Why Polymer Additive Manufacturing Makes Sense for Aerospace

Industry Report

On March 23, 2020, the commandant of the U.S. Marine Corps issued Order 4700.4. In typical fashion, it was written in a Situation – Mission – Execution format. The interesting part was the "mission," which read:

"Commanders at all levels shall employ and develop additive manufacturing (AM) to its fullest extent possible… ." The order's intent is to "…improve and standardize implementation of AM at all levels…across the Marine Corps enterprise."
- commandant of the U.S. Marine Corps

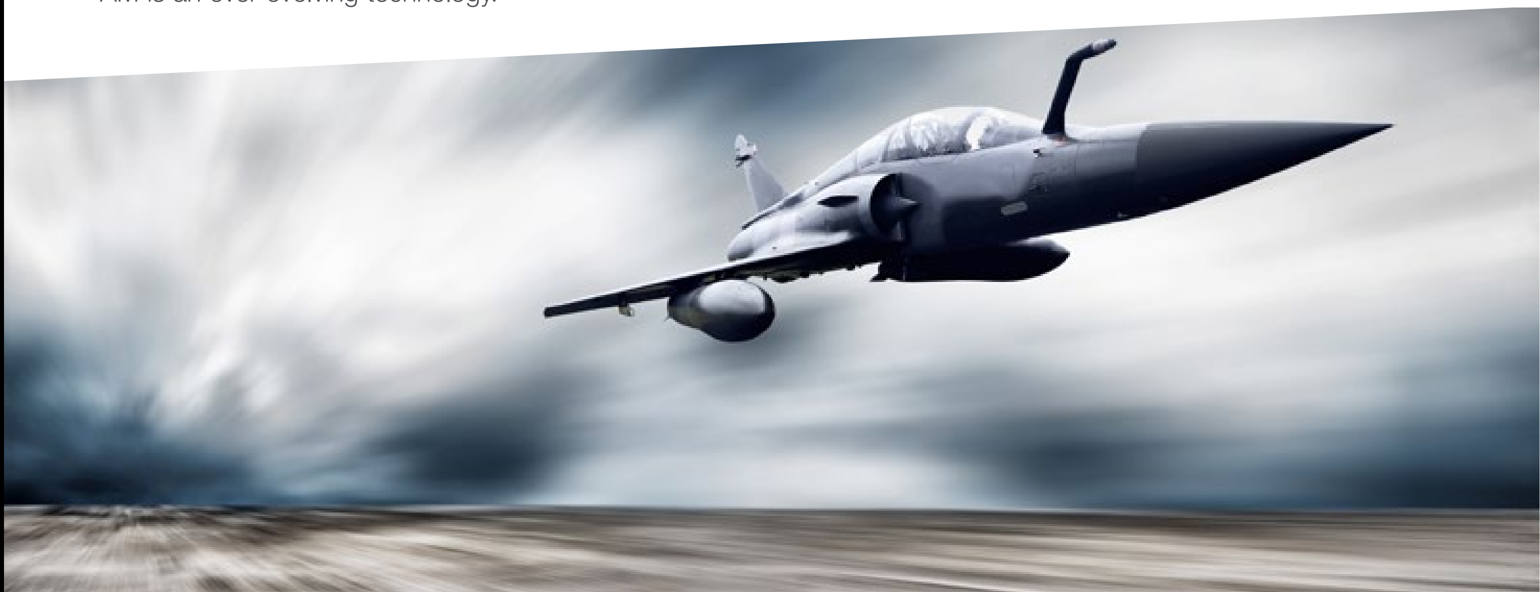
You may not be a military commander, but you're a leader, someone tasked with ensuring your division, operation, or team has the tools to achieve the company's objectives. And you're likely familiar with additive manufacturing and the benefits it offers throughout the product development cycle. So if you think about Marine Corps Order 4700.4 for a moment, can you say that your organization embodies that same level of commitment? Should you execute the same mission? If the U.S. Marine Corps believes additive manufacturing is important enough to implement across its entire organization, why wouldn't an aerospace and defense (A&D) company do the same, particularly since its core mission is manufacturing?

You might argue that the defense department has a healthy source of funding with the resources to implement such a plan. But the truth is, the military must adhere to a budget, not unlike any company whose objective is to earn a profit. The real question is whether those organizations, yours included, have the do-what-it-takes vision and boldness to make it happen.

The Marine Corps' commitment to AM is pretty clear and direct – implementation across all levels of the enterprise. And some aerospace businesses are taking a similar approach. They include many innovative nascent companies that have come on the scene in recent years, such as Boom Supersonic, Blue Origin, SpaceX, Sierra Space, and others. In other words, your competition.

Before you become complacent in believing your organization is already using AM, ask yourself these questions: Are you doing enough? How can you drive AM further into your organization to extract the most it can achieve? Are you staying ahead of your competition? Are you prioritizing metal AM over polymer AM?

This report will help reinforce polymer AM's value for the aerospace industry, particularly in light of current challenges and trends. While some information may tread familiar ground, other points may enlighten, as AM is an ever-evolving technology.



More Relevant Than Ever

The significance of AM for the aerospace industry deserves revisiting because not only has it proven valuable for the last three decades, it is still a highly relevant tool to address current and emerging trends.

Speed to Market

A core tenet of AM is its ability to accelerate multiple design and manufacturing processes. Unfortunately, the A&D industry has increasingly missed program timeline targets in recent decades. While there are several reasons for this, a potential solution could be a deeper integration of AM within the broader organization to achieve a compound effect of incremental process cycle time improvements.

Supply Chain Resilience

The COVID pandemic clearly revealed the weak links in global supply chains. More recently, the Ukraine invasion and the resulting embargoes have incurred new supply challenges, impacting shipments of raw materials widely used in the A&D industry. Additive manufacturing has shown it can alleviate some of these pain points through point-of-use production, agile production capabilities, and conservation of raw materials. One clear example of AM's positive impact on supply chains is how multiple companies quickly pivoted to making personal protective equipment and medical components to fight the pandemic. By leveraging digital design, connected networks, and close-to-point-of-use production, companies short-circuited the inertia and roadblocks that impacted traditional supply chains.

Sustainability and Climate Impact

Two ways AM can help aerospace manufacturers address environmental issues is by reducing fuel consumption and material waste. AM impacts the former through lightweighting practices – creating parts that reduce weight using lighter materials and optimized designs made possible with generative design and topological optimization. In addition, the additive process inherently produces less material waste than a subtractive process, a well-known trait of the technology but still significant, nonetheless.

The extent to which a company acquires these benefits depends on the intellectual and monetary investment it makes in AM, and the commitment to drive implementation. Making it happen isn't necessarily easy, particularly in an industry that's relied on metal as a foundational resource for a century. Metal 3D printing is obviously doable but comes with challenges, from pre- and post-processing requirements to manufacturing quality control considerations. And metal isn't always the best solution either, especially when it simply isn't necessary, based on the application (many forms of tooling and non-critical flight structures, for example). It's those applications where polymer AM plays a significant role, and it's what this report will explore next.

The Benefits of Polymer

Just as each aircraft in our nation's front line of defense is designed for a specific mission profile, AM technologies have their respective roles and best-fit applications. And while metal 3D printing has its place in A&D, polymer AM and the FDM® extrusion process, in particular, are well suited to handle a wide variety of engineering, production, and flight-part applications. Moreover, this broad mission capability enables companies to implement AM deeper and wider across different organizations, reaping cumulative benefits.

Three primary advantages of FDM additive technology stand out:

1 Advantage: Faster Time-To-Solution

The time it takes to solve a problem is usually orders of magnitude faster using FDM technology vs. conventional methods. This has been shown through countless use cases not only in A&D but also in the auto and general manufacturing industries. The same result occurs when comparing FDM technology to metal 3D printing. Parts are in hand sooner primarily due to fewer processing steps needed to get the result.

Benefit Ability to take time out of the design and production processes, ultimately contributing to faster time-to-market.

2 Advantage: Ease of Use

FDM technology is a relatively easy AM process to learn and adopt, with no specialized training required. In addition, later-generation FDM printers are even more user-friendly than previous versions, with features designed specifically to simplify their operation.

Benefit Lower adoption barrier, allowing faster and easier implementation throughout the organization. This enables a compounding effect on problem resolution, cost savings, and faster delivery.

3 Advantage: Ongoing Material Development

A change to the Stratasys polymer filament development philosophy has led to a tiered material ecosystem comprising three categories – Preferred, Validated, and Open. Preferred materials are developed within Stratasys or a third party and receive full tuning and optimization. Validated materials are typically developed with third-party polymer producers enabling faster market implementation. Open materials are available on select FDM printers through an Open Material License, allowing the use of any polymer filament produced by a third party or developed by the user.

Benefit Faster availability of more materials with specialized properties and capabilities for Stratasys FDM printers, developed by industry-leading material producers with polymer expertise.

The bottom line is that polymer AM technology is not standing still. Investment in materials and printing capabilities continues. Its overall benefit to a manufacturing organization is limited only by the creativity, commitment and imagination of the champions who understand its value.

FDM Success in the A&D Industry

Examples serve as the best means of demonstrating the capabilities of polymer FDM 3D printing within the aerospace and defense industry. The following use cases showcase a variety of companies that rely on the technology's time- and cost-saving benefits.

Application:
Rudder Limiter System Prototype

Challenges

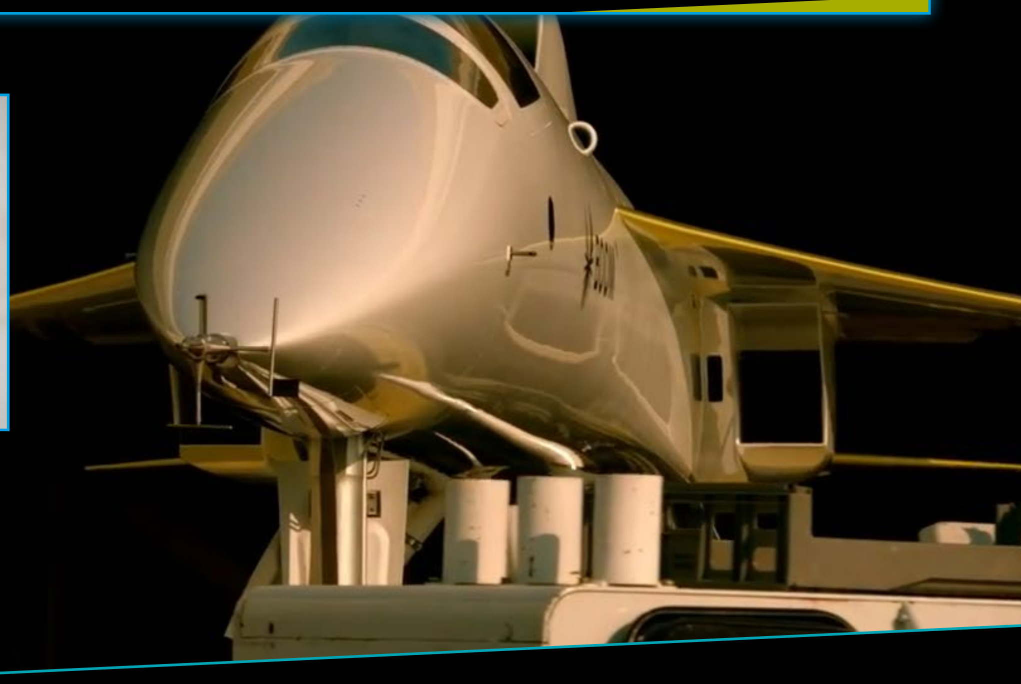
Boom Supersonic needed a faster way of validating the rudder limiter's design kinematics for its XB-1 supersonic concept aircraft. Relying on traditional machining would not meet accelerated production schedules and incur material waste and costs consistent with conventional subtractive machining.

Solution

Instead of machining all the required components, Boom 3D printed the system out of ASA thermoplastic, avoiding the typical lead times and machining costs. In addition, 3D printing avoided the limitations of designing for standard manufacturability and allowed engineers greater freedom in creating the design.

Impact

96% material cost savings and 86% lead time savings when compared to machining.



FDM Success in the A&D Industry

Bell Helicopter®

Application:
V-22 Stabilizer Conduit Upgrade Functional Prototypes

Challenges

Tail wiring upgrades required new conduits for on-ground wire testing. Conventionally made (cast aluminum) parts would take weeks to procure.

Solution

The rapid prototyping team chose to 3D print the conduits using polycarbonate (PC) and polyphenlysulfone (PPSF) materials. They provided the properties required for functional testing – dimensional stability, high heat distortion temperature, V0 flammability rating (PPSF), and chemical resistance. Engineers also cited easy, quick post-processing (time-to-part) as a reason for using FDM technology.

Impact

Engineers produced 42 conduit models in 2.5 days using additive vs. six weeks using conventional means – over a 90% time reduction. Engineers also noted the ability for faster iteration, leading to a better design.

FDM Success in the A&D Industry

Application:
Metal Forming Die

Challenges

East/West Industries, a tier-one aerospace supplier to Boeing, Lockheed-Martin, and others, sustained damage to a metal forming tool just before a contract job was to start. East/West's machine shop was committed to production parts, so a new forming tool would require outsourcing, jeopardizing the company's ability to meet the customer's delivery timeline.

Solution

Using its Fortus 450mc™ printer, East/West engineers designed and produced a replacement die using FDM® Nylon-12CF carbon fiber material.

Impact

The 3D printed thermoplastic die worked without fail, providing the rigidity and toughness to complete the job. Lead time savings over an outsourced die was seven weeks, an 87% time savings. In addition, the cost difference amounted to $1000 vs. $5000, an 80% improvement.

FDM Success in the A&D Industry

Application:
Heatshield Tile Installation Tooling

Challenges

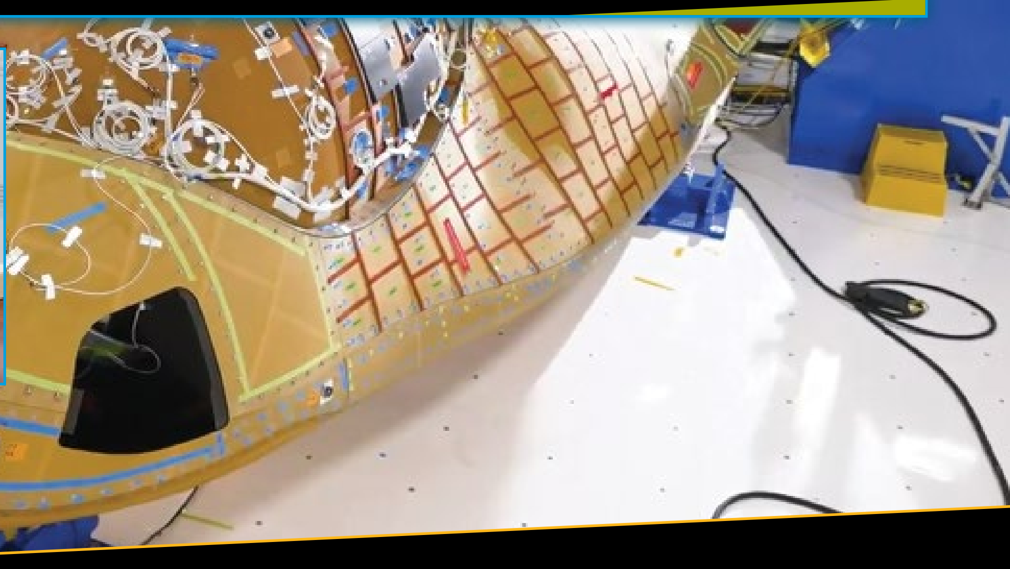
The Sierra Space Dream Chaser spaceplane uses 2000 thermal protection tiles to deflect heat during atmospheric reentry. Custom tools called “chucks” used to install each tile were typically made with a casting process, but this was a time- and labor-intensive process.

Solution

Wanting a better solution, Sierra Space engineers performed a trade study to compare 3D printing each chuck with the traditional cast method. Finding the labor savings alone would justify the cost of a Stratasys F900, Sierra Space purchased the system and printed the chucks using ASA thermoplastic.

Impact

Engineers reported that 3D printing saved tens of thousands of hours in CAD development and manufacturing to make all the chucks. The time savings allowed engineers to shift to other tasks, providing further time savings. Additionally, by optimizing the chucks’ designs, engineers reduced the original print time projection by 75%, opening printer utilization for other projects.



FDM Success in the A&D Industry

Application:
Avionics Cooling Duct

Challenges

United Launch Alliance (ULA) targeted the Atlas V rocket avionics cooling duct assembly for weight reduction and reduced part count in its pursuit of efficiency improvements. The existing duct comprised approximately 140 metal parts.

Solution

ULA chose to redesign and 3D print the duct using ULTEM™ 9085 resin material, qualifying the material and resultant parts.

Impact

The final 3D printed duct assembly resulted in only 16 parts, a nearly 90% reduction in part count achieved by AM's capability for part consolidation. This approach also resulted in a 98% reduction in production costs and a considerable weight reduction.

FDM Success in the A&D Industry

Application:
B-2 Spirit Bomber Cockpit Switch Cover

Challenges

To prevent the accidental activation of a cockpit accessory drive switch, the Air Force Life Cycle Management Center requisitioned the design and production of a new cockpit switch cover. However, the cover was not part of the B-2's original configuration. This required new parts to be designed and manufactured for an aircraft no longer in production.

Solution

B-2 program office engineers decided to use FDM technology to 3D print the prototypes and the final production parts, as it would be the fastest and lowest-cost option.

Impact

With no OEM part to use as a basis, engineers used 3D printing to rapidly iterate designs and arrive at the final switch cover configuration. Production of 20 units to cover the B-2 fleet resulted in a total cost of only $4000.[4]

4. Image reference: Air Force Life Cycle Management news (https://www.aflcmc.af.mil/News/Article-Display/Article/2279362/b-2-program-office-uses-additive-manufacturing-to-create-protective-cover-for-a/)

Accelerating the Qualification Cycle

There's no denying that qualifying materials and parts for flight is a long and costly endeavor, sometimes taking years. But a pathway is being paved to accelerate that process through the collaboration of manufacturers, regulatory agencies, and the National Center for Advanced Materials Performance (NCAMP). In short, NCAMP works with industry partners like Stratasys to qualify materials and add them to a database universally accessible by aerospace manufacturers. Then, instead of performing a complete material qualification, manufacturers can use the information from the NCAMP database and prove equivalency, making it faster and less expensive to gain regulatory agency approval.

The first AM material qualified using this process was ULTEM™ 9085 resin using the Stratasys F900 printer. As a result, companies now have a streamlined method for qualifying AM flight parts using the available allowables data for this high performance material. Stratasys continues to work with NCAMP to qualify other materials, which further cements Stratasys polymer AM as an essential element of aerospace manufacturing.

FDM Technology: Versatile – Timely – Capable

As the preceding use cases illustrate, FDM technology addresses all facets of aerospace manufacturing, from the engineering phase through production and on to the creation of flight-worthy parts for aircraft and space vehicles. It employs capable materials ranging from engineering plastics to high-performance, ESD-capable polymers that have already demonstrated their value with the successful Orion moon mission on Artemis I. In addition, it offers proven repeatability and reliability levels that are hard to match. And with Validated and Open materials, FDM technology's material portfolio will continue to expand and open new applications. That's why polymer FDM technology makes sense as a must-have tool for the aerospace industry.

Just as significant is the fact that FDM technology is still one of the most user-friendly, low-burden 3D printing processes available. It provides fast solutions and quickly gets parts into engineers' hands for fit and form checks, efficient tooling, or flight hardware.

This report started with the story of the Marine Corps' order to implement additive manufacturing at all levels. The Corps clearly sees a benefit to universal adoption for solving problems, safeguarding our nation, and helping the warfighter. It's no less than a "get it done" decree. The lesson for aerospace leaders should be to determine how the same can be done within their respective organizations – leveraging the benefits of additive manufacturing to innovate, reduce cost and deliver on time.

Stratasys is leading the industry in the release of publicly available data for Flight Parts.

Stratasys Headquarters

7665 Commerce Way,
Eden Prairie, MN 55344
+1 800 801 6491 (US Toll Free)
+1 952 937-3000 (Intl)
+1 952 937-0070 (Fax)

1 Holtzman St., Science Park,
PO Box 2496
Rehovot 76124, Israel
+972 74 745 4000
+972 74 745 5000 (Fax)

stratasys.com
ISO 9001:2015 Certified