposit ABS or another type of thermoplastic through a heated nozzle to form layers.

Aerospace has been an early adopter of additive manufacturing techniques, particularly in prototyping and tooling. Many believe AM is the future of the aerospace industry as advances in technology drive its use in the production of end-use parts. "Additive manufacturing will change the game forever by freeing engineers to design parts without the traditional limitations imposed by conventional manufacturing." Greg Morris, Leader, Additive Technologies, GE Aviation.

- AM is currently used in concept modeling and prototyping, printing low volume complex parts such as tooling, printing replacement parts and more recently in the production of end-use parts.
- Potential future applications include embedding additively manufactured electronics in parts, printing large parts such as aircraft wings, printing complex engine parts and printing repair parts on site.
- There is significant future growth potential. The AM aerospace market is expected to grow from just over $400MM in 2014 to $1.2B by 2023.
- While several significant advantages of AM have been validated, other potential advantages are yet to be seen. In certain cases technology needs to improve to realize potential, in particular with respect to materials.
  - Demonstrated advantages include: reduced lead time for components, ability to build complex designs not possible to build with traditional

means, ability to easily change designs, reduced tooling costs and reduced waste

  - Potential advantages include reduced component weight and reduced production costs
  - Issues that need to be resolved include demonstrating replication accuracy, developing the ability to produce large parts, expanding the use of materials that can be used (and bringing the cost down), increasing multi-material printing capability and decreasing finishing costs

- Many believe AM will have a significant role in MRO operations when it comes to the ability to replace parts on site without having to source them from elsewhere (reducing aircraft downtime) and replacing legacy parts on vintage aircraft that are difficult or impossible to find.
- There is some skepticism and reluctance among some aerospace executives about additive manufacturing, primarily related to lack of knowledge and also due to the fact that some of additive manufacturing's potential benefits are yet to be demonstrated.
- Aerospace engineers have also been challenged with the technology because they do not have the tools, training or experience to produce geometrically complex designs.
- Some examples of AM use in industry:
  - NASA used 70 AM produced parts on Mars Rover test vehicles
  - GE
    - producing LEAP fuel nozzle by AM, reducing 20 parts to 1 and creating a part that is 25% lighter and 5x more durable
    - increasing its AM staff by threefold in the next five years
    - developing dedicated AM facility for jet engine parts
  - Lockheed Martin using 3D printed parts for satellite manufacturing
  - Airbus

        - installed thousands of AM produced parts on A350
        - equipping the Test Bed 380 with an engine that has the largest civil aerospace component ever built using 3D printing techniques
    - Boeing
        - installed AM produced polymer air ducts on F/A 18
        - AM used in satellite brackets
- GKN Aerospace announced a three year project to develop a new titanium powder specifically for AM aerospace applications.
- Many believe the adoption of the technology by the big players signals the return on the investment is there. It is clear that the industry is moving towards more widespread adoption of AM as technology improves and if aerospace companies are not preparing to adopt it in some form of their operations, they will be missing out on opportunities in an expanding market, and may be left behind as other suppliers who are using the technology are chosen.

(Sources: "3D Printing for Aerospace", TCTMagazine July 2015; "Additive Manufacturing in Aerospace: Strategic Implications", a SmartTech White Paper August 2014; "3D Opportunity in Aerospace and Defense", Deloitte University Press 2014; Explorer Solutions preliminary report (**Exhibits C and D**).

III. SUMMARY OF LOCAL RESEARCH FINDINGS

The following summarizes information from more than 100 interviews conducted by NextJen Studios of aerospace/aviation companies operating in the Region, at AirVenture and at NBAA (National Business Aviation Association), strategy sessions of the Aviation Development Committee, with a focus on information concerning additive manufacturing. The findings and recommendations are divided into the following categories:

A) Workforce Development and Education

B) Supply Chain

C) Business Development and

D) Entrepreneurship and Innovation.

A. <u>Summary of Key Findings - Workforce Development and Education</u>

To support the Cluster activities, the Region will need aerospace engineers and researchers. The Region has a skilled workforce and supportive aviation educational programming but not enough engineering and research capacity.

1. Engineer positions were also downsized over the last 20 years as those jobs were streamlined. The industry is now realizing that the engineering positions create the opportunities for the skilled workforce. The US is far behind some European countries in its engineering curriculum.
2. UW Oshkosh has a newly-created engineering technology degree program with three areas of focus: environmental engineering, electrical engineering and mechanical engineering. There is an opportunity (through partnerships) to create a fourth emphasis on aerospace.
3. Because we do not have a comprehensive research institution in the Region, we lack local capabilities to provide the R&D support an additive manufacturing Cluster will need.
4. WEDC's new program which provides grants to K-12 schools to equip "Fab labs" with 3D printing capabilities provides opportunities to get students interested in AM at an early age.

Recommendations

- Aerospace opportunities need to be a part of STEM programs – promote and expand initiatives such as Fab Labs.
- More educational programming in AM for skilled trades and opportunity to create tailored programming; opportunity for aerospace focused engineering program at UW Oshkosh.

B. Summary of Findings - Supply Chain Status and Gaps

The Cluster will need a strong supply chain throughout the Region and state. As a whole, there are few issues with the supply chain operating in Wisconsin, but while there are some companies using additive manufacturing in their operations, most companies lack a basic understanding of how it could impact the industry and their business and the best way to adopt it.

1. Research continues to bring new materials to the aerospace sector en masse. Composite aircraft have demonstrated their capabilities and durability, as have glass cockpits. Several companies are focused on bringing new materials to market. New materials will create new AM applications.
2. A feature forum at NBAA conference was on 3D printing.
3. Overall there was a mixed response locally on additive manufacturing
   - Few local companies are taking advantage of these opportunities due to cost or not understanding the technology
   - Concerns about meeting FAA regulations for materials and parts

Recommendation

- Increase AM education and outreach to businesses in the Region

C. Summary of Findings – Business Development

Given the long-term nature of this Cluster strategy, the Region will implement the business development strategies in Phase II of the Cluster Project.

D. Summary of Findings - Entrepreneurship and Innovation

The Region has sources of entrepreneurship and innovation but they need more resources, support and better connectivity.

1. The AeroInnovate program is a source of entrepreneurs and innovation.
2. AeroInnovate and its entrepreneurs need additional resources to advance innovation in aviation such as mentors, access to capital and a talent pool.
3. Existing companies in the Region/state which work in the aerospace sector can also be source of innovation, i.e., Plexus. How do we leverage these resources to help advance the Cluster? Companies in the Region are not aware of the innovations occurring at other companies.

Recommendations

- Expand resources to support entrepreneurs working in AM - sources of investment capital, mentors, talent pool
- Provide forum to bring aerospace companies together to showcase new innovations, and developments in additive manufacturing

IV. REGIONAL ASSETS TO SUPPORT CLUSTER EFFORTS AND GAPS

The 1-41 Corridor Region has many strengths and competitive advantages which position it well for developing growth in AM in aerospace, but gaps exist which will require resources and additional capacity to fully realize the Cluster's potential.

A. Proximity to AirVenture. Oshkosh is home to the world headquarters of the Experimental Aircraft Association (EAA), which hosts AirVenture every year. For one week each summer, EAA members and aviation enthusiasts totaling more than 500,000 from more than 60 countries, 800 exhibitors and 10,000 airplanes attend EAA AirVenture at Wittman Regional Airport in Oshkosh, where they rekindle friendships and celebrate the past, present and future in the world of flight. For one week a year, Oshkosh's Wittman Regional Airport is the busiest in the world. EAA calls AirVenture the "world's largest general aviation marketplace." Many consider Oshkosh to be the "mecca" of general aviation. This is an unparalleled platform to showcase AM innovations.

B. The Region is supportive of innovation in aviation. AeroInnovate at UW-Oshkosh, first conceptualized in 2007, brings in aviation-related entrepreneurs from across the globe that are establishing and growing aviation-related businesses and bringing new technologies to the marketplace. Its goal is to facilitate the alignment of innovators to develop new aircraft, aviation products and services that will be commercialized and create global opportunities in aviation. AeroInnovate does this by bringing innovators and entrepreneurs together and offering top-notch educational forums, aligning the best companies with investors and industry leaders, exposing technology through technology showcases and connecting aviation related entrepreneurs to people and resources. AeroInnovate recently launched a comprehensive start-up accelerator program. AeroInnovate could be a source of new companies bringing AM technologies to the market.

C. The Region has aviation focused educational programs but lacks engineering programming specific to aerospace. As previously discussed.

D. The Region has a strong manufacturing labor force and aerospace supply chain. The Region has a long history as a manufacturing hub with skilled labor but this labor will need AM specific training.

E. The Region is committed to collaboration. The Project Partners have developed a Memorandum of Understanding and Code of Conduct setting forth their commitment to regional collaboration on Cluster development (attached as **Exhibit E**). Many see regional collaboration as critical to the Region's economic development success. If the Cluster is to be successful it will require collaboration at a comprehensive and sustained level. (See Green Bay Press Gazette article also attached as **Exhibit E**).

V. AM RESOURCES IN AND OUT OF STATE

There are currently no established AM resources "in-state" with an aerospace-specific focus. Included below is a summary of non-industry-specific resources that could be engaged as future partners for our aerospace development objectives. The out-of-state resources listed below are those which provide resources in AM specifically to aerospace.

A. In Wisconsin

1. MSOE Rapid Prototyping Center: The Rapid Prototyping Center of the Milwaukee School of Engineering (MSOE) is dedicated to the application of new and advanced prototyping technologies, particularly 3D printing. It is a consortium of industry members who help fund the Center in exchange for prototyping and product development services. Its 72 members include Johnson Controls, Oshkosh Corporation, Precision Plus, and Rockwell.
2. FVTC Fab Labs: Fox Valley Technical College is part of the MIT Fab Lab network with the 17th Fab Lab in the world. The lab focuses on helping students to generate interest and development talent; inventors with design and prototype services; and with R&D departments of businesses to gain them access to equipment they may not otherwise have. The Lab is equipped with a state-of-the art 3D printer and associated equipment.
3. UW Madison Advanced Materials Industrial Consortium: UW Madison's AMIC gives commercial partners the opportunity to collaborate with faculty and students in advanced materials research across campus through programs such as the AMIC Seed Program (short term collaborative projects which seek to find commonality between industry needs and academic expertise) and the AMIC Industrial Fellows Program (where industry can send a fellow to campus to complete a research project with faculty and staff).

B. Outside Wisconsin

1. Pratt & Whitney AM Innovation Center (Connecticut) is a partnership between P&W and University of Connecticut to build a $4.5MM state of the art facility with goals to develop metal and train engineers and designers in AM for aerospace.
2. GE Additive Development Center (Ohio) mission to "lead, explore and advance industrialization of 3D printing, by proving out designs, techniques and procedures that, over the next decade, will redefine, reinvent and reimagine manufacturing at GE Aviation, the GE corporation and the industry as a whole."
3. Defense/Aerospace Supply Chain Manufacturing Technology Acceleration Center (Texas) is part of national initiative to bring together teams of experts in specific technology and supply chain areas to offer services and deep expertise in order to improve small U.S. manufacturers' supply chain competitiveness and the rates at which they adopt technology. AM will be a key component of MTAC's projects.

VI. CLUSTER DEVELOPMENT STRATEGY

The Project Partners have developed the following strategy:

A. Phase 1: Build capacity for the Cluster

1. Dedicating staff to Cluster development
2. Fostering entrepreneurship and innovation in AM by
    - o increasing access to capital with aerospace investment fund
    - o increasing the mentor and talent pool for new companies
    - o getting established companies together to share innovations – i.e., additive manufacturing symposium
3. Building the workforce by
    - o getting students interested in AM by partnering with K-12 and building on programming such as the new Fab Labs program
    - o working with FVTC on AM programming for skilled labor
    - o explore possibilities with UW Oshkosh & Northeast Wisconsin Education Resource Alliance for aerospace engineering technology degree
4. Educating the supply chain about AM
    - o hold educational forums featuring AM such as additive manufacturing symposium
5. Fostering connections between companies and AM resources in and out of state (see **Section V**) and populate the New North Supply Chain Directory with companies identifying their AM capabilities

B. Phase 2: Develop the Cluster

1. As part of the effort to build the MRO Cluster, the Region will build a network among the aviation-focused business parks located on the four Partner Airports – Wittman Regional Airport, Fond du Lac County Airport, Appleton International Airport, Austin Straubel

International Airport – with an AM focus through regional collaboration and joint marketing efforts.

2. After Phase I, the Cluster will engage in business development efforts.

VII. CLUSTER ORGANIZATIONAL STRUCTURE AND OPERATIONS

A. Governance

Regional Aerospace Development Council: This is a body to-be-created to provide governance and oversight to the cluster development activities. Each Project Partner shall designate a representative to sit on this Council with voting rights. The Council may become a committee of the Wisconsin Aerospace Partners, once it is formed, so long as WAP has as a strategic priority developing the regional cluster and staff dedicated to the effort. Staff dedicated to the cluster development may report directly to the Council, or to WAP. The Council may form the following subcommittees:

1. Business Development and Marketing – to communicate the importance of aerospace and technology as a priority for business, economy and community and assist current businesses with identifying new opportunities in aerospace and attracting new aerospace businesses to the region.
2. Education and Workforce - to foster education and growth of science, technology and engineering related to aerospace and ensure we have an educated and skilled workforce available for the aerospace industry.
3. Entrepreneurship and Innovation - to foster the growth of new companies and innovation in aerospace in the region and make connections between industry innovations and opportunities.

B. Staff. Initially it is anticipated that a dedicated staff person with expertise in aerospace will serve as the point person to execute Cluster activities. As the Cluster grows, Airport Directors and local economic development professionals will provide assistance with marketing, prospect handling and tenant relations.

C. Strategic Partners

1. Airports, cities and counties in the Region
2. Economic development organizations in the Region
3. Fox Valley Technical College and UW Oshkosh
4. Wisconsin Economic Development Corporation
5. Wisconsin Aerospace Partners
6. AeroInnovate
7. AM resources in and out of state
8. East Central Wisconsin Regional Planning Commission
9. Department of Defense – Office of Economic Adjustment (proposed funding source for some of the activities outlined in Section IV)

D. Budget

A three year budget for the Cluster is attached as **Exhibit F.**

E. Success Metrics

1. Short term
    - Establishment of partnerships with AM resources in and out of state
    - Increased awareness and adoption of AM in the Region among aerospace suppliers
    - AM symposium
    - Development of additional AM educational programs in the Region
2. Long term
    - Number of businesses starting, expanding, and locating in the Region as part of the Cluster
    - Number of FTEs employed by businesses in the Cluster
    - Growth of existing businesses in the Region due to Cluster activities
    - The Region being recognized as a AM resource
    - A more diversified Regional economy
    - The "Paper Valley" of the past is transformed into "Aerospace Valley"!

APPENDIX

Exhibit A: Summary of Economic Development Studies

Exhibit B: Aviation Development Committee

Exhibit C: Explorer Solutions Preliminary Report, select pages

Exhibit D: 3D Printing and Additive Manufacturing Articles

Exhibit E: Regional Collaboration information

Exhibit F: Budget

Exhibit A

Exhibit A: Summary of Economic Development Studies conducted in the Fox Valley Region

From 2010 to present with conclusions related to development aviation businesses

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The Garner Economics *"Ignite Fox Cities"* 2011 Economic Report commissioned to identify regional assets for targeted industry development recognized the Fox Valley Region as having a unique and strong presence in the Transportation Equipment Manufacturing industry (NAICS 336), which specifically includes Aerospace Product and Parts Manufacturing (NAICS 3364). This report suggested that the existing skilled labor pool and supporting infrastructure offers a solid competitive advantage over other locations. Aerospace is a recognized industry cluster emerging in the Oshkosh area which ties into Transportation Equipment Manufacturing. For this reason, the Oshkosh Aviation Business Park is tailored specifically towards Transportation Equipment Manufacturing industries, specifically the Aerospace industry.

The Northeast Wisconsin Global Trade Strategy is another recent regional study suggesting that further research on the Transportation Equipment Manufacturing cluster would be valuable to the Northeast Wisconsin Region. East Central Wisconsin Regional Planning Commission (ECWRPC) partnered with Bay Lake RPC and Newmark Knight Frank (NKF, economic consultant) to focus on how Northeast Wisconsin can leverage its core assets and overcome weaknesses to increase exporting capabilities to key foreign markets. Funded in part by an EDA-TAA grant, the Global Trade Strategy identified the Transportation Equipment Manufacturing cluster as an area that merits further research and disaggregation.

The Oshkosh Area Targeted Business & Industry Cluster Analysis, funded in part by an EDA Local Technical Assistance grant, provided research to identify components of company and industry specific issues, scenarios, strategies and actions to be taken to address potential contributions and/or losses within the local economy. They have collected data and conducted interviews to provide specific insights into the potential expansion and growth of existing industry clusters and the current and potential interrelationships between individual companies and industries within the cluster. Aviation was identified as an industry cluster of focus for the Oshkosh area.

Exhibit B

ORDIDI Aerospace Cluster Committee
Planning Grant Co-Chairs: Meridith Jaeger & Elizabeth Hartman
Tasks/Responsibilities: Responsible for ORDIDI Planning grant deliverables as it relates the development of the regional Aerospace Cluster short term & long term strategies. More of an advisory group – not hands on.

Committee Members:
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Exhibit C

Additive Manufacturing

Trends

Additive manufacturing (AM), also known as 3D manufacturing, has captured industry's imagination; as the first parts are developed for jet engines and interiors, the technology's possibilities are only just being realized. The aerospace industry is adopting additive manufacturing at a very fast paste to manufacture complex parts in a single production process, reduce weight and save costs.

- GE has recently acquired two companies specialized in AM; it also plans to develop aerospace's first large, dedicated AM facility for jet engine parts in Auburn, AL. GE Aviation's Additive Technology Center in Cincinnati, OH is also expected to expand in size by more than 300% over the coming year.
- Lockheed Martin Corp. is aggressively deploying additive manufacturing: the company plans to use the technology to produce much larger parts for spacecraft programs.
- Boeing, for its part, sees metal-AM processes as a key sector for future competitiveness.
- Rolls Royce's Civil aerospace division is currently at work devising ways of using 3D printing to build various jet engine parts
- Pratt & Whitney has opened a AM lab in partnership with the University of Connecticut

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Additive Manufacturing

The opportunity

OEMs and manufacturers all agree that AM has the potential to revolutionize the aerospace industry; it is a game changer. The market, currently worth $2 billion, is expected to increase at a 13.5% compounded annual growth rate (CAGR) until 2017.

Nevertheless, significant amounts of research, testing and development will be required. AM is presently most used as a cost effective and flexible prototyping tool, but using it for mass production will require a lot more research and development, particularly in aerospace which is a closely regulated industry.

The industry is at a point where it needs to understand and identify the areas where manufacturing operations and end-use parts can truly benefit from AM. Significant opportunities lie in addressing the aerospace industry's specific needs. More specifically:

- Identify and increase the number of suitable AM parts
- Expand the technology to new materials (metals, high-temperature superalloys, reinforced plastics, composites, etc.)
- Produce larger parts
- Increase the capacity to produce at a faster rate and on a larger scale
- Increase the production rate capacity of AM technology machinery

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Additive Manufacturing: a Definition

Additive manufacturing (AM) – often referred to as 3D printing – consists of making a three-dimensional object of almost any shape from an electronic data source through additive processes in which successive layers of material are laid down under computer control.

Materials currently used in additive manufacturing include, but are no longer limited to, plastics.

Plastics
Plastics are currently the most widely used materials in additive manufacturing

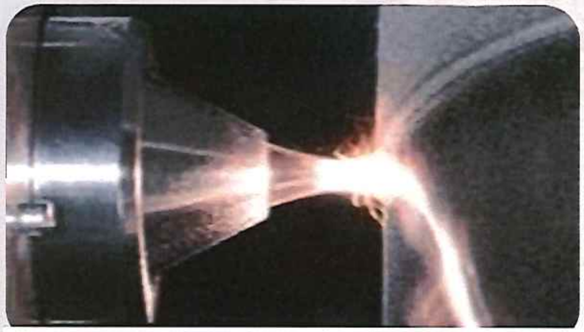
- ABS – acrylonitile butadiene styrene
- PLA - polylactic acid
- PVA - polyvinyl alcohol
- PC – polycarbonate
- SOFT PLA

Metals
Some of the metals used in 3D printing include the following:

- Steel
- Stainless steel
- Cobalt alloys
- Nickel alloys
- Titanium

Additive Manufacturing: a Definition

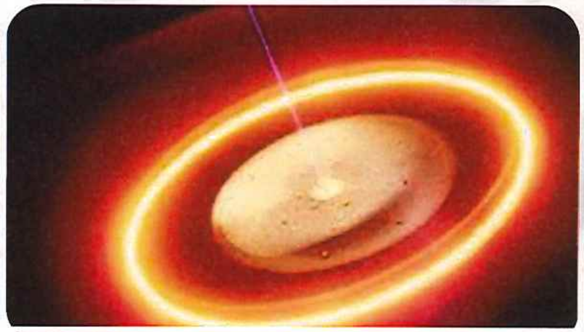
There are numerous processes that fall under the Additive Manufacturing umbrella. All techniques have differing finishes, durability and size capabilities.



Direct metal laser sintering (DMLS)

AM technique that uses a laser as the power source to sinter powdered material (typically metal)

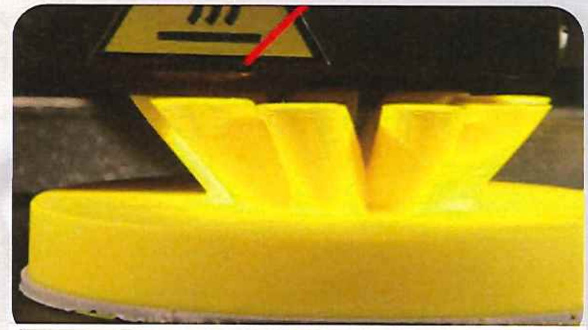
A net-shape process, producing parts with high accuracy and detailed resolution, good surface quality and excellent mechanical properties.



Electron Beam Melting (EBM)

AM technique that fully melts the metals (typically titanium and cobalt) using an electron beam as the power source.

Unlike DMLS, parts produced with EBM and melting techniques are fully dense, void-free, and extremely strong



Fused Deposition Modeling (FDM)

FDM machines deposit ABS plastic or another type of thermoplastic through a heated nozzle to form the layers.

The materials used in FDM are known for their heat resistance and fire retardant properties, making them suitable for aerospace and aviation applications.

- ✓ High accuracy
- ✓ Strength
- ✓ Heat resistance

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Additive Manufacturing - Key Benefits

Increase Design Freedom

- *Ability to produce optimally-designed components that would be difficult to make with traditional manufacturing*

Reduce Assembly Risk

- *Ability to produce complex assemblies in a single process, thereby reducing assembly risk*

Weight Saving

- *Weight-saving: a key advantage in the aerospace industry*

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- The use of AM for the production of parts for final products continues to grow and currently represents 28.3% of the total AM expenses worldwide. In 2003, it represented only 3.9% of revenues.
- The production of parts for final products is expected to far surpass prototyping applications for 3D-printed parts

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Market Value & Forecast

Global market

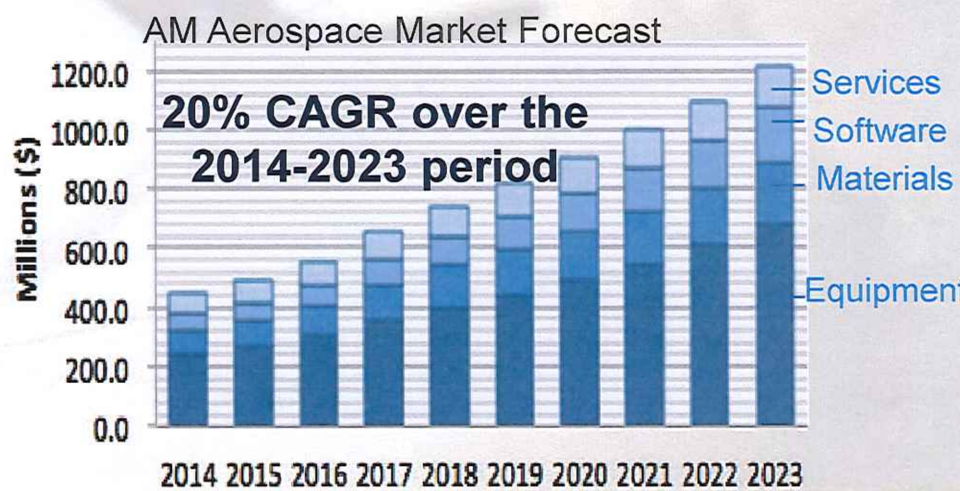
- Global market of AM products and services grew 29% to over $2 billion in 2012
- AM in the manufacturing sector is expected to grow at a CAGR of 13.5% to reach over $3.4 billion by 2017 (conservative estimate)

Sources: Royal Academy of Engineering, Ibisworld, 2013

13.5% CAGR over the 2014-2017 period

Aerospace segment

- The largest AM adopter has been the aerospace industry with the entrance of metal-fed AM machines into the industry in 2011
- Engine, turbine parts and cabin interior components are the most common applications for Additive Manufacturing.
- Aerospace is one of the 3 fastest growing segments for AM



Sources: Smartech Market Publishing, 2014

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Additive Manufacturing and Aerospace Current and Potential Future Applications

	Most Current Applications	Potential Applications
Commercial Aerospace & Defense	• Concept modeling and prototyping • Printing low-volume complex secondary aerospace parts • Printing replacement parts	• Embedding additively manufactured electronics directly on parts • Printing large structures • Printing complex parts, including structural parts
Space	• Printing specialized parts for space exploration • Printing parts with minimum waste	• Printing critical structures using lightweight, high-strength materials • Printing large structures directly in space, thus circumventing launch vehicle's size limitations

Sources: Deloitte Analysis, *3D Printing and the Future of Manufacturing*, 2012

As aerospace companies look to expand AM through the entire production process, they need to be aware of the practical challenges that might undermine the full realization of AM benefits in their industry

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Aerospace Benefits & Practical Challenges

Expected benefits	Practical Challenges
Cost Reduction • No need to create an expensive mold that can represent up to 93% of the part cost. • AM reduces material usage - printer can handle shapes that eliminate unnecessary bulk and create them without the typical waste. • Capacity to simplify and shorten the manufacturing supply chain through radical simplification: sub-assemblies can be printed in either a single or a few parts, thus reducing or eliminating assembly costs. • Fewer parts means fewer component checks and less documentation for an aircraft operator, further saving on costs.	**Hidden Costs** • Often, components emerging from the AM process still require significant finishing work – including annealing, machining and inspecting. Such processes can double the actual cost of making the part. • The financial overhead for running machines and buying raw materials remains significant and volatile.
Reduced lead time • Reduced lead times (80% on average) for both new and replacement parts. • Increased responsiveness can result in lower inventory levels and better support for 'sunset aircraft' where machines made to build their parts have been mothballed.	**Speed** • While low-volume production is faster than conventional manufacturing, high volume production is considerably slower because the entire part needs to be done from scratch every single time (as opposed to using a mold). • Making parts in parallel production (side by side in the machine) is one of the avenues explored to speed up the process.

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Additive Manufacturing and Aerospace Benefits and Practical Challenges

Expected benefits	Practical Challenges
Significant Weight Reduction • Reduce weight of aerospace components by printing more efficient geometries and lattice structures that carve out large amounts of unnecessary material. • Weight reduction savings is commonly around 30% of the component weight. • Some argue that AM could reduce the total weight of an aircraft by 30%	**Materials and Airworthiness** • Limited to certain materials: for example, it is not currently able to supply Aluminum 4043 parts that meet air regulation requirements. • For now, the technology can address a plane's secondary structural components. This precludes the utilization of AM components for heavy primary structural components. • One of the strongest barriers to AM's further use resides in the parts certification process. AIRBUS is working with engineering firm GKN on certification for ALM-produced parts as part of a research partnership.

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Additive Manufacturing and Aerospace
Benefits and Practical Challenges

- The practical challenges identified in the previous table highlight that AM might not be attractive for all aerospace parts. Bearing that in mind, the ultimate challenge is to identify all those aerospace components that can be produced more efficiently and affordably through AM technology compared to traditional manufacturing.
- To increase aerospace applications, AM developers will need to invest in technology development and overcome a number of challenges pertaining to materials, scale, finishing and speed.
- Despite current limitations – particularly with materials and structural integrity – aerospace companies are exploring 3D printing potential for manufacturing a variety of their components.

Who is doing what

GE

- Looking to expand technology capacity in order to produce 85,000 fuel nozzles for its LEAP engines
- Acquired two companies specialized in 3D manufacturing
- Established the Additive Development Center in Cincinnati, OH

✓ **Capacity**

LOCKHEED MARTIN

- Currently using 3D-printed parts for satellite manufacturing
- Plans to print larger parts, including a 7-foot diameter forward bay cover
- Increased investments to develop capacity and technology

✓ **Larger Parts**

BOEING

- Polymer-based air ducts already on board of F/A-18
- Additive manufacturing used to make satellite brackets
- Ongoing R&D: Boeing sees additive manufacturing for metals as a strategic field

✓ **New Materials**

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Additive Manufacturing
About reducing complexity…

From 20 pieces to…one!

GE's forthcoming LEAP engines, built in collaboration with Snecma, will include 19 3D-printed fuel nozzles each. While 20 pieces would need to be made and joined to get this assembly through traditional manufacturing, the company is able to build the nozzle in a single process.

Additive Manufacturing and Aerospace
Examples of Suitable AM Components

GE's fuel nozzles are typical examples of parts where large-scale production through AM is more advantageous than traditional manufacturing. The table below presents a number of other high-value components for which AM has been deemed beneficial after thorough analyses.

Component	Reasons for AM production	Associated Company
Airfoils	Complex, heavily machined parts	RTI Int'l
Rakes	Complex, pressurized line	RTI Int'l; Mercury Centre
Guide Vanes	Complex, heavily machined parts	RTI Int'l
Impellers	Optimized Design	Mercury Centre
Turbine Blades	Lower Potential Scrap Rates	Arcam; GE

Source: Smartech Market Publishing, 2014



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Additive Manufacturing: Key Takeaways

The Demand

- Recent advances in AM offer truly innovative capabilities for aerospace companies; in the right production context, this will allow them to simultaneously lower costs and achieve superior supply-chain and product performance.
- The defense and aerospace industry is one of the fastest growing segments of AM: manufacturers are eying the technology as a way to cut costs and improve efficiency, and multiply investments.

The Issue

- In practice, a vast amount of research, testing and development is still required to take AM from being a cost effective and flexible prototyping tool into being a profitable and validated production process. To date, there are no identified AM initiatives exclusively dedicated to address the specific needs of aerospace:
  - need to develop processes and materials that meet the industry's stringent requirements
  - need to determine which aircraft parts and components that AM has the potential to match standard manufacturing methods in terms of cost, production volume and quality

The Solution

- The opportunity lies to create an integrated cluster dedicated to aerospace applications of additive manufacturing:

Wisconsin Additive Manufacturing Aerospace Consortium // Paradigm

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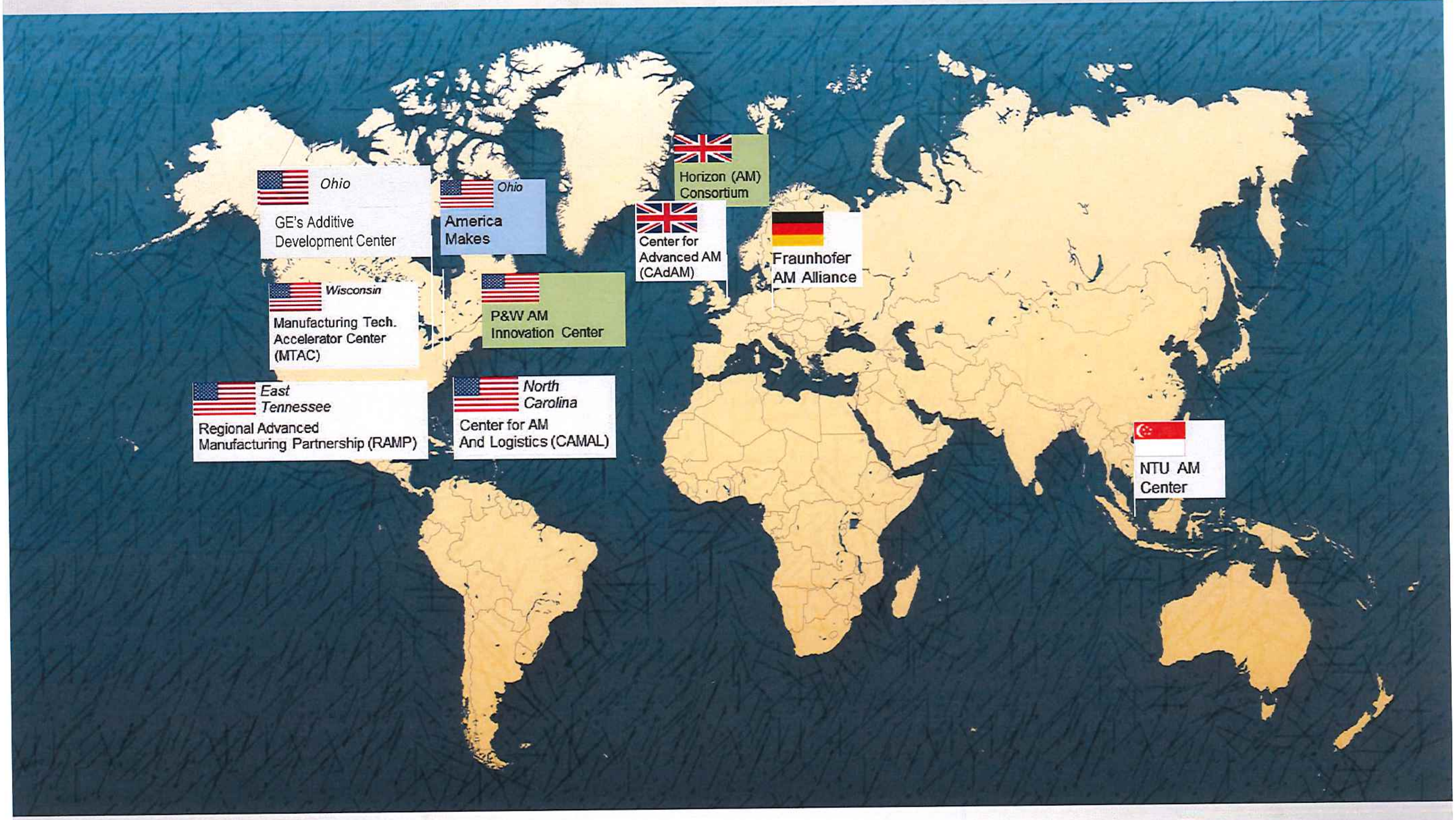
Mapping of the Competition



National initiative | All industries | Aerospace

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Competitive Landscape

U.S. AM Initiatives

- Regional Advanced Manufacturing Partnership (RAMP) – East Tennessee

Oakridge lab initiative. RAMP aims to create a high-performing AM industry cluster in East Tennessee, where manufacturers from disparate disciplines collaborate to:

  - Apply AM to their existing operations
  - Develop a reliable supply chain in the region
  - Develop and retain a properly trained next-gen workforce

- Center for Additive Manufacturing and Logistics (CAMAL) – North Carolina

NC-based initiative serving industry through fundamental and applied research in the additive technologies and an active program of technology transfer.

  - Provides fabrication and prototyping services for both internal NC State projects and for external customers. Polymer and metal based additive technologies are available for use.
  - Research projects include material development and address some aerospace issues like production pace and finishing.

- GE's Additive Development Center – Ohio, 2012

  - Research Center acquired by GE in 2012 – formerly Morris Technologies
  - Mission statement: to lead, explore and advance the industrialization of 3-D printing, by proving out designs, techniques and procedures that, over the next decade, will redefine, reinvent and reimagine manufacturing at GE Aviation, the GE corporation and the industry as a whole.
  - 85 engineers and state-of-the-art equipment. The market focus is broad and includes all GE's segments.

Competitive Landscape

U.S. AM Initiatives

- Manufacturing Technology Accelerator Centers (MTAC)
  - The National Institute of Standards and Technology (NIST) has awarded nearly $2.5 million in funding for five pilot projects designed to act as Manufacturing Technology Accelerator Centers
  - MTACs will bring together teams of experts in specific technology and supply chain areas to offer services and deep expertise in order to improve small U.S. manufacturers' supply chain competitiveness and the rates at which they adopt technology. Additive manufacturing technology will be a key component of most of MTACs projects.
  - The following table presents the five MTACs and their areas of focus:

Awarded Institute(s)	MTAC pilot project	Partners
California Manufacturing Technology Group	Transportation Manufacturing Technology Acceleration Center	• GENEDGE Alliance (Va.) • The Illinois Manufacturing Excellence Center • Corporation for Manufacturing Excellence (Ca.)
Georgia Tech Research Corporation Georgia Manufacturing Extension	Southeast Automotive Manufacturing Technology Acceleration Center	• Alabama Tech. Network • Innovate MEP Mississippi • South Carolina and Tennessee MEP
Oregon Manufacturing Extension Partnership	Food Processors Manufacturing Technology Acceleration Center	• Impact Washington • Idaho TechHelp
University of Texas at Arlington Texas Manufacturing Assistance Center	Defense/Aerospace Supply Chain Manufacturing Tech. Acceleration Center	• Not listed
University of Wisconsin - Stout Manufacturing Outreach Center	Great Lakes Manufacturing Technology Acceleration Center.	• Wisconsin MEP

Case Study - America Makes

National Accelerator for Additive Manufacturing based in Youngstown, OH

Mission :
Accelerate the adoption of additive manufacturing technologies in the U.S. manufacturing sector and increase competitiveness.

How?
By linking and integrating U.S. companies with existing public, private, or not-for-profit industrial and economic development resources, and with business incubators.

America Makes

Public-Private Institute
- **Lead:** National Center for Defense Manufacturing and Machining (NCDMM)
- **Funding:** more than $50 million to support AM projects, working groups and initiatives
- America Makes periodically announces **project calls** and awards funds.

Members
- 50 companies, 28 Universities and Labs, and 16 other organizations
- **Members include:** NASA, Boeing Group, Lockheed Martin, Northrop Grumman, GE Aviation

A key institute in the United States
A potential partner and funding source for Paradigm

Aerospace AM Initiatives

Horizon (AM) Consortium – *United Kingdom, 2014*

- £13.4-million ($22.49 million) government-funded research program to help the aerospace industry maintain its competitive position
- Consortium led by GKM-Aerospace Consortium. Members include Delcam, Renishaw, the University of Warwick
- Goals:
  - *Continue the process of industrializing AM in the aerospace industry*
  - *Improve technology to produce lighter and greener aircraft parts*
  - *Develop integrated solutions to combine additive and subtractive technologies seamlessly*

Aerospace Growth Partnership

P&W Additive Manufacturing Innovation Center – *United States, 2013*

- Collaboration between P&W and Uconn
- $4.5 million state-of-the-art facility to further AM R&D
- 'Most advanced AM laboratories in the nation'
- Goals: *Develop metals, Train engineers and designers on AM.*

UCONN Pratt & Whitney

GE Aviation – Additive Manufacturing Plant (not operational yet)

- GE plans to develop aerospace's first large, dedicated AM facility for jet engine parts in Auburn, AL.
- The site will make complex fuel nozzles for the CFM Leap using a series of 3-D printing machines
- Expect to begin production in 2015

GE Aviation

Competitive Landscape

International AM Initiatives

Fraunhofer AM Alliance, Germany

- Largest interdisciplinary European alliance of competence for high-speed processes enabling AM of products made of metals, plastics, ceramics and other materials.
- The Fraunhofer Additive Manufacturing Alliance encompasses 11 institutes which are based throughout Germany to form the entire additive manufacturing process chain, comprising the development, application and implementation of additive manufacturing methods and processes.
- Goal is to develop new rapid strategies, concepts, technologies and processes to enhance the performance and competitiveness of AM.
- None of the 11 institutes are exclusively dedicated to aerospace, although it is one of IFAM's core focus

Center for Advanced Additive Manufacturing (CAdAM)

- University of Sheffield-led CAdAM conducts world leading research in the field of AM.
- Much of the research spans many departments and disciplines; it is published in high quality journals and is also valued by industry across many sectors including aerospace, medical devices, automotive, consumer products etc.
- *Examples of research include:*
  - Development of new materials for laser sintering and high speed sintering
  - Manufacture of parts for end users including F1 teams using Electron Beam Melting
  - Aerospace Designer Alloys for Selective Laser Melting
- The Center is also home to world class manufacturing and testing facilities
  - 11 AM machines
  - More than $5 million equipment value

NTU Additive Manufacturing Center (Singapore)

Brand new institute aiming to become a national center of excellence for AM. To achieve this goal, the center will:

- *contribute to manpower and talent development and address the growing needs in this area*
- *Provide a one stop shop environment for industry interaction through projects and consultations*

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Portrait of Wisconsin 3D Printing Initiatives & Research

MSOE's Rapid Prototyping Center

- Only university with the five commercially-available rapid prototyping systems
- RPC helps businesses achieve prototype through AM
- Fabricate end use parts in limited production volumes
- 72 members including ABB, Johnson Controls, Oshkosh Corporation, Eaton, Rockwell and Bombardier Recreational Products (marine and ATR products)

➔ No aerospace member;
No aerospace expertise yet but strong AM knowledge;
Potential Partner

Great Lakes Manufacturing Technology Acceleration Center

- Focus on methods, tools, and processes that help manufacturers identify, adapt and adopt advanced manufacturing technologies to their operations
- Focus on small/medium-sized manuf.
- AM is only one of the technologies MTAC will look into

➔ Different goals and targets;
More like a technology transfer program;
Not a direct competitor

No AM aerospace initiative found in the state of WI

	Aerospace driven	Public Advocating	Academic Research	Technology R&D	Technology Transfer	Development & Engineering	Workforce Development
US Initiatives							
P&W Additive Manufacturing Innovation Center	X 100%		X	X	X		X
GE's Additive Development Center - OH	X 30%			X		X	
Defense/Aerospace Supply Chain Manufacturing Tech. Acceleration Center - TX	X 100%				X		
MSOE's Rapid Prototyping Center			X			X	
Regional Advanced Manufacturing Partnership (RAMP) – East Tennesse					X		
America Makes		X	X		X		X
PARADIGM	**X 100%**		**X**	**X**	**X**	**X**	
International Initiatives							
NTU Additive Manufacturing Center (Singapore)			X			X	X
Horizon (AM) Consortium (UK)	X 100%		X	X		X	
Fraunhofer AM alliance (Germany)		X		X			
CAdAM (UK)	X 15%		X			X	

Wisconsin Additive Manufacturing Aerospace Consortium

The Concept

As a growing number of aerospace OEMs and manufacturers explore additive manufacturing to produce complex parts in a simplified single process, and reduce weight and costs, the Wisconsin Additive Manufacturing Aerospace Consortium, branded Paradigm, will provide a unique facility for developing, testing and improving the technology in order to meet the regulations and specific challenges within the industry.

Paradigm will offer a variety of engineering and consulting services. Among the services, the Center will help companies identify which parts and aircraft components are suitable for AM, determine what AM processes will provide the best results and develop designs and test the associated prototypes. The facility will be equipped with state-of-the-art AM machines and will propose contract manufacturing services.

The Positioning

Create a Center of Expertise aiming to brand the region as the premier location for additive manufacturing solutions in aerospace. Create an attractive portfolio of contract-based services for the aerospace industry.

Develop the infrastructure to attract developers and manufacturers to relocate in the incubator/manufacturing park and perform testing and development activities across the dedicated installations. Research and validate new additive manufacturing solutions and fabrication processes.

Tailor-made infrastructure to become the reference in AM for the aerospace market.

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Targeted Market and Clients

General Aviation

Piston, Turboprops and Turbine Aircraft

Clientele: OEMs, Tier 1 and Suppliers:

- OEMs looking to stay at the forefront of AM technology advancements.
- Manufacturers involved in the aerospace supply chain needing advice on how to integrate the technology into their operations.

Military

Clientele: DoD, AF, Marines, Army, Navy, Coast Guard

DoD is constantly looking for lighter and more durable solutions to reduce its dependency on non-renewable energy such as oil. AM technology allows for better and more efficient design and manufacturing processes thus reducing parts volume and weight.

General Aviation

Vintage, Warbird & Experimental Aircraft

Clientele: Private owners, homebuilders and suppliers:

Possibility to supply unique and/or legacy parts that are difficult to source (few suppliers) and just as hard to replicate because tools no longer or do not exist or because the parts do not match engineering drawings .

Commercial Aircraft

Clientele: OEM, Tier 1, Tier 2/3 and suppliers:

As OEMs are insourcing most of the AM work today, their suppliers will need to come up to speed on the technology and processes; in most cases, OEMs will start looking to Tier-1 and Tier-2s to get involved in R&D collaborative programs for in-service or future aircraft.

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Cluster Model

PARADIGM
Board of Directors

Innovation & Technology Committee

Marketing & Comm. Committee

Research Center

Mission: Create a specialized and aerospace dedicated AM research facility and center of expertise (TRL 1-4)

Focus: fundamental and applied research

- Research additive manufacturing processes and technologies applicable to the aerospace sector
- Study new material technology
- Partnership with universities and colleges across the State and nation-wide

Consulting Services

Mission: Assist aerospace companies with their AM requirements and strategies

- Identify the AM application for aerospace parts
- Determine the best material type
- Determine appropriate AM process
- Support the certification process
- Support AM integration and adoption: equipment, training & technical support

Development & Engineering Center

Mission: Develop AM solutions for aerospace

Contract Engineering

- Identify parts suitable for AM conversion and determine potential applications
- Design of 3D parts concept
- Testing of conceptual parts through functional prototyping

Contract Manufacturing

- Low volume production
- Medium volume prod.

Incubator & Technology Park

Mission: Accelerate the growth and maturity of start-up companies active in AM manufacturing

- Rental of space for spin-off and SME companies
- Provide infrastructure and business resources to support tenant's expansion
- Validate the commercial potential of technologies and business models.
- Training, coaching, business development and bidding services.

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The Context – Local Benefits

Key drivers for the community

- The project will differentiate the Fox Valley region from the competition. The unique positioning in additive manufacturing aimed at the development of aerospace applications will strengthen the manufacturing base in the region with the adoption of new manufacturing and engineering technologies as well as diversifying its economy through aerospace.
- **Direct benefits:** The project will bring additional R&D activities to the airport locations and within the region. Development and manufacturing activities will spur growth within the companies that will be established in the incubator and technology park.
- **Indirect benefits:** The project suggests higher-paid personnel, which will support economic growth, real estate construction & value, as well as regional commerce.

Key drivers for the community

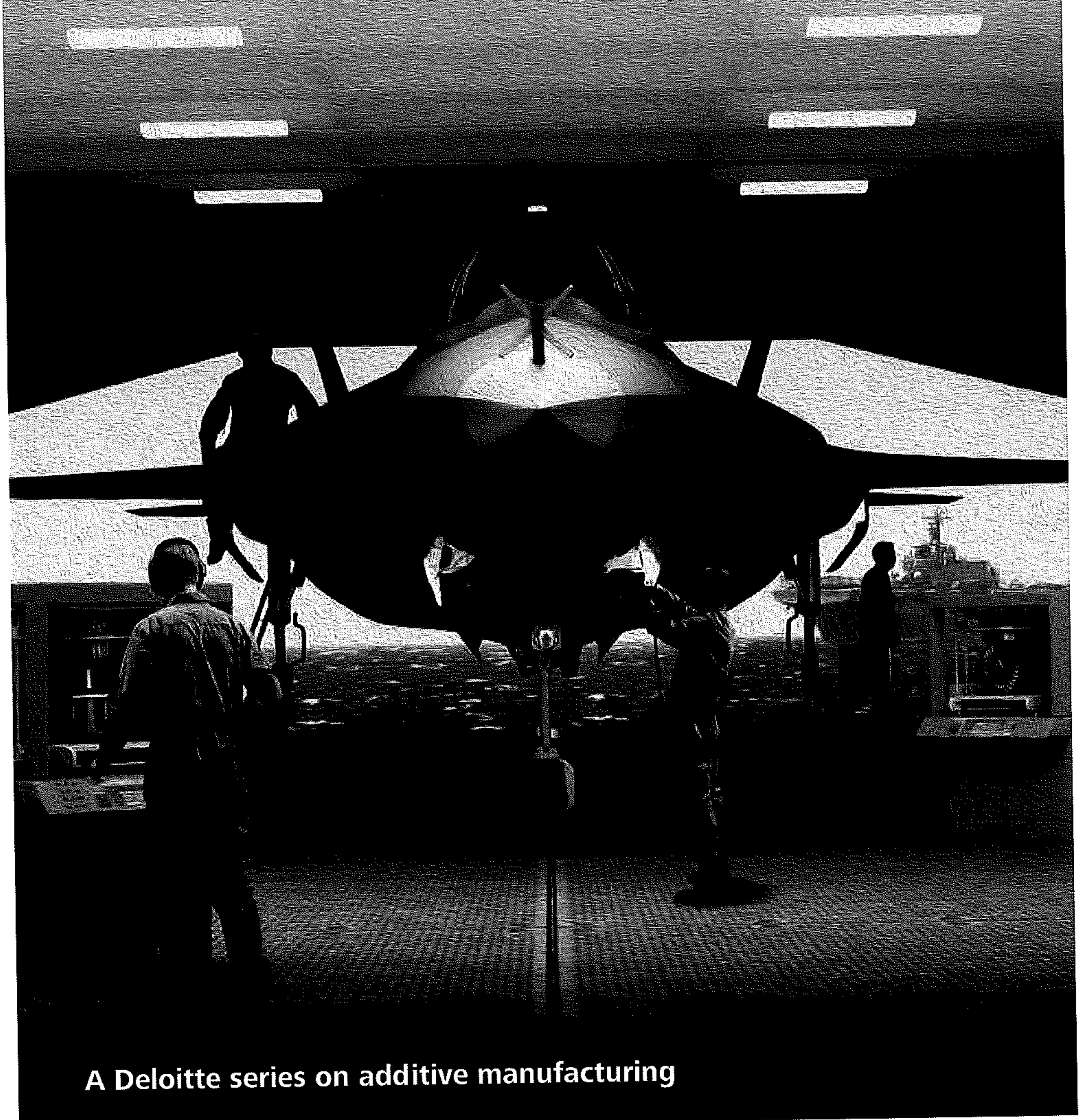
- Wisconsin is home to multiple manufacturing companies that have extensive expertise and potential to embrace a new manufacturing paradigm. AM will help in securing a leading position for WI in manufacturing.
- Initiatives like the Great Lakes Manufacturing Technology Acceleration Center further facilitate the access and adoption of advanced technology in the region.
- Milwaukee School of Engineering has a well-established additive manufacturing program and its capabilities are compatible with our project (including the state-of-the-art equipment of the Rapid Prototyping Center)

Exhibit D

3D opportunity in aerospace and defense

Additive manufacturing takes flight

Deloitte University Press



A Deloitte series on additive manufacturing

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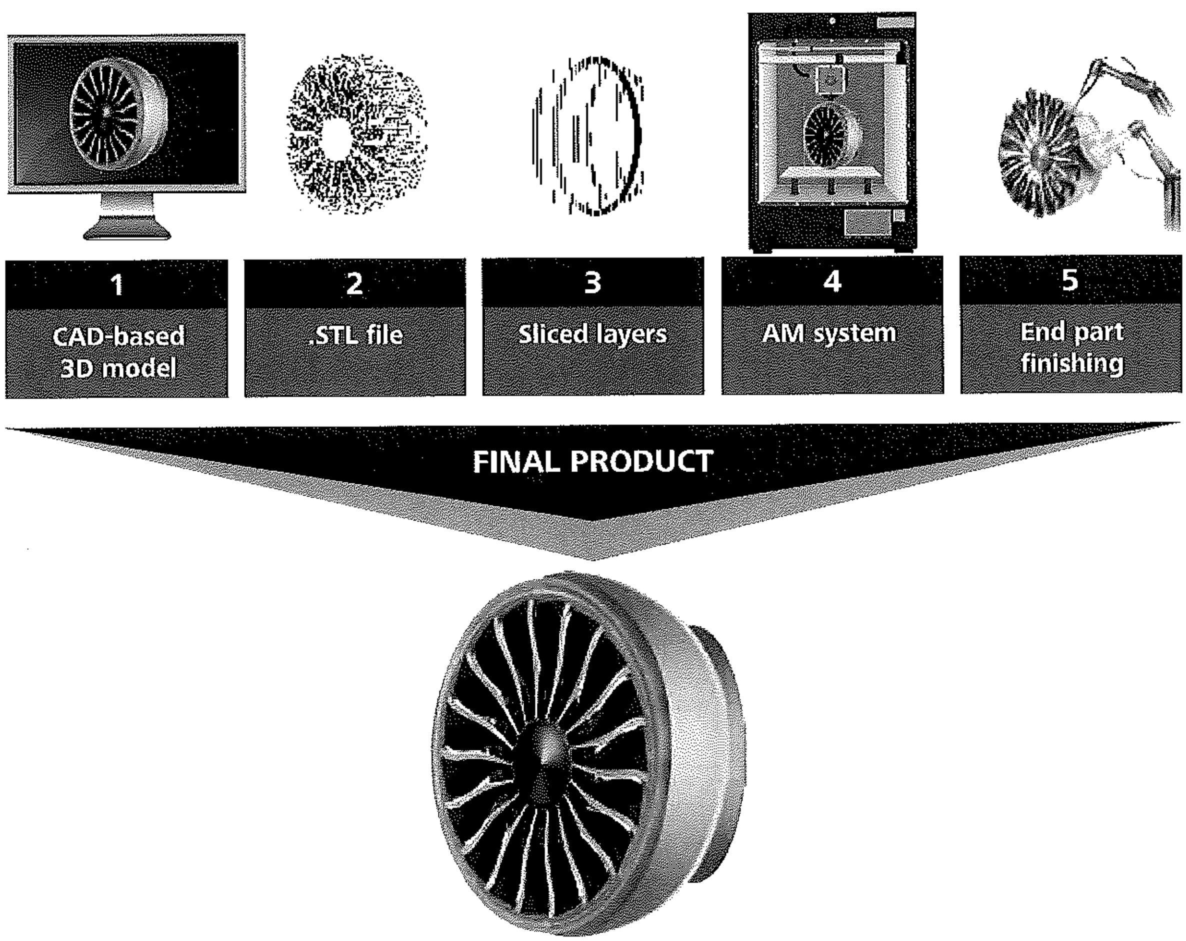
Contents

Introduction

ADDITIVE manufacturing (AM), popularly known as 3D printing, is a manufacturing technique that builds objects layer by layer using materials such as polymers, metals, and composites. Figure 1 depicts the overall AM process.[1] In the early stages of the 30 years of AM's deployment, the technology was largely geared toward prototyping and tooling applications; however, in recent years, AM has found success in end-part production, driven by improved manufacturability and reduced lead time compared to traditional manufacturing methods.

The aerospace and defense (A&D) industry was an early adopter of AM technology. The history of AM traces back to 1983 with some A&D companies beginning experimentation with the technology as early as 1988.[2] Over the years, AM's adoption has increased across industries, with the A&D industry contributing about 10.2 percent of AM's $2.2 billion global revenues in 2012.[3] Several reasons

Figure 1. Additive manufacturing (AM) process flow



Graphic: Deloitte University Press | DUPress.com

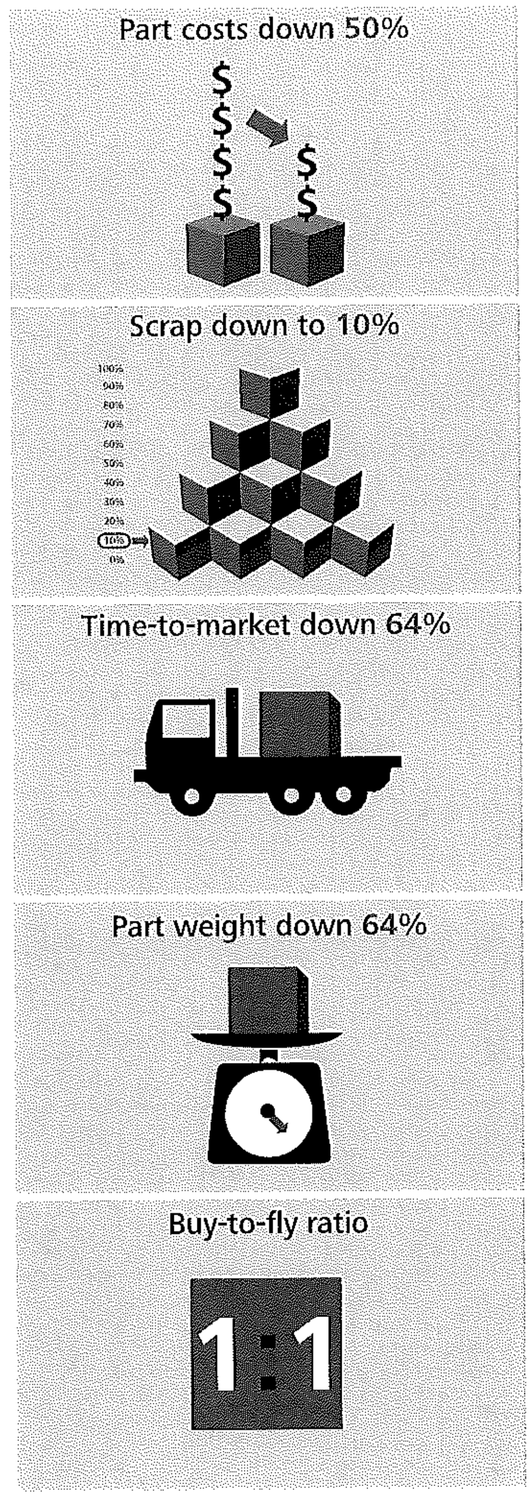
underlie AM's relatively widespread adoption in A&D. AM provides the flexibility to create complex part geometries that are difficult to build using traditional manufacturing. It can build parts with designs such as internal cavities and lattice structures that help reduce parts' weight without compromising their mechanical performance. Furthermore, AM machines produce less scrap than traditional machines, a critical attribute when using expensive aerospace materials such as titanium. Finally, AM's impact on economies of scale and scope make it a natural fit for A&D, which, in contrast to other mass production industries, is largely geared toward customized production. Figure 2 presents some of the performance enhancement benefits delivered by AM in various A&D applications.

AM's current applications in the A&D industry range from manufacturing simple objects such as armrests to complex parts such as engine components. Applications such as printing aircraft wings and parts in microgravity are foreseeable in the future.[4] Figure 3 shows the current and potential applications of AM in the A&D industry; this list is not exhaustive, as AM technologies and their applications are constantly evolving.

Currently, A&D companies are at different stages in adopting AM, and there is some debate about how real AM's impact on traditional processes will be. On the one hand, A&D executives who are skeptical of AM's potential may miss the opportunities the technology can offer. On the other hand, companies keen on benefiting from AM adoption may make hasty moves that do not align with their strategic imperatives.

The article *3D opportunity: Additive manufacturing paths to performance, innovation, and growth* provides Deloitte's perspective on the impact of AM, as illustrated in figure 4.[5] Using the framework as the basis, we reviewed relevant academic literature and case studies and interviewed AM experts to identify current and future trends that are expected to shape the application of AM in the A&D industry.

Figure 2. Examples of the benefits of producing different A&D parts



Graphic: Deloitte University Press | DUPress.com

Figure 3. AM applications in the A&D industry

	Current applications	Potential applications
Commercial aerospace and defense	• Concept modeling and prototyping • Printing low-volume complex aerospace parts • Printing replacements parts	• Embedding additively manufactured electronics directly on parts • Printing aircraft wings • Printing complex engine parts • Printing repair parts on the battlefield
Space	• Printing specialized parts for space exploration • Printing structures using lightweight, high-strength materials • Printing parts with minimal waste	• Printing on-demand parts/spares in space • Printing large structures directly in space, thus circumventing launch vehicles' size limitations

Sources: Deloitte analysis; CSC, *3D printing and the future of manufacturing*, 2012.
Graphic: Deloitte University Press | DUPress.com

As the AM technology evolves, its applications are bound to change; however, the larger dynamics that we have identified related to products and supply chains will not. This report will help readers appreciate how AM can aid their companies in achieving performance, growth, and innovation goals and help leaders choose the paths that best suit their organizations' value drivers.

AM paths to A&D companies' strategic imperatives and value drivers

AM is an important technology innovation whose roots go back nearly three decades. Its importance is derived from its ability to break existing performance trade-offs in two fundamental ways. First, AM reduces the capital required to achieve economies of scale. Second, it increases flexibility and reduces the capital required to achieve scope.

Capital versus scale: Considerations of minimum efficient scale shape the supply chain. AM has the potential to reduce the capital required to reach minimum efficient scale for production, thus lowering the barriers to entry into manufacturing for a given location.

Capital versus scope: Economies of scope influence how and what products can be made. The flexibility of AM facilitates an increase in the variety of products a unit of capital can produce, reducing the costs associated with production changeovers and customization and/or the overall amount of capital required.

Changing the capital versus scale relationship has the potential to impact how supply chains are configured, while changing the capital versus scope relationship has the potential to impact product designs. These impacts present companies with choices on how to deploy AM across their businesses.

The four tactical paths that companies can take are outlined in the framework below:

Path I: Companies do not seek radical alterations in either supply chains or products, but may explore AM technologies to improve value delivery for current products within existing supply chains.

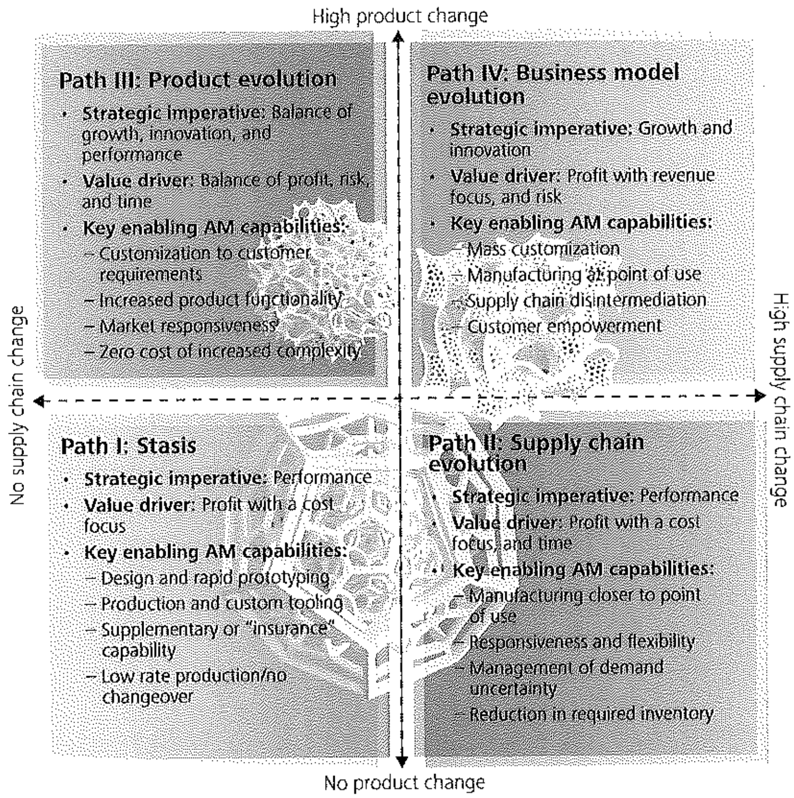
Path II: Companies take advantage of scale economics offered by AM as a potential enabler of supply chain transformation for the products they offer.

Path III: Companies take advantage of the scope economics offered by AM technologies to achieve new levels of performance or innovation in the products they offer.

Path IV: Companies alter both supply chains and products in the pursuit of new business models.

AM is an important technology innovation whose roots go back nearly three decades.

Figure 4. Framework for understanding AM paths and value[6]



Source: Mark Cotteleer and Jim Joyce, "3D opportunity: Additive manufacturing paths to performance, innovation, and growth," *Deloitte Review* 14, January 2014.

Graphic: Deloitte University Press | DUPress.com

Traditionally, A&D companies have deployed AM to create value through path 1—leveraging AM primarily for concept modeling, prototyping, tooling, and production of select end parts. Companies on this path are at different stages of AM adoption. While a few are using AM only for prototyping, others are using AM for short-run production.

In the medium term, with advances in AM technology and materials, A&D companies are likely to move from path I to path III in order to develop complex products with improved functionality, even new products altogether, without any major changes in their existing supply chain structures. A few leading A&D companies are already pursuing path III, and we expect increased momentum in the medium term.

Companies might also benefit in the area of maintenance, repair, and overhaul through the possibilities for cost-effective distributed production enabled by AM. Demand-driven production of spares through AM could be relevant for low-volume, complex parts; spares for out-of-production legacy aircraft; or spares required at remote locations.

In the long term, A&D companies are likely to deploy path IV—that is, they could pursue product customization along with on-demand AM that will likely lead to supply chain disintermediation and the evolution of new business models.

Detailed analysis on each of the AM paths is presented later in the report. When analyzing each of these paths, it is worthwhile to evaluate how different AM attributes may lead to changes in A&D companies' products and supply chain structures. Figure 5 lists some common attributes of AM that distinguish it from traditional manufacturing and the effect of each of these attributes on companies' existing product offerings and supply chains. Although not obvious, some product-related attributes have a bearing on a company's supply chains, and vice versa. For example, "manufacturing of complex-design products" appears to be a closely product-aligned attribute, but it also has supply chain implications: Companies that are designing complex parts need to ensure the fit of that complex part with other components sourced from suppliers. In a similar fashion, companies need to consider the impact of each AM attribute on their products and supply chain structures.[7]

Path I: Stasis—The path currently pursued by most A&D companies

COMPANIES ON PATH I DO NOT SEEK RADICAL ALTERATIONS IN EITHER SUPPLY CHAINS OR PRODUCTS, BUT MAY EXPLORE AM TECHNOLOGIES TO IMPROVE VALUE DELIVERY FOR CURRENT PRODUCTS WITHIN EXISTING SUPPLY CHAINS.

Most A&D companies have been following a conservative strategy by adopting path I, "stasis," to leverage AM for modeling, prototyping, tooling, and short-run production without making any substantial changes to their supply chains and products.

Reduced time to market: AM helps companies quickly build prototypes with the required fit, form, and functionality, thereby accelerating design cycles, reducing time to market, and giving organizations a competitive advantage.[9] Research has shown that when A&D companies switch from traditional manufacturing to AM, they could benefit from time savings in prototyping ranging from 43 percent to 75 percent, depending on the conventional techniques used.[10] For example, when the Defense Advanced Research Projects Agency (DARPA) asked for proposals to improve the design of vertical takeoff and landing (VTOL) aircraft in 2013, Boeing additively manufactured a prototype, whose construction would have otherwise taken several months, in less than 30 days.[11]

Complex-design tools: AM's ability to create free-form designs helps in building tooling fixtures that are difficult or impossible to produce with traditional machining techniques. For example, traditional machining can create cooling channels only in straight lines, thus making it difficult to optimize fluid flow in corners. AM can create cooling channels that conform to the curvature of a part, a feature that is especially important for engine parts.[12]

Flexibility of design iterations: AM offers the flexibility to design and test products as many times as required, helping A&D companies reduce risks and uncertainties and improve product functionality at lower costs. With changes in software design files, companies can undertake multiple design iterations without expensive retooling. For example, NASA used 70 additively manufactured parts (such as flame-retardant vents, camera mounts, and housings) for the Mars Rover test vehicles.[13]

Tooling at lower costs: AM not only enables companies to quickly design and test products, but also helps bring down the cost of manufacturing tooling and fixtures.[14] A case in point is offered by the repair company

Figure 5. Impact of AM attributes on A&D companies' product offerings and supply chain structures[8]

AM attributes compared to traditional manufacturing	Impact on product offerings	Impact on supply chains
Manufacturing of complex-design products	●	◕
New products that break existing design and manufacturing limitations	●	◕
Customization to customer requirements	●	◕
Ease and flexibility of design iteration	◕	◑
Parts simplification/sub-parts reduction	◑	◑
Reduced time to market	◑	◑
Waste minimization	◑	◑
Weight reduction	◑	◔
Production near/at point of use	◑	●
On-demand manufacturing	◔	●

Potential impact	Very high	High	Medium	Low
	●	◕	◑	◔

Source: Deloitte analysis.

Graphic: Deloitte University Press | DUPress.com

Advanced Composite Structures (ACS). ACS produces the majority of its tools using AM, leading to overall cost savings of 79 percent and lead time reduction of 96 percent compared with traditional tooling.[15] Tooling using AM is particularly relevant for short-volume applications in the A&D industry, as described below by Bruce Anning, a director at ACS:

> For the repairs and short-volume production work that we specialize in, tooling often constitutes a major portion of the overall cost. Moving from traditional methods to producing composite tooling with fused deposition modeling has helped us substantially improve our competitive position.[16]

Overall, path I, a starting point for AM adoption, leads to improved performance by reducing design and development costs and accelerating the speed at which cash flow can be realized without requiring significant changes in companies' products and supply chain structures.

Path II: Supply chain evolution—Limited AM impact expected in the medium term

ON PATH II, COMPANIES TAKE ADVANTAGE OF SCALE ECONOMICS OFFERED BY AM AS A POTENTIAL ENABLER OF SUPPLY CHAIN TRANSFORMATION FOR THE PRODUCTS THEY OFFER.

The A&D industry structure involves the manufacture and assembly of complex systems and sub-systems at select locations; the storage of parts in centralized warehouses; and maintenance, repair, and overhaul by skilled labor at relatively few locations. Boeing and Airbus aircraft typically consist of some 4 million parts sourced from across the globe. To avoid having an aircraft grounded, airlines commonly maintain an inventory of spares, some of which remain unused, and sometimes become obsolete with new aircraft designs. AM addresses the issue of warehousing and inventory obsolescence costs by enabling on-demand manufacturing where required. In line with Pareto's 20/80 rule, AM can co-exist with conventional manufacturing to make A&D companies' inventories leaner and save warehouse space.[17]

In the medium term, as AM machines become less expensive, aircraft maintenance, repair, and overhaul processes could benefit from cost-effective distributed production. Demand-driven production of spares through AM is relevant for low-volume, complex parts; spares for out-of-production legacy aircraft; or spares required at remote locations.

BAE Systems offers an example of AM's use in manufacturing spare parts. Earlier this year, the company received approval from the European Aviation Safety Agency (EASA) for its additively manufactured window breather pipes used in regional jetliners.[18] These additively manufactured pipes cost 40 percent less than pipes made through injection molding and are manufactured and shipped to customers on an as-required basis.[19]

In addition to manufacturing spare parts using AM, the technology is also helpful for manufacturing parts that are difficult to repair using traditional processes. Laser metal deposition (LMD) is an AM technology in which metal powder is melted using a laser beam to form a metallurgical bond to repair parts. LMD systems can be installed at locations where repairs of high-value aerospace parts are expected. Rolls Royce offers a case in point: The company has installed LMD machines for the repair of complex engine components at its facilities in Germany.[20] Starting this year, Lufthansa Technik also plans to repair high-pressure compressor blades in aircraft engines using AM. Dr. Stefan Czerner, consulting engineer at Lufthansa Technik, says, "Working with material which in some cases is just 0.2 millimeters thick is beyond even our best manual welders. We need high-precision positioning—accurate to a hundredth of a millimeter—and precisely metered energy input. The only way to do that is with a laser."[21]

Path III: Product evolution—AM raising the bar for product performance in the medium term

Currently, a few leading companies are looking for ways to integrate AM into their

ON PATH III, COMPANIES TAKE ADVANTAGE OF THE SCOPE ECONOMICS OFFERED BY AM TECHNOLOGIES TO ACHIEVE NEW LEVELS OF PERFORMANCE OR INNOVATION IN THE PRODUCTS THEY OFFER.

mainstream applications to produce end parts with the required fit, form, and functionality. AM applications in the A&D industry range from manufacturing engine components to food trays. According to one AM expert we interviewed, "Simple areas where I see growth in AM are seat belts, food trays, arm rests . . . All these things are getting additively manufactured. One of the interesting things you will notice is that companies are looking at bionic structures for parts such as arm rests. Additively manufactured bionic parts help improve the strength and aesthetic appeal of the parts while lowering their weight."

In the medium term, with improvements in AM technologies and materials sciences, an increasing number of companies are likely to adopt path III and leverage AM to improve product performance without making significant changes to their supply chains.

Complex-design parts: AM enables product designs and dimensions that are hard to create through traditional manufacturing, thus transcending existing design and manufacturing limitations.[22] In traditional manufacturing, some designs that are optimized for topology are not feasible to manufacture due to their complex shape and design. However, with AM, parts can be designed not to accommodate manufacturing capabilities but to deliver maximum performance.[23] GE Aviation is using AM to create fan blade edges with complex shapes to optimize airflow; it is difficult and time-consuming to machine such blades through traditional manufacturing. By 2016, the company plans to manufacture these blade edges in large production runs using AM.[24]

Intricate geometries: Parts with designs such as internal cavities and lattice structures can be fabricated using AM. The AM process, while maintaining the parts' strength by providing support only where required, can keep the parts' weight low. For example, while producing Airbus A320 nacelle hinge brackets, EADS used direct metal laser sintering (DMLS) to build an optimized design that brought down the part's weight by 64 percent while maintaining its strength and performance.[25] The cumulative weight reduction enabled by additively manufacturing such parts can have a significant impact on the industry. Literature suggests that removing one pound of weight from each aircraft of a 600+ fleet of commercial aircraft could save about 11,000 gallons of fuel annually, cutting down on fuel bills—which, as of 2013, typically absorbed 35 percent of an airline's annual revenues.[26]

Waste reduction: Aerospace parts are built using expensive materials such as titanium, and it takes cost and effort to recycle scrap produced during machining.[27] Conventional machining can entail a scrap rate as high as 80–90 percent of the original billet; AM can bring the scrap rate down to 10–20 percent, given the basic distinction between subtractive and additive methods of manufacturing. Research shows that the buy-to-fly ratio of Lockheed Martin's bleed air leak detector (BALD) brackets used in engines can be reduced from 33:1 to 1:1 by using electron beam melting (EBM).[28] In terms of cost comparison, even though the titanium alloy (Ti-6Al-4V) used in the AM process costs more than the wrought Ti-6Al-4V used in the traditional process, 50 percent of the cost of a bracket can still be eliminated without compromising its mechanical properties.[29]

Part simplification: AM's ability to manufacture multiple A&D parts as a single component, thereby reducing assembly effort, is another product-enhancement attribute. Typically, it is easier to modify a single-component product than a system built out of multiple components; hence, uncertainty in demand becomes more manageable. A classic example is GE's additively manufactured fuel nozzles, which are additively manufactured as a single part; they formerly involved the assembly of 20 different parts.[30] These nozzles, used in GE's LEAP engines, are reported to be five times more durable than those produced using conventional methods.[31]

Improved functionality with embedded electronics: Ongoing advances in additively manufactured electronics embedded in parts offer product innovation opportunities. The field of embedded electronics, particularly for unmanned aerial vehicle (UAV) applications, is gaining momentum. Says David Kordonowy, aerostructures research group lead at Aurora Flight Sciences:

> "The ability to fabricate functional electronics into complex-shaped structures using additive manufacturing can allow UAVs to be built more quickly with more customization, potentially closer to the field where they're needed. All these benefits can lead to efficient, cost-effective fielded vehicles."[32]

The marriage of embedded electronics and AM is still nascent, and it currently appears relevant in the context of simple electronics. Its applicability to harsh defense environments is foreseeable only in the long term.

Ease of product customization: As discussed earlier, the scope economies enabled by AM can allow companies to customize products to customer requirements in much lower volumes than possible with traditional manufacturing. Companies that seek to develop customized versions of existing products, or develop new products altogether, need not change their production machinery. Savings in changeover time and effort enable companies to get products to their customers faster, improving their market responsiveness. One AM expert gave the following example:

> "A supplier of storage cabins moved completely from plastic molding to AM to print storage cabins and handles for the first-class cabins of a large commercial aircraft. First class is situated close to the nose of the aircraft, which is pointed, and each part has to be customized to fit in the "arch" design, thus making these parts a right fit for AM. Conversely, economy cabins are situated in a straight body, so parts are repeatable."

Overall, improved product functionality as well as the development of new products using AM will offer opportunities for product innovation as well as revenue growth in existing and new market segments. Progress down path III can improve companies' market responsiveness, thus enhancing their performance and prospects for growth.

Path IV: Combined supply chain and product evolution—AM's long-term role in business model changes

ON PATH IV, COMPANIES ALTER BOTH SUPPLY CHAINS AND PRODUCTS IN PURSUIT OF NEW BUSINESS MODELS.

In the last 30 years, AM applications have expanded from rapid prototyping to rapid tooling to end-part production as well as to the production of replacement parts. Path IV, "business model evolution," foreseeable in the long term, is the most significant path in terms of its impact on A&D companies' products and supply chain structures.

Collaboration with suppliers to create new products using AM: Currently, companies are using AM to improve the functionality of existing products or to build customized products. Going forward, this will continue. Additionally, in the long run, as AM technology improves, companies will likely take a step forward and leverage AM for designing new products altogether that are difficult to design and manufacture through conventional techniques. A&D companies are likely to collaborate with their suppliers and AM providers to build improved or new products using AM. The need to choose suppliers based on their AM expertise is likely to impact A&D companies' legacy supply chains. Some companies have already taken steps in this direction. Lockheed Martin is working with Sciaky to develop structural components for the F-35 aircraft.[33] An F-35 flaperon spar made through EBM can save about $100 million compared to the cost of a spar made through traditional manufacturing over the 30 years of an aircraft's lifetime.[34] Savings will naturally multiply as more parts are fabricated using AM.

Acquisition of niche AM providers to build in-house AM capabilities: On path IV, A&D companies may also choose to acquire select AM players to improve their in-house AM capabilities for critical applications, thus leading to some degree of supply chain disintermediation. For example, in early 2013, GE Aviation acquired Morris Technologies and Rapid Quality Manufacturing (RQM); both companies had earlier supplied additively manufactured parts to GE.[35] GE Aviation also plans to triple its AM staff over the next five years from a headcount of 70 in 2013.[36]

With an increasing emphasis on AM's adoption through organic and inorganic means, AM and traditional manufacturing can serve as complementary technologies to further companies' long-term strategic imperatives. Lockheed Martin's recent initiative to introduce a digitally integrated design and manufacturing process for its space applications is a good example. As highlighted by Dennis Little, vice president of production at Lockheed Martin, there are no hitches when the product advances from a 3D CAD model to the shop floor as traditional fabrication is replaced with an automated process:

> "Our digital tapestry of production brings digital design to every stage of the production process for a fluid product development cycle. From 3D virtual path-finding simulations to 3D printing, we are using innovative digital technology to streamline the manufacturing process for lower cycle times and reduced costs for our customers."[37]

Significant changes in products through the use of AM will create opportunities for innovation and revenue for A&D companies.

Production at or near the point of use: As AM has the potential to reduce the capital required to reach the minimum efficient scale for production, companies can set up newer facilities at or near customer locations. Currently, we see only limited examples of on-site manufacturing, but on-site manufacturing is likely to expand to wider commercial and defense applications in the long term. The US Army's Rapid Equipping Force is deploying mobile AM labs in Afghanistan to manufacture quick replacements for products on the battlefield.[38] Similarly, NASA is working to install an AM device at the International Space Station.[39] Printing on-demand parts in a micro-gravity environment is well within the realm of the possible.[40]

Significant changes in products through the use of AM will create opportunities for innovation and revenue for A&D companies. As AM's adoption increases, fueled by economies of scope, companies may choose to manufacture critical components in-house. For other applications, they are likely to work with a limited number of suppliers that have experience and expertise in AM deployments. These changes are likely to lead to some degree of supply chain disintermediation, as well as changes to how suppliers are chosen. Overall, the changes that path IV will drive in companies' products and legacy supply chain structures will cause their business models to evolve in ways that bring the value embedded in paths II and III.

What's holding back A&D executives?

IN December 2013, we interviewed several experts in the field of AM to get their views on the implications of the technology for the A&D industry. We took them through a structured interview process and cross-compared their responses. Although we cannot claim a comprehensive review of all opinions that might exist, we are confident that we obtained a representative sample of qualified reviews of the AM industry.

Our literature review and discussions with AM providers and experts highlighted that only a few leading A&D companies are proactively ramping up their existing manufacturing capabilities to be able to leverage AM for mainstream applications as AM systems improve in functionality and materials science matures.

Only a few leading A&D companies are proactively ramping up their existing manufacturing capabilities to be able to leverage AM.

Other executives are conservative and apprehensive about the stress that AM could bring to their operations. They are looking for successful case studies before committing capital to AM setups. It is here that the role of service bureaus becomes critical, as A&D companies can use them to access the AM technology without the need for huge capital investments and technical know-how. The following are some common reservations expressed by A&D executives.

How real is AM? Is it just another new technology or are there any long-term implications?

Currently, the benefits of AM for A&D applications have been demonstrated through research studies conducted by select A&D companies and AM providers under controlled conditions. However, the approach used to conduct these studies is not always available in the public domain, making it difficult for executives with limited practical exposure to AM to judge the studies' validity. One AM expert we spoke with said, "Of course, some of the leading aerospace companies have done extensive research, and they have all the data about the heating and cooling rates and how the structure is formed, etc.—but it is kept in-house and is not in the public domain." AM providers need to sensitize and convince A&D customers that AM performs, not just in research labs, but on the shop floor as well.

We own and understand existing manufacturing processes, but we are not so sure about AM.

As with any new technology, A&D executives have varying risk appetites when it comes to embracing AM. A&D experts have decades of experience and expertise in metals, plastics, and composites, as well as in their use in conventional machining. But their understanding of AM continues to be limited, because even though the technology has been around for 30 years, activity has accelerated only in recent years. One AM expert we interviewed said, "A lot of senior executives I speak to are not very comfortable with AM. With their collective experience in conventional machining that runs into the hundreds of years, they are comfortable with the knowledge they have about how metals behave, the properties of the materials, what can be done, what cannot be done. Suddenly a new technology comes along, and they are very apprehensive, as there is limited understanding of the grain structure and how the parts will be formed in AM."

We are a diversified manufacturer. Can AM help across the board?

A&D executives are keen to understand the extent to which AM systems can be deployed for varied applications in their organizations. We believe AM is especially relevant for diversified companies, as they can use AM systems for applications across business segments. AM can produce a "sword and a plowshare" sequentially without any change in the production machinery, thus demonstrating the technology's versatility to produce different products with reduced changeover time and effort.[41] GE, for instance, uses AM for applications across segments such as aviation and health care. Christine Furstoss, global technical director of manufacturing and materials technologies at GE, said:

> "We are committed to driving [AM] in as many areas as we can…We will always work with our strategic partners to do what's right for our collective companies."[42]

We make specialized equipment; we can't take chances with reliability.

Amid stringent regulations for commercial and defense manufacturing processes, consistency of quality is something on which A&D executives cannot compromise. As one AM expert described A&D executives' concerns about repeatability in AM applications, "A&D executives are particularly skeptical about replication accuracy, which is yet to be brought down to about the 2 micron level." An AM parts manufacturer that supplies parts to A&D customers described the gap between what the A&D industry requires and what AM systems typically deliver: "The accuracy that you can get through most metal AM machines is about 30–40 microns, while aerospace companies' tolerance limit is less than 10 microns; so currently we have the additional task of machining [the excess] away." AM providers need to improve existing systems to be able to consistently deliver high-quality parts; only then will AM likely reach its full potential in the A&D industry.

Increasing AM adoption: Challenges and potential solutions

AM'S ability to manage small volumes, create complex designs, and fabricate lightweight but strong structures makes it a natural fit for the A&D industry, which is not a mass-production industry in the typical sense of the term. In its current state, the technology faces some challenges associated with size and scalability, high material costs, narrow range of materials, limited multi-material printing capabilities, and consistency of quality. Continuing advances in AM technology and materials science are likely to address these limitations and are expected to drive wider adoption of AM in the A&D industry.

Continuing advances in AM technology and materials science are likely to address these limitations and are expected to drive wider adoption of AM in the A&D industry.

Size limitations: AM underperforms traditional manufacturing when it comes to the production of large A&D components.[43] AM providers are focusing their R&D efforts on addressing the size limitations of existing AM systems. Lockheed Martin is working with Oak Ridge National Laboratory (ORNL) on a big-area additive manufacturing (BAAM) system in which multiple deposition heads work in coordination to build large parts in an open environment, unconstrained by the typical envelope size.[44] BAE Systems developed a 1.2-meter titanium wingspar in collaboration with Cranfield University in December 2013.[45]

Scalability limitations: A&D companies that use traditional manufacturing and sourcing methods face the challenge of stocking large inventories, a majority of which may be unused. On the other hand, AM systems may not be able to scale up production when required. AM providers are working to improve the build speed of existing AM systems to support the industry's bulk-production needs.[46] As one AM expert suggested, AM systems where different parts can be produced concurrently or where production and unloading can happen simultaneously will help improve AM's scalability.

Narrow range of materials and high material cost: AM predominantly uses a narrow range of polymers and metal powder to manufacture A&D parts, and the costs of these materials are much higher than that of the materials used in traditional manufacturing methods. In 2013, AM thermoplastics cost about $200 per kilogram, while those used in injection molding cost only $2.[47] Similarly, the stainless steel used in AM costs about $8 per square centimeter, which is more than 100 times the commercial-grade stainless steel used in traditional manufacturing methods.[48]

Over the next few years, advances in materials science are likely to expand the choice of AM materials and bring their cost down. One of the AM experts we interviewed said:

> "Traditionally, hardware capabilities have driven materials science developments. But we are going through a change now where material developments will start to lead hardware developments ... In the intermediate to long term, it should not be surprising to see AM companies getting into materials science in a pervasive symbiotic relationship—the marriage of technical science with materials science."

Limited multimaterial printing capability: AM systems that can print with multiple materials at a time offer huge design flexibility. Currently, only a few such systems are available.[49] Advances in multimaterial printing capabilities will help designers make a part using different materials with varying properties. For example, one section of an aerospace part can be built from a material with flame-retardant properties, while other sections can be made of an extremely lightweight material.[50]

Quality consistency: Quality consistency issues, especially in producing fully dense metal parts, result from excess heat that leads to stress and voids, particularly on layer boundaries. Repeatability can be improved by embedding controls within the machines so that in-situ dimensional accuracy is ensured, as well as by subsequently conducting automated inspections. According to one expert we interviewed: "Currently, the strength in the plane of layers is not uniform. Those are issues to be dealt with. In principle, you can deal with those quite well because you have access to each layer and the entire geometry. You can see every layer being laid down. I see these [issues] as temporary hiccups to getting good-quality parts, because you can, in principle, do a 100 percent computerized inspection in a completely automated process."

The way forward

AM'S capabilities speak to the core of the A&D industry's objectives and concerns. The technology enables design complexities that are hard to match with traditional manufacturing techniques. At the same time, AM helps reduce parts' weight, leading to improved fuel efficiency. The technology can also manufacture complex parts as single-component systems. And as discussed earlier, AM reduces the capital required to achieve economies of scale and scope, helping companies to enhance products and supply chains.

With these inherent attributes, AM is a natural fit for many A&D applications. It is not surprising that the technology has been increasingly adopted in the last three decades, starting from prototyping to end-part production in recent years. Figure 6 summarizes ways that AM can help A&D companies improve their production processes.

Figure 6. Where can AM help?

- Manufacturing parts with complex designs
- Manufacturing components that require extensive machining
- Reducing parts' weight
- Reducing complex assembly efforts
- Speeding time to market

Figure 7. AM considerations/impact on companies' business functions

R&D/product development	• Choose components that favor AM over traditional manufacturing • Crowdsource ideas to break existing product design and manufacturing limitations
Supply chain	• Balance in-house manufacturing and outsourcing • Choose suppliers based on their AM capabilities • Explore co-production opportunities with suppliers and customers
Legal	• Be aware of IP issues • Understand regional and country regulations
Human resources	• Anticipate lower headcount needs • Look for talent with requisite skills in areas such as design and material sciences
Finance	• Make fixed and variable cost comparisons between AM and traditional manufacturing
IT	• Evaluate/reconfigure CAD/CAM systems • Integrate IT systems with R&D and manufacturing platforms

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There is little doubt that AM's penetration into the A&D value chain will grow. A&D companies should carefully assess how AM can help advance their performance, growth, and innovation goals. Companies' choice of AM paths will depend on their choice of strategic imperatives and value drivers.

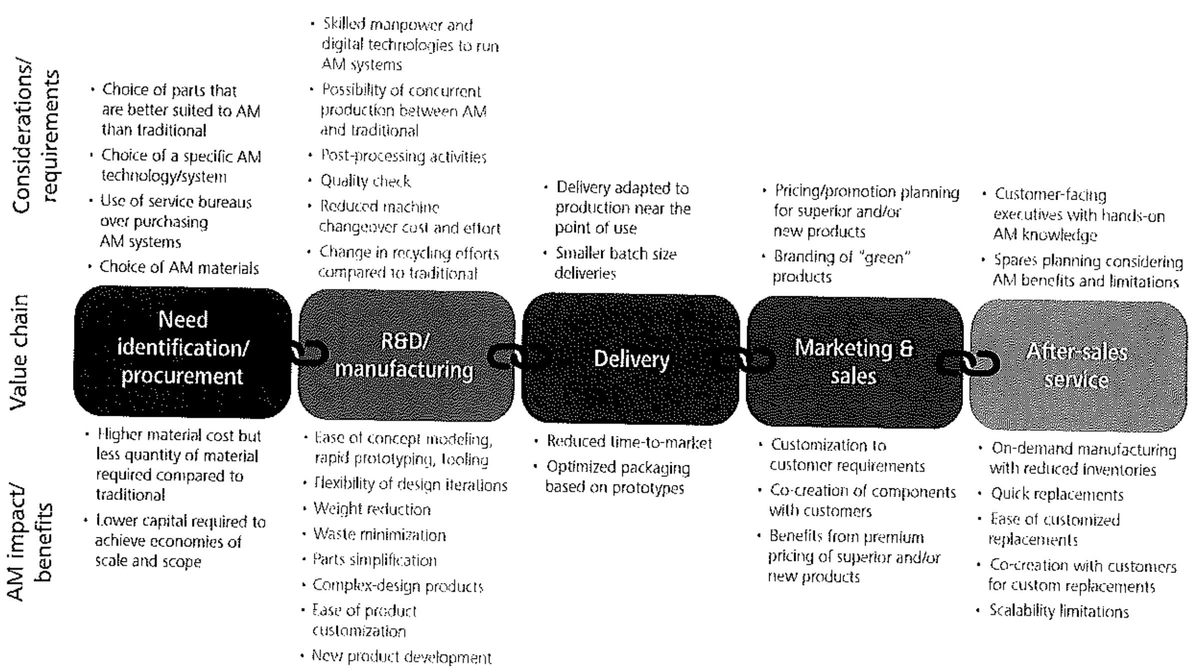
Historically, A&D companies have pursued path I, the least risky AM path. Even with no major changes in their product offerings and supply chains, companies can reap benefits by deploying AM in prototyping and tooling applications that help reduce product development time and costs. In the medium term, as AM technologies and materials science advance, companies are likely to pursue path III to build end parts with improved functionality. The prospect of additively manufacturing increasingly complex items at little additional cost will likely fuel the development of new products that can lead to growth opportunities within new customer segments. Also, AM's increasing use in the MRO industry may lead to a certain degree of distributed production. In the long term, A&D companies are likely to leverage AM for both product evolution and supply chain improvements. A combination of improved manufacturability and supply chain disintermediation could lead to changes in companies' business models.

As companies increasingly look to AM in pursuit of their strategic imperatives, they will need to factor various strategic considerations into their business functions (figure 7).

As shown in figure 8, depending on the extent of AM deployment, A&D companies will need to make changes that will allow them to reap benefits at each stage of the value chain. While AM opportunities, as well as the likely benefits from AM, are more significant in the earlier stages of the value chain, the technology's impact across the other stages should not be dismissed. Some benefits, such as parts simplification and weight reduction, can be obtained in current applications; others, such as production at/near the point of use, are foreseeable only in the longer term.

The comparison of what companies need to know and do and the benefits they could accrue highlights AM as an important element of the way forward for leading A&D companies.

Figure 8. Strategic considerations and benefits for AM adoption across value chain elements



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Deloitte Consulting LLP's supply chain and manufacturing operations practice helps companies understand and address opportunities to apply advanced manufacturing technologies to impact their businesses' performance, innovation, and growth. Our insights into additive manufacturing allow us to help organizations reassess their people, process, technology, and innovation strategies in light of this emerging set of technologies. Contact the author for more information or read more about our alliance with 3D Systems and our 3D Printing Discovery Center on www.deloitte.com.

Endnotes

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Additive Manufacturing in Aerospace: Strategic Implications

A SMARTECH WHITE PAPER

PUBLISHED AUGUST 2014

Additive Manufacturing in Aerospace: Strategic Implications

SmarTech has identified four ways that the aerospace industry expects to derive value from additive manufacturing (AM) in the aerospace field at the strategic level. In this White Paper, we examine four supposedly critical aspects of AM in the aerospace industry, which are (1) reduction of lead times, (2) reduction of component weight, (3) reduction of both production and operational costs, and (4) reduction of the negative environmental impacts of production. Our research has revealed that some of these factors will be a source of great value for aerospace manufacturers over the next ten years, while others contain more fluff than substance.

The analysis in this report comes from SmarTech's recent report **"Additive Manufacturing Opportunities in the Aerospace Industry: A Ten-Year Forecast."** More details of this report can be found at Additive Manufacturing Opportunities In The Aerospace Industry: A Ten Year Forecast[1] , or by contacting Rob Nolan at (804)-938-0030.

Prolog to Additive Aerospace

Aerospace manufacturers have used additive manufacturing systems since AM's beginnings in the '80s. But in the past few years, rapid advancements in AM technology have led applications of the technology in the aerospace industry to proliferate. AM formerly occupied a niche role in aerospace manufacturing as a technology for prototyping. As recent developments suggest, however, AM is rapidly becoming a strategic technology that will generate revenues throughout the aerospace supply chain.

Firms that are already committed to shifting the strategic dynamics of AM in the aerospace industry include: Boeing, Airbus, Lockheed Martin, Honeywell, and Pratt & Whitney. Some of the most important recent examples include:

- Airbus is exploring 90 separate cases where AM might be applied on its next generation commercial aircraft.
- GE is set to manufacture up to 100k parts with AM by 2020.
- EOS envisions a future where ten to twenty metal laser-sintering systems whir away in a production center creating large runs of end-use parts. This is a vision that GE has already started down, when it announced a $50-million investment to outfit its facility in Auburn, Alabama to manufacture its AM fuel nozzle. This announcement it seems is the first of many to come.

[1] http://smartechpublishing.com/reports/additive-manufacturing-opportunities-in-the-aerospace-industry-a-ten-year-f

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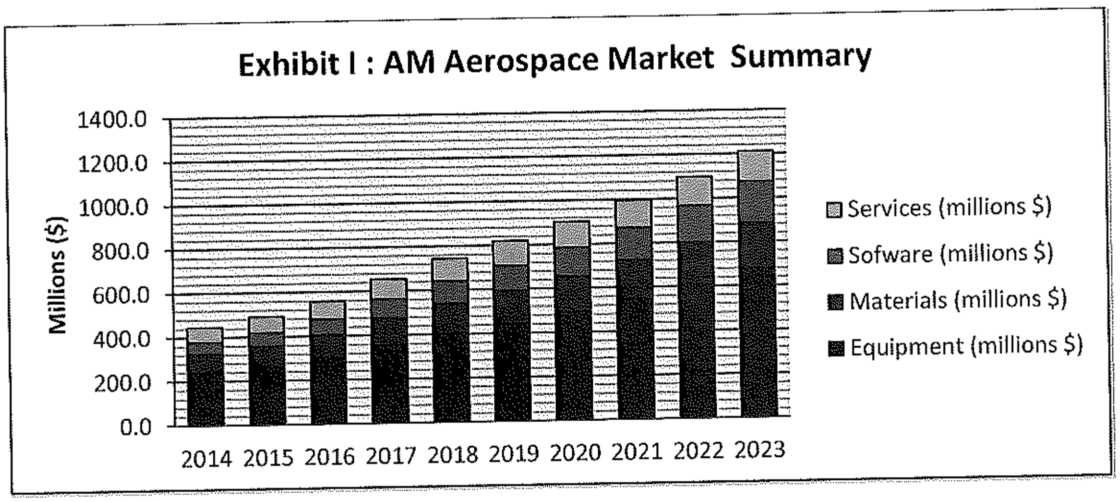
- Boeing already uses this technology to build everything from ducts to turbine blades to UAV parts.

As these companies continue to yield impressive results from their AM endeavors, **SmarTech** expects the pressure to mount for companies not currently investing in the technology to jump in so as not to be left behind. As we see it, AM will become part of the regular lexicon of aerospace engineers over the next ten years. For some projects, it will even become *the* go-to manufacturing technology.

Still, there are many question marks that stand in between now and when AM will become a serious manufacturing technology in the aerospace industry. Many potential *operational* hurdles, such as high metal powdered material costs and a lack of in-situ monitoring systems, threaten to deflate AM's ascendency. Such issues create confusion around the ultimate value of AM in aerospace. However after in-depth research of aerospace applications, end-users, and AM equipment manufacturers, **SmarTech** believes that the market for AM will indeed be substantial. The summary forecasts of our research are presented in **Exhibit I** below.



Source: SmarTech Markets Publishing

Reducing Lead Times for Components: Greatest Source of Value

SmarTech's analysis suggests that AM has considerable potential in aerospace. We also believe that reduced lead times for both new and replacement parts are perhaps the greatest source of value for AM in aerospace over the next ten years.

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As a rule of thumb, aerospace experts now believe that AM can reduce the lead-time for a part by 80%, compared with conventional manufacturing methods. This may allow aerospace manufacturers to redesign a part up to five times more during a standard component development cycle, leading to significant performance improvements of the components.

Manufacturers are already realizing dramatic cuts in lead-time for AM produced parts. For example, Kelly Manufacturing Company was able to reduce the production time for 500 housing components from three-to-four weeks to just three days using plastic laser sintering technology. Applications like these will, we believe, create significant value for producers and customer alike over the next decade.

Meanwhile, reduced lead-time for older replacement parts can be quite valuable in commercial airliners:

- In the future, lean manufacturing with AM equipment could shift the entire inventory for aerospace parts. The ability to quickly feed a CAD/CAM design into a 3D printer and produce a part can lower the number of minimum inventory aerospace manufacturers need to keep of a part

- For commercial planes whose average life expectancy is now 30+ years, circumventing the need to maintain and replace old tooling is a notable inventory cost advantage for manufacturers. According to Airbus the turnaround for test or replacement parts can now be as low as two weeks. These parts can be rapidly shipped to and installed in a broken down plane to help get the plane back into the air and making money for the airline.

- Furthermore, the ability to incrementally scale capacity of 3DP parts by adding individual machines means that one no longer has to produce numerous extra components to recognize economies of scale in manufacturing. However, it is still very difficult to covert old part plans to digital files.

Design Improvements: The Future of Aerospace Components is Optimized

Another potential source of value in AM is through optimized design of components. AM production enables new geometries or parts that can only be build one layer at a time. These features include organic contours, lattices, internal cooling channels, and even integrated electronics. **Exhibit II** presents a number of high-value components whose design AM has been used to optimize in the last two years.

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Exhibit II: Engine Components Suitable for AM Manufacturing		
Component	**Reasons For AM Production**	**Company Associated With**
Airfoils	Complex, heavily machined part	RTI Int'l
Rakes	Complex; pressurized line	RTI Int'l; Mercury Centre
Guide Vanes	Complex, heavily machined part	RTI Int'l
Impellers	Optimized design	Mercury Centre
Turbine Blades	Lower potential scrap rates	Arcam; GE

Source: SmarTech Markets Publishing

Many designs are improved by through radical simplification. Sub-assemblies that once had to be melded to together in many separate processes can now be printed in either a single or a few parts:

- Perhaps the most publicized example of this is the GE fuel nozzles, whose organic internal cavities reduce "coking", or carbon build-up within the nozzle. This enhances the performance and fuel efficiency of the nozzle over time. GE engineers state that these geometries could only be realized through the AM process.
- In the F/A-18 E/F forward fuselage, Boeing was able to consolidate its design into 41% fewer parts than what they required previously. Component simplification trickles down through operational processes, further reducing costs. Fewer parts means fewer component checks and less documentation for an aircraft operator, further saving on costs.

These are dramatic developments and **SmarTech** expects to see more of this kind of this redesign process occurring in aerospace development over the next few years.

Reduced Component Weight: An Advantage Overstated?

Weight reduction of aerospace components carries a huge premium because airline operators can recognize the value of these reductions over the average plane's 30+ years of operation:

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- AM can undoubtedly help reduce the weight of aerospace components by printing more efficient geometries and lattice structures that carve out large amounts of unnecessary material.

- Early tests have shown that component reduction is commonly around 30% of the component weight. Thus, a study published by equipment manufacturer EOS and Airbus Group Innovation Team in February of 2014 showed that the weight of a Nacell Hinge could be reduced by 35-55% and shave 10 kgs off the entire aircraft weight.

- Nonetheless, **SmarTech** finds the overall opportunities to reduce aircraft weight as wholly overstated:

- Some studies have cited weight reduction of parts that are not actually airworthy. By the time such components are bulked up sufficiently to be used in an airplane, weight reduction is less impressive; on the scale of 10-20%.

- AM is limited to titanium applications. AM is not currently able to supply Aluminum 4043 parts that meet air regulation requirements

- AM can only currently address planes' secondary structural components. This precludes the substitution of AM components for heavy primary structural components, such as wing spars.

These limitations on applications in an aircraft lower the overall weight savings attainable through AM applications. As **SmarTech** sees it, this is not enough to make a strong case for rapid implementation of AM parts across an airplane. This is especially true, given the fact that total weight reductions will most likely be measured against the last major weight saving initiative, which substituted advanced polymers for aluminum hulls. This initiative is posited with a 20% weight reduction over the entire plane, not just over individual components. When compared to previous weight reduction initiatives, it's clear that AM will not easily match previous levels.

Reduce Environmental Impact: Reputation vs. Actualities

AM has often been pitched as a "green" technology. But much of the environmental benefits are realized through reducing the weight of components which, as we have already discussed, has its limitations.

Another "green" impact can also be realized through lower material consumption during the print process because only the material being formed into the object is used:

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- Excess powder can be sifted and re-used, increasingly with automatic powder recovery systems attached to the 3D printers. However, the 3D print process itself is an energy intensive process.
- AM can improve buy-to-fly ratios well past an industry standard 30%. The buy-to-fly ratio is the weight ratio between the raw material used for a component and the weight of the component itself.

SmarTech believes that as many companies in the aerospace industry continue to shift strategies to become more environmentally responsible, AM's reputation as a green technology may be more valuable than actual energy savings. The facts are that energy consumption for AM processes are quite high and don't lead to recognizable carbon reduction in the actual manufacturing process. Furthermore, while the process may result in better material consumption rates, the high price of suitable metal powder material limits these rates from translating into cost reductions for manufacturers.

Imperatives and Challenges for AM in Aerospace Over the Next Ten Years

As shown in **Exhibit III**, there are many things that need to occur for AM to become a mainstream manufacturing technology in the aerospace industry. These bottlenecks hold the key to gauging future opportunities in this sector.

Exhibit III: Imperative to Advance AM In Aerospace

Imperative	Current Gap	Solution
Aerospace suppliers (especially lower-tier suppliers) must beef up CAD/CAM expertise	Limited skills in CAD/CAM means suppliers can't recognize the benefits of AM systems. Aerospace can't define its exact requirements from AM equipment suppliers, leaving them to guess at what equipment is needed.	Aerospace manufacturers need to develop the expertise to participate more in the AM design process. This includes not only defining exactly what they need from AM equipment manufacturers, but also taking actual stakes in the ongoing development of these machines.
AM manufacturers must advance their engineering and materials expertise.	AM equipment manufacturers lack the skills to address high-end aerospace applications and develop necessary quality monitoring equipment.	AM manufacturers can no longer afford to be specialty equipment manufacturers. Instead, they have to develop the skills in materials that will drive better qualification methods and allow

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Exhibit III: Imperative to Advance AM In Aerospace		
Imperative	**Current Gap**	**Solution**
		them to communicate with aerospace engineers.
AM manufacturers need to open up machines to non-proprietary materials	Closed material supply and equipment that only works with proprietary material strips the market of supply, reducing competition and innovation. Material costs are too high for mass adoption	Opening equipment to other materials will invite new entrants. The flexibility to use a greater variety of materials allows aerospace manufacturers to find more applications. Meanwhile, more price competition will help fuel equipment sales across the industry.
Better communication standards must be established in the AM and CAD/CAM industries	Awkward communication between different programs makes collaboration more difficult.	Bridge or translational software could be viable stopgap, but real improvement will take collaboration in the industry to establish common protocols.
Development of in-situ monitoring systems within AM equipment	There are very few tools currently available to track what's going on inside AM equipment. This increases lot sizes of test components and requires expensive post-manufacturing checks.	This presents opportunity for either OEMs or third party metrology equipment companies to develop solutions, such as Sigma Labs is attempting to do.

Source: SmarTech Markets Publishing

Then again, AM applications in aerospace face some serious challenges that may prove more resistant to solutions than those listed above. Three of the biggest challenges are:

- Extended product development cycles threaten to protract AM adoption patterns. In commercial aviation, new generation planes are designed every seven-nine years. If large enough benefits cannot be realized with AM in a given generation of planes, either because (1) the technology is not advanced enough or (2) engineers are not familiar enough with the technology, then AM might have to wait for the next plane generation to find substantial applications in the aerospace industry.

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- Even more daunting is the fact that aerospace is an industry where products—that is, the planes themselves—are pre-sold up to eight years in advance. So the question is: where is the real impetus to radically change production methods at all? As the examples that are provided in this White Paper show, this factor has not proved daunting for some major aerospace companies, but might for some.

- Aerospace manufacturers may have to endure a painfully slow period where regulatory authorities get familiar with this new manufacturing process.

SmarTech expects that innovators will find unique solutions to the imperatives and challenges discussed above. This will all be accomplished with the intent of deriving value from the benefits discussed that are the focus of this White Paper. As we have indicated, we think that not all of these benefits were created equal, but they all matter. In fact, **SmarTech** believes that the best AM strategies that aerospace firms can deploy will be those that take advantage of several of the factors we discuss.

An obvious example of this can be found in the GE nozzle, which has become such a poster child for AM aerospace manufacturing. Here, GE was able to reduce the number of parts in the fuel nozzle, reduce weight, and improve the performance of the nozzle over time.

Final Conclusions

As we see it, all the fuss and excitement over AM in aerospace is justified. At the same time, like any business strategy implementation, an AM-centric strategy takes careful forethought that includes leveraging AM to augment aerospace manufacturing processes.

AM in aerospace therefore still has some way to go before it finds a mature strategic role as a technology for rapid manufacturing. Given the time frame at which the aerospace manufacturing business operates, it could be a decade before that maturity sets in. However, this process will be important not just to the aerospace industry, but to the AM sector as a whole. This is because the aerospace sector is, for now, the largest single source of demand for production-grade AM equipment.

In **SmarTech's** report *"Additive Manufacturing Opportunities in the Aerospace Industry: A Ten-Year Forecast"* we break down the AM in aerospace into its most basic elements. Available equipment, industry make-up, 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.

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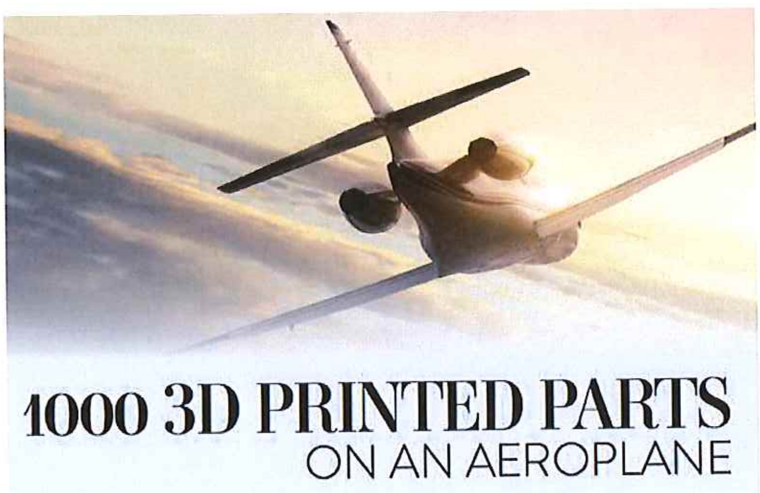
3 July 2015 11:44

3D printing for Aerospace: "Additive manufacturing will change the game forever"

TCT brings you up to date with the latest developments in the aerospace sector and finds out why the major players are working towards the day when 1000 3D printed parts on a plane is not a major story - just simply part of the job.

by Laura Griffiths

RSS Print



Paramount to additive manufacturing is the ability to create objects we wouldn't have previously thought possible. We've heard a lot about these 'impossible objects', sometimes it's the AM experts that are offering these breakthrough ideas to various industries and other times it's the clients themselves, major industrial companies, asking 'is this even possible?'

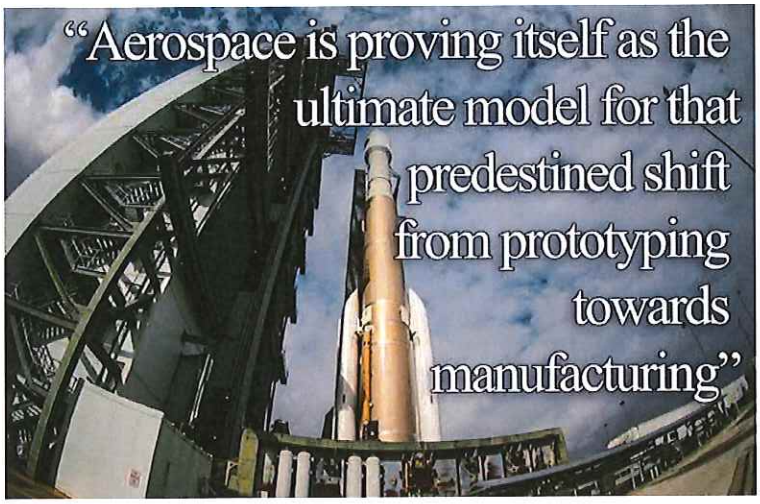
The aerospace industry has provided some major headline grabbing developments over the last few years and that's been even more evident in just the last few months. Talk to anyone about 3D printing and chances are they've heard one of the more famous examples like the one about the plane that's being flown with 1,000 3D printed parts or the one with the huge 3D printed turbine.

The radical fact about aerospace is we're not just talking about prototypes but real functional parts that are being used in aircraft, some of which have been on commercial vehicles for the last year without the need for a huge parade and ceremony to back them up,

Airbus was the name behind the recent sexy "1,000 3D printed parts on board an aircraft" story that saw Stratasys FDM 3D Production Systems used in place of traditionally manufactured metal parts.

Stratasys, Aerospace & Defense Business Development Manager, Scott

Sevcik, explained: "With Airbus they identified a risk within the supply chain and with bringing parts to the aircraft in time so they looked at 3D printing as an alternate means of production. They spent about a year qualifying the material and the process so they could have high confidence in putting these parts on aircraft and meeting certification requirements. Once they reached that threshold of having the specifications in place and being able to meet them that opened up a world of opportunity for them and they took advantage of it and in the A350 case, printing a large number of parts for the first few aircraft."



Delivered in 2014, the parts were 3D printed using Airbus certified ULTEM 9085 resin which provides high strength to weight ratio and is flame, smoke and toxicity (FST) compliant for interior aircraft applications.

"With aerospace everything takes time," Scott commented. "The relevant materials have now been on the market for a few years so companies can get that testing under their belt and that understanding, to understand material properties better and build that confidence. With a company like Airbus that's very significant."

Materials are high on the agenda in the sector with developers working on new, high strength resistant materials that are tailored towards aerospace applications.GKN Aerospace recently launched a three-year project to develop a new titanium powder for aerospace components. The Titanium Powder for net-shape component manufacture (or TiPOW) program is a £3.1 million collaborative research project which will investigate and define suitable development, production and reusability of titanium alloys and powders for aerospace.

Demonstrating the force of these dedicated materials, rocket manufacturer, United Launch Alliance is set to fire a 3D printed component on board the Atlas V launch vehicle next year. Also using ULTEM 9085, the Environmental Control System duct was printed on a Stratasys Fortus 900mc 3D production system, consolidating its previous 140-part count to just 16. Scott explained:

> "With United Launch Alliance they kind of take it a step further. They're actually looking at applications on their vehicles and

> redesigning them to reduce part count, weight and cost and really take advantage of not just an alternative faster production method but a method that can produce a part that couldn't have been produced before."

Redesigning the launch component significantly reduced the installation time and was able to lower part production costs by a huge 57%. The component has undergone extreme environmental tests to ensure its capability, which proved the part was able to withstand the same intense stress and pressures faced by the traditionally manufactured, original part.

Scott added: "With the design freedom you can consolidate parts which simplifies the supply chain and reduces costs and risk. There are a lot of benefits to being able to redesign. You can take that a step further in applications where you can actually replace metal components with plastic components and have a pretty dramatic weight reduction. "

Certification is a major part of the development process for AM in the aerospace sector with parts and materials having undergo rigorous testing and certification examinations to ensure they reach industry standards of functionality, quality and safety. The U.S. Federal Aviation Administration recently approved the first 3D printed part to fly in a commercial jet engine developed by GE Aviation, which took flight in April.

Greg Morris, Leader, Additive Technologies, GE Aviation, explained: "Using additive manufacturing, we cut the design process by a year: we could test prototypes quickly and move the best design to production much faster than conventional manufacturing techniques. Once in production, the part can also be made in a fraction of the time."

The new T25 3D printed sensor housing made from cobalt-chrome alloy took one year less to manufacture than the original part. Powering Boeing's 777 planes, the GE90 engine series is the world's most powerful engine and GE Aviation is currently working with the aerospace giant Boeing to retrofit more than 400 GE90-94B jet engines with the 3D printed part.

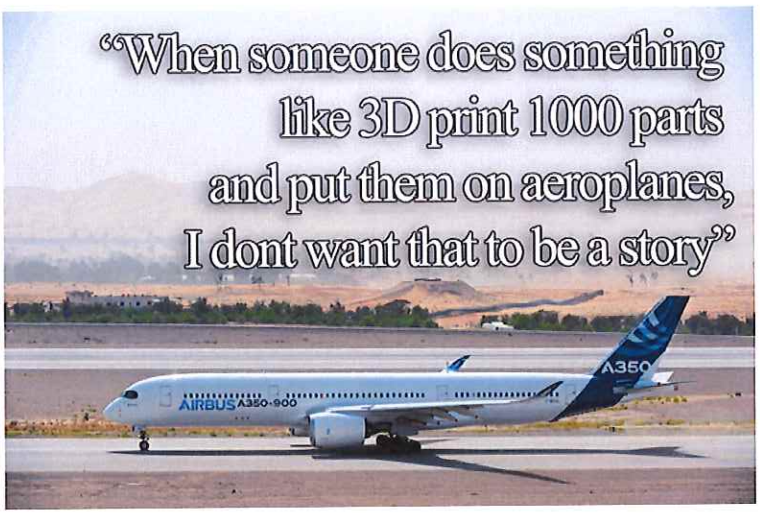
Greg, added: "In contrast to traditional machining methods, additive manufacturing enables us to build parts from the ground up. This advanced technique means less material waste and more complex parts that can be built precisely to optimise how they work inside a machine. Additive manufacturing will change the game forever by freeing engineers to design parts without the traditional limitations imposed by conventional manufacturing.

GE Aviation is currently working on several next-generation engines that benefit from advance manufacturing techniques. On the LEAP engine for narrowbody aircraft and the GE9X for the Boeing 777X aircraft, GE Aviation will produce part of the fuel nozzles with additive manufacturing, a project which has already received more than 8,500 orders.

A new era of design

Effective design for AM requires sophisticated software and UK-based Additive Design Consultancy (ADC) has been assisting the aerospace industry with AM components and assemblies using specialist software that allows efficient design and testing of components. Most recently, ADC has been conducting research into the potential of AM in RF antenna design by looking at a range of different technologies that allow the design freedom to create perfect geometry's to bring new levels of efficiency and performance.

ADC director, Adam Arnold, explained: "We are particularly looking at Aluminium as it has the electrical properties and great strength to weight ratio. However there are further weight improvements to be gained from looking at electroplated polymer based printed materials. This is of great interest in aerospace and particularly UAV platforms for performance reasons."



The key requirement from customers in the aerospace sector is weight reduction but in order to achieve that CAD designs must meet all the formal standards of aerospace engineering to produce quality parts capable of withstanding intense environments and performance targets. Adam explained:

> "Being such an open ended design process, designing to get the most out of AM for weight reduction is challenging many engineers, who do not have the tools, training or experience to produce geometrically very complex designs."

Adam believes the importance of this knowledge and expertise is vital to highlighting advanced manufacturing methods as a competitive form of production.

"Large companies, like airframe manufacturers, have teams of people looking into the problem, and big budgets to throw at it. However, the majority of the market, being made up of tier 1 and 2 suppliers to the likes of Airbus, do not. In the future, the higher management of these suppliers will need to buy in to the idea that making their products using well designed AM parts will give them a significant competitive edge in terms of performance and weight, and thus invest internally or buy in expertise."

With more companies looking at the possibilities of advanced manufacturing and implementing these technologies into real end-use parts, aerospace is proving itself as the ultimate model for that predestined shift from prototyping towards manufacturing.

Scott added: "When someone does something like print a 1,000 parts and put them on aeroplanes – I don't want that to be a story, I want that to be commonplace and I think it will be very, very soon."

Additive Design Consultancy 3D Printing News Aerospace Manufacturing GE 3D Printing Additive Manufacturing aerospace Stratasys GE Aviation

by Laura Griffiths
3 July 2015 11:44

Exhibit E

FOX VALLEY REGION COLLABORATIVE AEROSPACE CLUSTER DEVELOPMENT MEMORANDUM OF UNDERSTANDING

I. Background

The East Central Wisconsin Regional Planning Commission was the recipient in 2013 of a federal grant from the Department of Defense, Office of Economic Adjustment (DoD-OEA) following cuts in defense spending which resulted in the loss of more than 2000 direct jobs at Oshkosh-based DoD contractor Oshkosh Corporation and hundreds more in the regional economy. The purpose of the grant was twofold: to provide direct assistance to suppliers and employees in the region and to assist with economy diversification efforts already underway. One such diversification effort was to develop a business cluster focused on aerospace to better leverage significant regional assets to support such a cluster. Leaders in Oshkosh had begun work on this effort in 2009 and financial support for continued planning work on the project was provided through the DoD-OEA grant.

DoD-OEA provided funding support for a study to determine which types of aerospace businesses were best suited for the region and to devise an aerospace cluster development plan. The airports included in the study are Wittman Regional Airport in Oshkosh, Appleton International Airport in Appleton, Fond du Lac County Regional Airport in Fond du Lac and Austin Straubel International Airport in Green Bay (Partner Airports).

DoD-OEA also provided funding for the Partner Airports and the communities in which they are located to determine how best to work with each other collaboratively to develop the aerospace business cluster on a regional level ("Aerospace Cluster"). The Partner Airports and their communities (the "Fox Valley Region") also understand the value of developing the Aerospace Cluster regionally. The Fox Valley Region will be stronger and the Aerospace Cluster more successful if we work together rather than individually or against each other or in competition with each other.

Accordingly, the Partner Airports wish to enter into a Memorandum of Understanding setting forth their agreement with respect to the Aerospace Cluster

(MOU). In addition, the airport directors and economic development professionals in the Fox Valley Region also wish to enter into a Code of Conduct with respect to the Aerospace Cluster, which is set forth as Exhibit A to this MOU.

2. Agreement

A. Collaborative Cluster Development. The Partner Airports agree to collaborate with each other to develop the Aerospace Cluster.

B. Role of Wisconsin Aerospace Partners. It is recognized that a neutral party is needed to assist with Aerospace Cluster development efforts. Wisconsin Aerospace Partners ("WAP") is a state-wide industry-led organization created with the purpose of advancing the development of aerospace businesses, opportunities and resources in Wisconsin. It is an independent, private not for profit corporation funded primarily by industry. The Partner Airports agree that WAP will have responsibility to market the region to advance the Aerospace Cluster and function as the initial point of contact for prospects interested in the region; provided, however, so long that WAP has one or more staff members dedicated to supporting the Fox Valley Region Aerospace Cluster. WAP will share information with prospects about each Partner Airport and it will be up to the prospect to choose its location. Once the prospect has chosen its location, the Partner Airport takes responsibility for handling that prospect. Other Partner Airports will not contact a prospect directly before or after it has made a location decision except at the direction of WAP.

C. Regional Aerospace Cluster Development Council. The Partner Airports agree to join and participate in the Regional Aerospace Cluster Development Council ("Aerospace Cluster Council"), a committee of WAP. Each Partner Airport shall appoint one designee to serve on the Aerospace Cluster Council. The Aerospace Cluster Council shall have responsibility for providing guidance on Aerospace Cluster development efforts.

D. Deal Team Designee. The Partner Airports agree to designate a staff person who will participate on a regional "deal team" which will be the point of contact for Aerospace Cluster activities and a liaison to WAP. The deal team designee will be responsible for providing WAP information about its Airport and community when requested and work with WAP on Aerospace Cluster marketing efforts.

E. Joint Marketing. The Partner Airports agree to jointly market the region first as a destination for aerospace related businesses, and their individual airport second. Each Partner Airport shall work with WAP to develop marketing materials and to secure funding to support regional marketing.

F. Code of Conduct Approved. The County approves the Code of Conduct, attached, and directs the Airport Director to sign it.

G. Independence Preserved. Nothing in this MOU shall prevent a Partner Airport from promoting and marketing its airport independent from the cluster marketing efforts or from communicating with prospective prospects which contact the respective airport directly for information.

Dated this ____ day of _____, 2016

____

Mark L. Harris, Winnebago County Executive

____

Allen J. Buechel, Fond du Lac County Executive

____

Thomas Nelson, Outagamie County Executive

____

Troy Streckenbach, Brown County Executive

FOX VALLEY REGION COLLABORATIVE AEROSPACE CLUSTER DEVELOPMENT CODE OF CONDUCT

1. Introduction

This communities of Oshkosh, Appleton, Fond du Lac and Green Bay, Wisconsin ("Fox Valley Region") have determined that it is desirable to collaborate to establish and develop a regional aerospace business cluster ("Aerospace Cluster"). Each of the counties in which these communities are located have signed a separate Memorandum of Understanding in connection with the Aerospace Cluster which sets forth their agreement with respect to joint marketing of the region and staff support for the Aerospace Cluster (attached as Exhibit A). The airports involved in the Aerospace Cluster development are Wittman Regional Airport, Fond du Lac County Airport, Appleton International Airport, and Austin Straubel International Airport ("Partner Airports").

This Code of Conduct ("CoC") represents the standards that each signatory participating in the Aerospace Cluster supports and practices in its daily conduct of business. The signatories are: Peter Moll, Airport Director, Wittman Regional Airport, Abe Weber, Airport Director, Appleton International Aiport, Sam Tobias, Planning Director, Fond du Lac County, Tom Miller, Airport Director, Austin Straubel International Airport, Jason White, CEO, Greater Oshkosh Economic Development Corporation, Steve Jenkins, CEO, Fond du Lac County Economic Development Corporation, Manny Vasquez, Vice President, Fox Cities Regional Partnership and Peter Zaehringer, Vice President, Economic Development, Green Bay Chamber ("Participants")

2. Purposes

The Participants wish to make the Fox Valley Region attractive to aerospace businesses and work collaboratively to develop the Aerospace Cluster. While the Participants want to encourage businesses to locate at their respective airports, they prefer not to do so at the expense of other Partner Airports. Inevitably, some businesses, for their own reasons, will choose to explore relocation between Partner Airports or location in at one Partner Airport over another. In cases of relocation, a balance should be struck to allow the first Partner Airport the opportunity to retain the business and the second Partner Airport/s the opportunity to attract it. However, if a business has not expressed an interest in relocating, the Participants believe that Partner Airports should not actively pursue or "poach" that business to encourage it to move from its current location.

Also, the Participants recognize that we are a regional economy and the location of a business in one community is not a determent to other communities in the region but a benefit to all communities. The Participants also recognize that we will be more attractive to businesses and site selectors if we collaborate and join together as a region, rather than as individual communities.

The Wisconsin Aerospace Partners ("WAP") is a new industry led consortium with a mission to advance the aerospace industry in Wisconsin. It is believed that WAP will be well positioned to provide assistance in developing the Aerospace Cluster within the next twelve (12) months.

The purpose of this CoC is to: (1) facilitate interactions between the Partner Airports to promote regional aerospace cluster development; (2) agree on attraction protocols or the handling of prospects; (3) express the commitment of the Participants that they will not actively pursue the relocation of a business that has not indicated that it is considering a move from its current location at a Partner Airport; and (4) in instances where a business is exploring a possible move, establish procedures to balance the interests of the business' home Partner Airport and other Partner Airports.

3. Preamble

We, the Participants, set forth the following guiding principles of behavior, standards of conduct and protocols to guide efforts in promoting the long-term economic health of the Fox Valley Region through collaborative development of the Aerospace Cluster. We fully realize that no Code of Conduct is of value without an inherent level of trust in the integrity of one another and a commitment from each of us to conduct ourselves at the highest levels of professionalism. The Participants acknowledge the trust and respect for one another and in that spirit, set forth this Code of Conduct.

4. Guiding Principles

A. Regionalism. We are committed to the promotion of the Fox Valley Region as a desirable business location for new and expanding aerospace related businesses. We understand we will be stronger if we work together as a region rather than individually or against each other. We shall endeavor to sell the Fox Valley Region first and our individual communities and Airports second when it comes to the Aerospace Cluster. We will not engage in attraction efforts that encourage relocation of businesses between Partner Airports or that denigrates a Partner Airport.

B. Transparency. We are committed to sharing among our Partner Airports as much information as is necessary and prudent on any activity undertaken in connection with the Aerospace Cluster. Our guiding principle shall be that "more information is better than less."

C. Business in the Driver's Seat. Location choices are to be driven by the business seeking to locate (or relocate) in the Region.

D. Confidentiality. We will keep in confidence information shared by another Partner Airport. We also understand that prospects we are working with may request confidentiality and we each agree to respect that confidentiality and the confidentiality pledges of our Partner Airports.

5. Pledges and Protocols

A. Attraction Protocol. We are committed to locating aerospace businesses in the Fox Valley Region. We agree to permit WAP to undertake initial prospect intake to determine the prospect's needs and share information about each Partner Airport. It is up to the prospect to choose its location. We will not solicit a prospect already working with another Partner Airport/s. In the event that our

Airport/community cannot meet the needs of a particular prospect we shall communicate with our fellow Partner Airports in an effort to meet the prospect's needs elsewhere in the Fox Valley Region.

B. Anti-Poaching Pledge. We agree that, where a business has not indicated that it is considering a move from its current location at a Partner Airport, we will not actively pursue that business to encourage it to re-locate. "Actively pursue" means to initiate contact with the business directly, with the intent of luring the business, through cold calls, visits, mail solicitations, or marketing directed specifically at that business. This does not preclude a community from generally marketing itself as a good place to do business or generally advising its residents about the benefits of locating their businesses in their home communities.

C. Relocation Protocol. In the event a business located at another Partner Airport contacts any Participant about a possible location at the Partner Airport in their jurisdiction, we agree we will: 1) advise the business that we want to assist the business so that their needs can be met; 2) advise the business of the terms of this COC; 3) ask the business whether it has advised the Partner Airport or the community in which the Partner Airport is located that they are considering re-location and, if not, whether it objects to our advising the Partner Airport/community of the inquiry, if the business does not object, we will promptly notify the Participants from that community of the Partner Airport in writing of the inquiry; 4) we will not propose or offer incentives to the business in support of a relocation until either the business verifies that it has notified the its home Airport of the possible re-location or we have given that notice to that Airport and the Airport has had an opportunity to respond. This protocol applies only to businesses with five (5) or more employees.

6. General

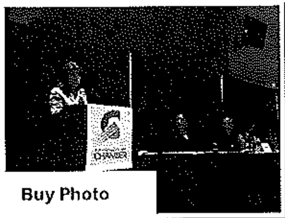
A. Review, Renewal, Withdrawal. This CoC shall remain in effect with respect to a particular Participant until that Participant advises WAP in writing of its intent to withdraw from the CoC. Such withdrawal shall be effective as of the date of the notice. This CoC shall be reviewed and acknowledged by Participants on an annual basis and such review and acknowledgement shall be communicated in writing to WAP.

B. Modification. Should any Participant desire a modification to this CoC, it shall advise WAP of this desire in writing. WAP shall then advise all Participants in writing of the proposed modification and request their approval of disapproval of it. Modifications shall be approved by a majority of Participants. If a Participant does not agree with an approved modification, it may withdraw from this CoC.

Agreed to this ___ day of _____, 2016 by

Regional collaboration key to economic development

Jeff Bollier, Press-Gazette Media 7:39 p.m. CDT August 13, 2015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(Photo: Jeff Bollier/Press-Gazette Media)

Stronger collaboration and marketing are needed to boost regional economic development efforts in Brown County and the Fox Valley.

That was the message four site selectors relayed to local and regional economic development leaders Thursday after they spent three days with business executives, educators and community leaders from Green Bay, Appleton, Oshkosh and surrounding communities.

"You've got to talk about your success stories. We went up and down the Fox River in a helicopter, and I didn't know any of that stuff existed. It's just not out there," said Brad Migdal, executive managing director for Transwestern, a Chicago-based commercial real estate firm. "We're bombarded by economic developers on a continual basis trying to share their success stories. You have to share your information."

Based in Chicago, Migdal is one of 275 site selectors in the United States whose job is to help companies find the right community for future factories, offices, call centers and other business operations.

He said Northeastern Wisconsin boasts many of the assets companies seek, including a solid workforce, available land, resources and an improving business climate. But he said the state and region fall far short of states like Michigan and Indiana when it comes to delivering a unified economic development message.

"There's no big problem to fix here, but there's also plenty of room for improvement," Migdal said. "I heard the message from everyone else, but I still don't know what the message from Wisconsin is. These efforts are not led by Green Bay's strategy or Appleton's strategy; it's led by the state. ... You are going to do a lot better if you work together as a regional alliance."

Peter Zaehringer, the Greater Green Bay Chamber's vice president of economic development, said he received the site selectors' message loud and clear.

"We have to work on marketing, but we do have the assets and industry to give us some bragging rights," he said. "We also need to get to know (site selectors). If you don't know them, you're not going to be part of the original evaluation process."

Although the site selectors may have called for more collaboration and better marketing, some of that cooperation is already happening, as evidenced by the partnership that helped produce the site selectors' tour of the region, said Fox Cities Regional Partnership Vice President for Existing Industry Services Manny Vasquez.

The tours and Thursday's summit were co-sponsored by the Greater Green Bay Chamber and Fox Cities Regional Partnership.

"It's great when you have two neighboring communities that typically compete for business come together to deliver a cohesive message," Vasquez said. "We hope to continue to do this into the future. We're very excited about what this means to the region and taking it a step further as we continue to collaborate."

Site selectors' role in economic development is relatively low profile, but NCS International President Jim Beatty said companies like his play a role in about 60 percent of business development decisions.

Beatty, an Omaha-based consultant, helps place call centers, offices and information technology operations. The tour of the region was his first experience in Wisconsin, but he said it was a solid first step toward raising the region's profile.

"I would have no hesitation about putting Wisconsin on a list and looking specifically at this area," Beatty said. "A visit like this enhances my ability to represent the area to clientele. Each decision will come down to how an area compares to others, but I would be excited to bring a client here."

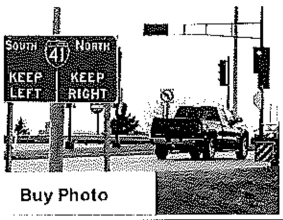
Aliquantus Consulting President Alison Benton, a Dallas-area-based site selector, agreed that the state and the region need to streamline marketing efforts, highlight the workforce's capabilities, speed up the response to companies' needs and plan for future growth.

"Companies need to know there's a pipeline of workers, but also that there's customized labor training when they need to upgrade employee skills," she said.

— jbollier@greenbay.gannett.com and follow him on Twitter @GBstreetwise and on Facebook at GBstreetwise.

Branding could attract businesses to I-41

Nate Beck, Gannett Wisconsin Media *10:52 a.m. CST December 15, 2015*



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(Photo: Doug Raflik/Action Reporter Media)

Among the factors that impede outside development in the Fox Valley along Interstate 41 is the unknown. Companies unfamiliar with the area don't know the corridor's advantages. It appears as a blank space to them, site selectors say.

The answer to combat this perception — and compete with out-of-state business regions — could be simple: better branding.

For the last few months, economic development leaders from Appleton, Green Bay, Oshkosh, Fond du Lac and in between have met regularly to flesh out how to better market the Fox Valley region. They hope to turn the Interstate 41 corridor into a strip of profitable businesses.

Wanting better branding of the Fox Valley isn't new. But actually doing it has been difficult. Branding strategies have flopped in the past due to sniping among economic development leaders and communities.

Steve Jenkins, president of the Fond du Lac County Economic Development Corporation, said northeast Wisconsin can't compete with neighboring states' business sectors if communities here don't approach economic development as a unit.

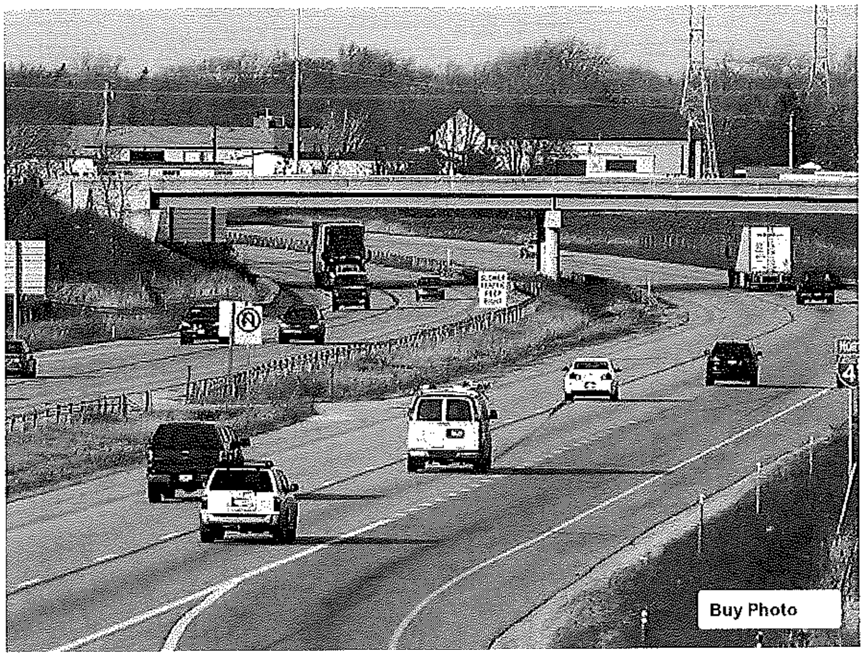
New protocol

For years, cities in northeast Wisconsin have competed with one another to attract businesses to their area, said Jerry Murphy, executive director of The New North, an economic development firm that covers 18 counties in northeast Wisconsin. But this slowed the process and bred animosity.

Under a new protocol, The New North filters business site proposals submitted by more than 200 lawyers, developers and other professionals who deal in real estate to draft a list of companies that might make a good fit along the Interstate 41 corridor.

Developers answer site inquiries in about 36 hours, down from a wait of up to two weeks, as it used to be, Murphy said. The New North then creates a short list of best sites based on company needs.

That means better service for prospective companies, and less in-fighting among communities across the area, Murphy said. To attract businesses, northeast Wisconsin pitches itself as a region, because a new company, say, in Oshkosh or Fond du Lac benefits cities throughout the Fox Valley.



In the past, cities have worked separately and selfishly when trying to attract out-of-state businesses to drop roots along Interstate 41, experts say. A new protocol has been put in place by an economic development firm that some contend is a more successful approach. *(Photo: Doug Raflik/Action Reporter Media)*

"We can broadcast the merits of the region," he said. "More is better. We need more people getting involved. More people taking ownership."

Rob Kleman, senior vice president of economic development at the Oshkosh Chamber of Commerce, said that through regular meetings, regional developers hope to figure out how to better tell the Fox Valley's story when marketing outside of Wisconsin.

"We would be developing branding, not to compete but to enhance what we already have," he said. "We have to be aggressive."

Asked how Wisconsin could better compete with surrounding states to attract business, Gov. Scott Walker, speaking Dec. 2 at the New North summit in Oshkosh, said the state remains "heavily dependent" on manufacturing. The state must fortify that industry, while seeking ways to diversify, he said.

"We need to continue to strengthen manufacturing for the 21st century," he said. "At the same time, we need to do more to diversify our economy, whether it's clean water, clean energy, whether it's looking at food and beverage manufacturing. It's a mix of things."

Marketing the corridor

Wisconsin's technical college system has effectively retrained workers to fill high-demand jobs, and executives are accessible and receptive to growth in new and existing industries, said Brad Migdal, executive managing director for Transwestern, a Houston-based real estate firm, and NCS International President Jim Beatty, an Omaha-based site selector.

But before they toured northeast Wisconsin in August with a group of site selectors, neither Migdal nor Beatty knew that. Northeast Wisconsin hasn't really competed with neighboring states in attracting businesses.

When scouting a location for a company, Beatty chiefly considers a region's available workforce and what skills those workers have. Among the last items on that list are a state's laws that support business and tax incentives — these are "icing on the cake," "There is no level of incentives that will make it worth it to relocate," Beatty said.

In general, site selectors don't see the Fox Valley as a place to locate businesses, in part because of poor marketing.

"There had not been an effort to market the region," Beatty said. "This is economic development. If you don't tell the story, you're already behind."

Building momentum

Momentum matters, Beatty said. Site selectors tend to hone in on industry clusters.

Beatty said the region's future could be in industries like food processing — think the Grande Cheese headquarters under construction in Fond du Lac — or advanced manufacturing, which has been hiring people with tech backgrounds.

Migdal said there may be a misconception that the tip of this Interstate 41 corridor ends deep in the Northwoods. Green Bay is less than three hours from Milwaukee, and there's a fairly dense cluster of communities in between.

Wisconsin is moving in the right direction, Migdal said. The state has strong scruples in industries like manufacturing. The challenge, he said, is communicating locally, and broadcasting to industries nationally, that success at a company in Oshkosh and Fond du Lac means success across the valley.

"Wisconsin is a place where people make things with their hands," Migdal said. "Wisconsin needs to show these stories."

Reach Nate Beck at 920-858-9657 *or nbeck@gannett.com; on Twitter: @NateBeck9*

Exhibit F

Aerospace Cluster Development Budget - MRO and AM 2016-18

		2016		2017		2018	
Revenue							
	Department of Defense Grant (applied for)	$ 565,446.00		$ 459,554.00		$ -	
	City of Oshkosh	$ 20,601.00	match/in kind	$ 20,601.00	match/in kind	$ -	
	Greater Oshkosh EDC	$ 36,852.00	match/in kind	$ 36,852.00	match/in kind	$ -	
	Wisconsin Aerospace Partners/WEDC (proposed)	$ -		$ -		$ 100,000.00	
	Project Partners	$ 10,000.00	marketing	$ 20,000.00	marketing	$ 120,000.00	
	Revenue from Operations	$ -				$ 50,000.00	
	Reserve	$ -		$ -		$ 868.00	
	Total	$ 632,899.00		$ 537,007.00		$ 270,868.00	
Expenses							
	Staff						
	Cluster Director Salary and Benefits	$ 121,500.00		$ 127,575.00		$ 127,575.00	
	Greater Oshkosh EDC CEO	$ 44,862.00	match/comp	$ 45,726.00	match/comp	$ -	
	City of Oshkosh Community Dev Dir	$ 20,601.00	match	$ 20,601.00	match	$ -	
	Greater Oshkosh Comm Dir	$ 9,936.00		$ 10,433.00		$ -	
	Administrative Support .5	$ 22,080.00		$ 23,184.00		$ 25,000.00	
	Interns	$ 10,000.00		$ 10,000.00		$ 5,000.00	
	Contract - Wisconsin Aerospace Partners						
	Manufacturers' Roundtable	$ 19,200.00		$ 19,200.00		$ 20,000.00	every other year
	Supplier Forum	$ 37,100.00		$ 37,100.00			every other year
	Additive Manufacturing Symposium	$ 42,450.00		$ 59,950.00	incl video	$ 45,000.00	
	Contract - Angels on the Water						
	Aerospace Fund Network Template and Fund	$ 151,400.00		$ 43,600.00		$ -	
	Talent Upload	$ 45,000.00		$ 45,000.00			every other year
	Employer Best Practices Seminar Series	$ 30,000.00		$ 30,000.00		$ -	
	Travel conferences and training	$ 15,000.00		$ 15,000.00		$ 5,000.00	
	Office Costs	$ 13,770.00	match/comp	$ 13,770.00	match/comp	$ 12,000.00	office share
	Marketing	$ 10,000.00		$ 20,000.00		$ 30,000.00	
	Professional Services legal accounting website	$ 30,000.00		$ 5,000.00		$ 2,500.00	
	Memberships	$ 5,000.00		$ 5,000.00		$ 5,000.00	
	Supplies	$ 5,000.00		$ 5,000.00		$ 5,000.00	
Total Expenses		$ 632,899.00		$ 536,139.00		$ 272,075.00	
Total Over/Under		$ -		$ 868.00		$ (1,207.00)	