ADDITIVE MANUFACTURING TRENDS IN AEROSPACE

LEADING THE WAY

By Joe Hiemenz, Stratasys, Inc.

Aerospace is the industry that other industries look to for a glimpse at what's on the horizon. Aerospace has a long history of being an early adopter, innovator and investigator. What this industry was doing decades ago has now become commonplace, almost pedestrian. For example, the aerospace industry was the earliest adopter of carbon fiber, and it was the first to integrate CAD/CAM into its design process. There are many other examples that show that trends in aerospace are predictors of future trends in manufacturing across all industries.

EXECUTIVE SUMMARY

Until the 21st century, all disruptive innovations followed the same adoption curve. But with exponential technologies and digital connectedness, disruptive innovations now have steeper adoption bell-curves as implementation rates accelerate.

3D printing is one such accelerating disruptive innovation – and it's ready for aerospace manufacturing now.

Ideal for small volumes and customized production, 3D printing makes lighter-weight, fully assembled components at a fraction of the cost and time compared to just a few years ago.

EXTENDING THE FRONTIER OF THE POSSIBLE

Innovation in aerospace is accelerating, advancing frontiers at the component and product levels in manufacturing operations, in rethinking supply chains and, in some cases, at the business model level.

Parts can now be created with complex geometries and shapes that in many cases are impossible to create without 3D printing.

Low aerospace volumes make 3D printing an attractive, lower-cost alternative to replace conventional CNC machining and other tooling processes for smaller-scale parts and finished assemblies.

Aerospace innovators are embracing 3D printing beyond prototyping and are aggressively pursuing new applications for the technology. Some leading aerospace manufacturers are already using it to fabricate jigs and fixtures, production tooling and final end-use parts for lightweight wing assemblies in small aircraft and unmanned aerial vehicles (UAVs).

500 toroid housings are produced overnight with an FDM-based Fortus® machine.

Production parts for instrumentation (Kelly Manufacturing), air ducts (Taylor Deal) and wingspans (Aurora) are airborne today in commercial, military aircraft and UAVs.

New 3D printing design freedoms encourage simpler, lower-cost design and assembly. 3D printing poses a competitive threat to slow adapters wedded to status-quo methods for prototyping, tooling and custom part production using CNC machining, aluminum casting and injection molding.

NASA outfitted the Mars rovers with 70 3D printed parts.

Complexity is free with 3D printing.

BARRIERS TO ADOPTION AND THE STATUS QUO

Despite widespread interest, the biggest barriers in implementing this new manufacturing revolution are internal: breaking down status-quo beliefs on what's possible and rethinking existing tooling and manufacturing methods prove difficult.

True, existing processes and behaviors are hard to change and manufacturing without a traditional factory is unrealistic. However, we see accelerated adoption of 3D printing in specific industries such as aerospace and a general spread of the use of technology as designers and engineers expand what's possible with this technology.

Additionally, unlocking investment capital and resources to learn and adopt new design and manufacturing techniques is difficult for some aerospace original equipment manufacturers (OEMs) and suppliers, who are locked into a quarterly driven revenue cycle and budgets.

However, the improvements that 3D printing offers should drive adoption deeper into related processes and increase competence, confidence and competitive flexibility.

DRIVING DOWN COST AND WEIGHT, SAFELY

Innovative aerospace manufacturers want to drive down cost and weight of aircraft, improve economy and design aesthetics and adhere to stringent FAA regulatory and compliance standards.

The type and scale of 3D printable parts is increasing alongside the size of print bays and the range of 3D printable material types. For aerospace, the availability of lightweight, flame- and chemical-resistant 3D printing material is key to broader application. Fracture-resistant material able to withstand temperature extremes and G-force stress also increases the range of applications.

MANUFACTURING PROCESSES

3D printing has helped shape aerospace for 20 years and is well established for prototyping and testing concepts. Before the term “3D printing” gained notoriety, manufacturing experts employed the process known as “additive manufacturing” to cut costs and time to market.

Beyond design and prototyping lie many additional opportunities to leverage 3D printing for custom manufacturing tools.

ACS helicopter fin (center) with a 3D printed drill guide (front).

TOOLING

Rotary wing and fixed wing repair specialist Advanced Composite Structures (ACS) performs low-volume component manufacturing using composite parts.

This work requires layup tools, mandrels, cores and drill guides. When these are produced through CNC machining, ACS invests several months and many thousands of dollars. And when changes occur, costs rise and delays mount.

ACS adopted 3D printing and uses it for nearly all of its composite tooling needs. On average, 3D printed layup tools cost only $400 and are ready for use in 24 hours – saving thousands of dollars and weeks of production time from traditional methods – and leaving room for last-minute corrections or changes.

3D printing really shines for hollow composite parts, such as a capsule for a remotely piloted vehicle. Wrapping composites around a soluble core made with 3D printing eliminates tooling bucks and two-piece clamshell tooling.

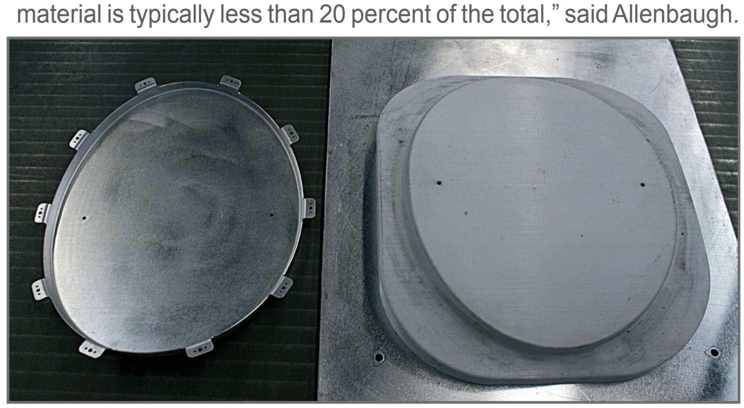
SelectTech chose FDM technology to avoid tooling headaches with this UAS with an all-FDM airframe.

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

Piper Aircraft uses hydroforming for hundreds of aluminum structural parts on new aircraft. In the past, it used machined tools for sheet metal forming. Piper determined that polycarbonate tools could withstand hydroforming pressures ranging from 3,000 to 6,000 psi, making it suitable for forming all of its structural parts.

And 3D printing’s speed can’t be beat. “I can program an FDM part in 10 minutes while a typical CNC program takes four hours to write,” said Jacob Allenbaugh, manufacturing engineer, Piper Aircraft. “The FDM machine can be much faster than a CNC machine and does not require an operator in attendance.”

Another 3D printing advantage: “Material waste with FDM-based 3D printing is much less than CNC machining because the FDM support material is typically less than 20 percent of the total,” said Allenbaugh.



Piper Aircraft hydroforms sheet metal parts using FDM-created tools.

Piper's next phase of plastic 3D printing hydroforming tools will focus on building a more efficient aircraft by moving to more complex and organically shaped parts made possible by 3D printing.

JIGS, FIXTURES AND SURROGATES

While 3D printing is making a significant impact in manufacturing, some of its applications such as injection molding and jigs and fixtures are being overlooked due to lack of headline appeal. But attention should be paid: Many manufacturing tools can be created with 3D printing faster and less expensively than with traditional methods. Molds, templates, surrogates, jigs and fixtures can all be ready for use in hours, not weeks.

Surrogates — which are placeholders for the production assemblies — are full-featured low-cost replacements for high-value parts. 3D printed surrogates are used on the production floor and in the training room.

This CH-53E Super Stallion is a good candidate for surrogate parts. Photo by Lance Cpl Steve Acuff.

For example, Bell Helicopter used surrogates to assess an Osprey hybrid aircraft's tail-wiring configurations. Bell used an FDM-driven 3D printer to build polycarbonate wiring conduits. Technicians installed the branching conduit's six mating sections inside the Osprey's twin vertical stabilizers for on-the-ground confirmation of the wiring path. Using FDM-driven surrogates, conduits were ready for installation in two and a half days, nearly a six-week reduction from Bell's alternative using cast aluminum parts. Bell also spent substantially less for the 3D printed parts.

PRODUCTION

Surrogate landing gear for commercial jet.

In addition to prototypes and tooling, modern 3D printing technology can produce durable, stable end-use parts — bypassing the production line altogether. The Production Series of 3D production systems — the Stratasys® line of larger, top-of-the-line 3D printers — uses a range of materials, including high-performance thermoplastics, to create parts with predictable mechanical, chemical and thermal properties.

Boeing, for example, uses 3D printing while manufacturing aircraft for multiple airlines. Although the plane itself is essentially the same from one order to the next, the interiors vary; as a result, a particular air duct may bend to the right instead of upward. Thus ordering a custom $40,000 tool made overseas to create just 25 of these parts is extravagant and time-consuming. Boeing overcomes these problems by 3D printing the custom end-use parts and installing them directly on the aircraft.

GE Aviation is another company using 3D printing in its production process. 3D printing has realized a weight reduction of over 500 pounds per engine in external fittings and castings, which can result in significant fuel consumption improvement for its customers.

"The current machines will rapidly find applications in tooling and jigs, replacing long cycle machined parts in the near term," said Dr. Todd Rockstroh, consulting engineer for GE Aviation. "As your technical staff engages the technologies, the applications will follow."

COMMERCIAL/ MILITARY

Taylor-Deal Automation uses 3D printing to prototype for its engineering and modification of specialty fluid and air handling parts. "With 3D printing we have design flexibility, cost reductions, weight savings and improved lead times," said Brian Taylor,

This instrument contains a toroid housing, produced via 3D printing.

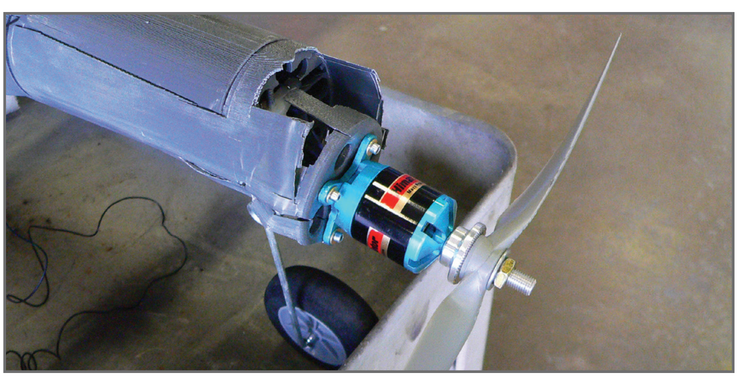
president, "all with low-quantity production."

Taylor's 3D printing material of choice is ULTEM® 9085 resin, which meets FAA flame regulations. Having a flight-grade material "gives designers much more flexibility when designing parts. It allows us to reduce engineering time and manufacture a less expensive part."

The design and manufacturing flexibility results in more efficient aircraft. The 3D printed parts contain less material, so their weight is approximately one-third or less that of the metal parts they replace.

UNMANNED AERIAL SYSTEMS (UAS)

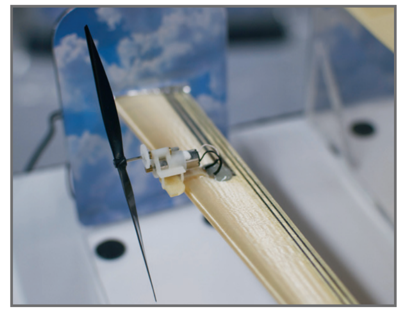
UAS production is another rapidly growing segment for 3D printing because of the industry hurdles 3D printing easily clears: complex systems, manufacturing iterations, low volumes, structural complexity, the need to save weight and the absence of passenger safety regulations to hinder deployment.



SelectTech's 3D printed unmanned aerial system underwent performance test flights. This broken nose cone sustained from a rough landing convinced engineers to redesign and reinforce the part.

Aurora Flight Sciences, which develops and manufactures advanced unmanned systems and aerospace vehicles, fabricated and flew a 62-inch wingspan aircraft — where the wing was composed entirely of 3D printed components.

This manufacturing approach reduces the design constraints that engineers face when using traditional fabrication techniques. The design of the wing's structure was optimized to reduce weight while maintaining strength. "The success of this wing has shown that 3D printing can be used to rapidly fabricate the structure of a small airplane," said Dan Campbell, structures research engineer at Aurora. "If a wing replacement is necessary, we simply click print, and within a couple days we have a new wing ready to fly."



Aurora smart wing: 3D-printed structure with printed electronics.

Aurora also uses 3D printing for an emerging application: "smart parts," which are hybrid parts that include 3D printed structures and 3D printed electronics. Aurora worked with Stratasys and Optomec to combine FDM and Aerosol Jet electronics printing to fabricate wings with integrated electronics.

"The ability to fabricate functional electronics into complexly shaped structures using 3D printing 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 field vehicles," said Campbell.

Smart parts enhance performance and functionality in two ways: 3D printers enable lighter-weight mechanical structures, and conformal electronics printed directly onto the structure free up space for additional payload.

Another company, Leptron, produces remotely piloted helicopters. For its RDASS 4 project, Leptron used 3D printing to make 200 design changes — each component had at least four modifications — without incurring a penalty in time or cost.

When the design was ready to take off, Leptron had flight-ready parts in less than 48 hours. Although Leptron created multiple designs for specific applications, such as eight variations for the nesting integrated fuselage components, it still saved time and money on the project. If it had used injection molding, as it had in the past, Leptron's tooling expense would have exceeded $250,000 and production parts would have arrived six months later. Instead, 3D printing saved Leptron $147,000 and six months' time just on its RDASS 4 project.

CONCLUSION

For aerospace, 3D printing has become a tool for designing, testing, tooling and production that extends beyond aircraft manufacturing into ground support systems and repair. Aerospace OEMs, defense contractors, MRO players and "new space" startups are growing their use of 3D printing for a wide range of parts, extending usage into production of airborne parts and complete assemblies.

Ground support systems use 3D printing.

3D printing allows smaller companies to compete with industry giants through agility. It empowers companies to accelerate time to market, improve the quality of their designs and become more cost-effective. Whether used in prototyping, tooling or short-run manufacturing, 3D printing is essential to staying competitive in this rapidly changing world.

Leptron's RDASS 4 UAS.

Have you embraced 3D printing to help you accelerate innovation? The pattern of adoption and outcomes from implementation are clear: 3D printing accelerates change in aerospace manufacturing, and companies small and large should embrace and learn to leverage this technology.

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