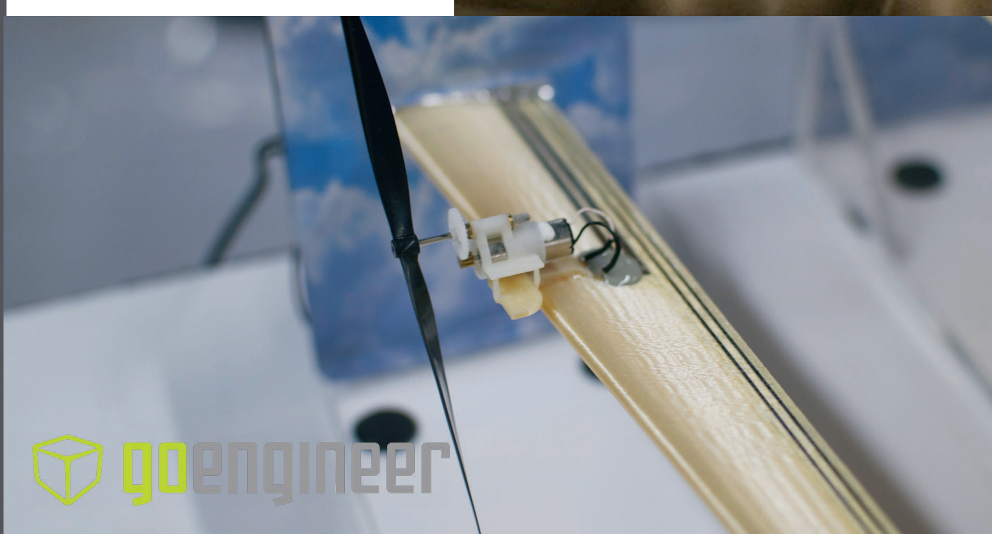
Additive Manufacturing Trends In Aerospace

Leading the Way

stratasys



White Paper

Additive Manufacturing Trends In Aerospace

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.

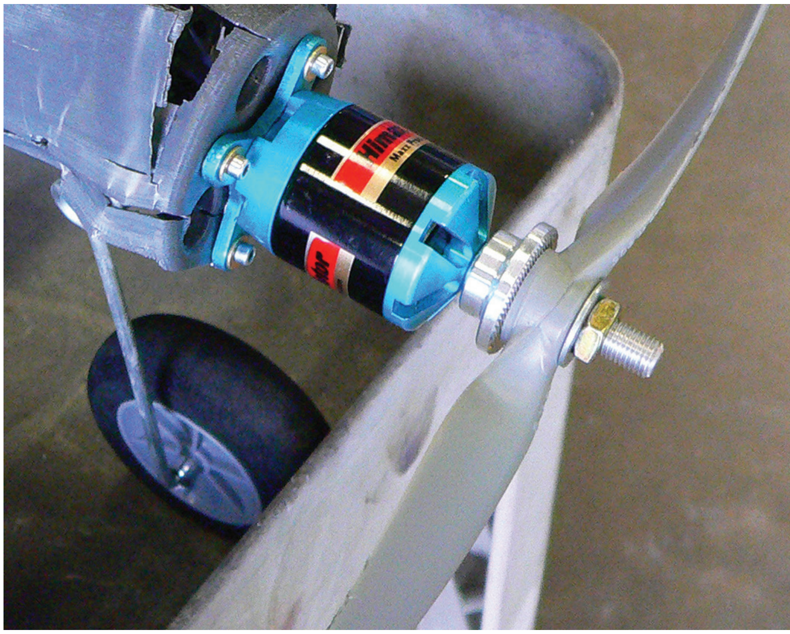
Additive Manufacturing Trends In Aerospace

EXECUTIVE SUMMARY

The Economist calls additive manufacturing using 3D Printing technology, the 3rd industrial revolution.

All discontinuous innovations follow the same adoption curve, except in the 21st century. Now exponential technologies and digital connectedness are causing disruptive innovation and steeper adoption bell-curves as implementation rates accelerate Additive manufacturing is a disruptive innovation and it is ready for aerospace manufacturing now.

Ideal for small volume and customized production, additive manufacturing is enabling a new, iterative design-build process – allowing lower cost production of lighter weight, completed products in a fraction of the time, compared to just a few years ago.


For SelectTech, UAS test flight damage is a learning experience.

EXTENDING THE FRONTIER OF THE POSSIBLE

Aerospace innovators are embracing additive manufacturing beyond prototyping and are aggressively pursuing new use cases for the technology. Some leading aerospace manufacturers are already using this technology to fabricate jigs and fixtures, production tooling and final end use parts for lightweight wing assemblies in small aircraft and UAVs.

Innovation in aerospace is accelerating, advancing frontiers of understanding at the component/ product level 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 any other way.

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

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

New additive manufacturing design freedoms encourage simpler, lower cost design and assembly through designing-in simplicity. Additive manufacturing poses a competitive threat for laggards wedded to status-quo methods for prototyping, tooling and custom part production using CNC machining, aluminum casting and injection molding.

Complexity is free with additive manufacturing.

NASA outfitted the Mars rovers with 70 AM parts.

Additive Manufacturing Trends In Aerospace

BARRIERS TO ADOPTION AND THE STATUS-QUO

Despite widespread interest, the biggest barriers in implementing the new manufacturing paradigm today are internal, based on breaking down status-quo beliefs around what's possible and rethinking existing tooling and manufacturing methods.

Existing human processes and behaviors are hard to change however, and manufacturing without a traditional factory is today an unrealistic concept. Instead, we see accelerated adoption in specific applications and industries such as aerospace and a general spread of the use of technology as designers and engineers expand the frontier of the possible.

Unlocking investment capital and resources to learn and adopt new design and manufacturing techniques is difficult for some aerospace OEM's and suppliers, locked into a quarterly driven revenue cycle and budgets.

However, where additive manufacturing is adopted, each success drives adoption deeper into related processes increasing competence, confidence and competitive flexibility.

The pattern of adoption and outcomes from implementation are clear; additive manufacturing is accelerating change in aerospace manufacturing, and companies should embrace and learn to leverage this technology.

DRIVING DOWN COST AND WEIGHT, SAFELY

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

The type and scale of 3D printable parts in additive manufacture is increasing as the size of print-bays and the range of 3D printable material types increases. For aerospace, the availability of lightweight, flame and chemical resistant 3D printing material is key to broader application.

For structural airframe parts, fracture-resistant material with the ability to withstand temperature extremes and the strength to withstand G-force stress is increasing the range of applications.

MANUFACTURING PROCESSES

3D printing has been in use in aerospace for 20 years and is well established for prototyping and testing concepts.

Beyond design and prototyping lie many opportunities to leverage additive manufacturing for custom manufacturing tools.

TOOLING

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

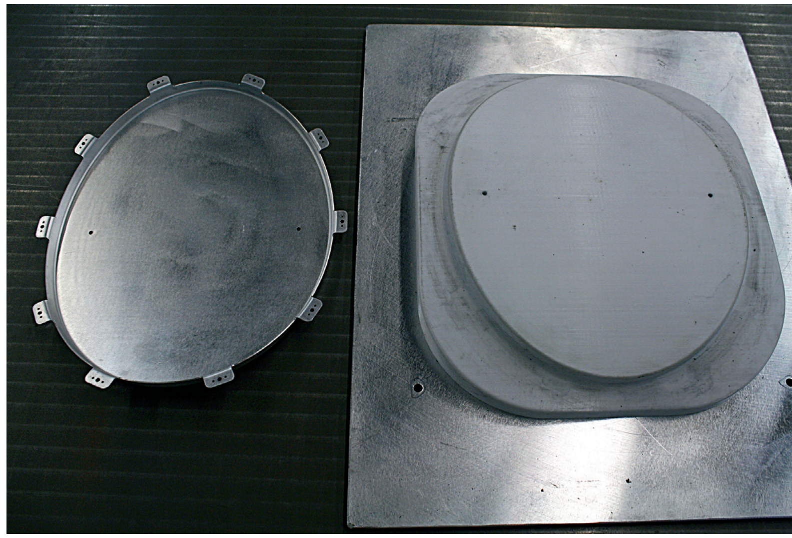
This work needs layup tools, mandrels, cores and drill guides. When these are CNC machined, ACS invests several months and many thousands of dollars. And when changes occur, costs rise and delays mount.

ACS has adopted additive manufacturing and uses it for nearly all of its composite tooling needs.

On average, layup tools cost only $400 and are ready for use in 24 hours, which means that changes are no longer a serious issue.

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

ACS helicopter fin (center) with AM drill guide (front).



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

“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 (FDM) has helped us substantially improve our competitive position,” said Bruce Anning, ACS owner.

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. “I can program

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

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 3D Production System can be much faster than a CNC machine and does not require an operator in attendance."

Another additive manufacturing 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's next phase of plastic additive manufacturing forming tools will focus on building a more efficient aircraft by moving to more complex and organically shaped parts. These parts will be made practical by additive manufacturing.

JIGS, FIXTURES & SURROGATES

3D printing is making a significant impact in manufacturing today, but due to its lack of "headline" appeal in the media, applications such as injection molding and jigs and fixtures are being overlooked. Many manufacturing tools can be created with additive manufacturing faster and less expensively, than with traditional methods. Molds, templates, jigs and fixtures, surrogates — all can be ready for use in hours, not weeks.

Ryan Sybrant, Business Development Manager at Stratasys, noted that this is one of the fastest-growing applications for 3D printing. "These functional tools help us do our jobs and lead to more factory-floor efficiency by reducing labor costs and manufacturing time," he explained.

The value in surrogates – which are placeholders for the production assemblies — is that they are full-featured low cost replacements for highvalue parts. 3D printed surrogates are used on the production floor and in the training room. For example Bell Helicopter used surrogates to assess the Osprey hybrid aircraft's tail-wiring configurations. Bell Xworx used an FDM system 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 surrogates, conduits were ready for installation in two and a half days, nearly a sixweek reduction from Bell's alternative, using cast aluminum parts. In addition to the reduction in build time, Bell spent substantially less for the 3D printed parts.

PRODUCTION

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 from Stratasys uses a range of materials, including high-performance thermoplastics, to create parts with predictable mechanical, chemical, and thermal properties.

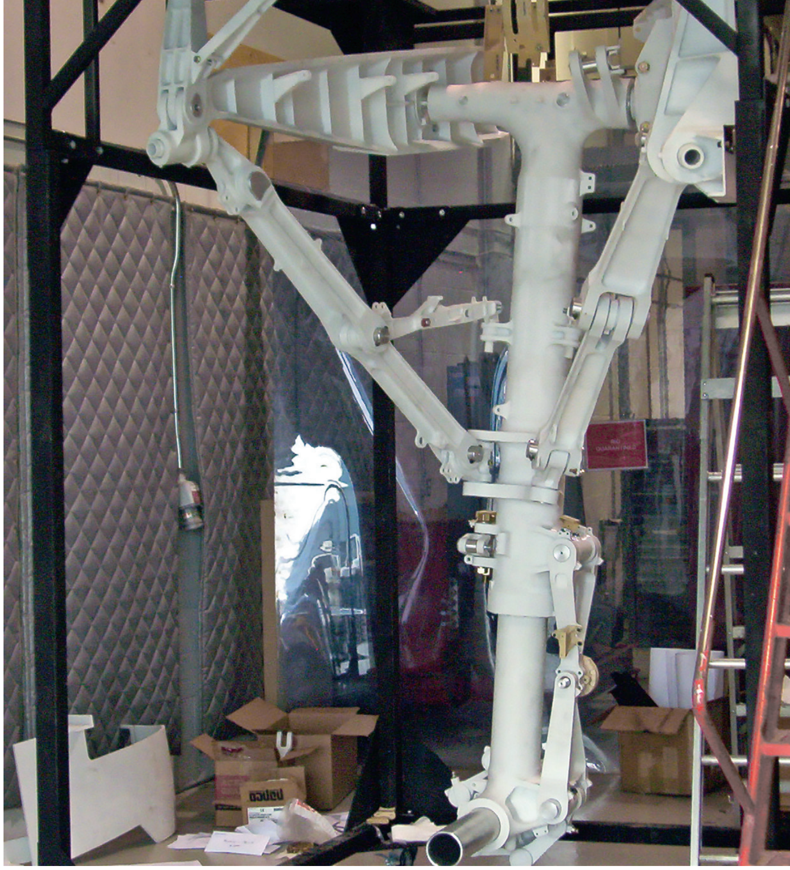
"Low-volume production is a market segment that traditionally hasn't been covered well," Sybrant noted. "Most injection molding houses, for example, won't take an order under a set number of components, or they charge a high fee to make it worth their while. It often makes more sense to complete the job in-house instead."

Boeing, for example, makes 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. They don't want to have to go have a $40,000 tool made overseas to create just 25 of these parts. They're better off printing them off their 3D printer and using them as a finished part directly on the aircraft.

COMMERCIAL/ MILITARY

Taylor-Deal Automation is one such company. It uses additive manufacturing for prototyping through production for its engineering and modification of specialty fluid and air handling parts. "With additive manufacturing we have design flexibility, cost reductions, weight savings and improved lead times," said Brian Taylor, 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



Surrogate landing gear for commercial jet.

This instrument contains a toroid housing, produced via additive manufacturing.

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) of that of the metal parts they replace.

UNMANNED AERIAL SYSTEMS (UAS)

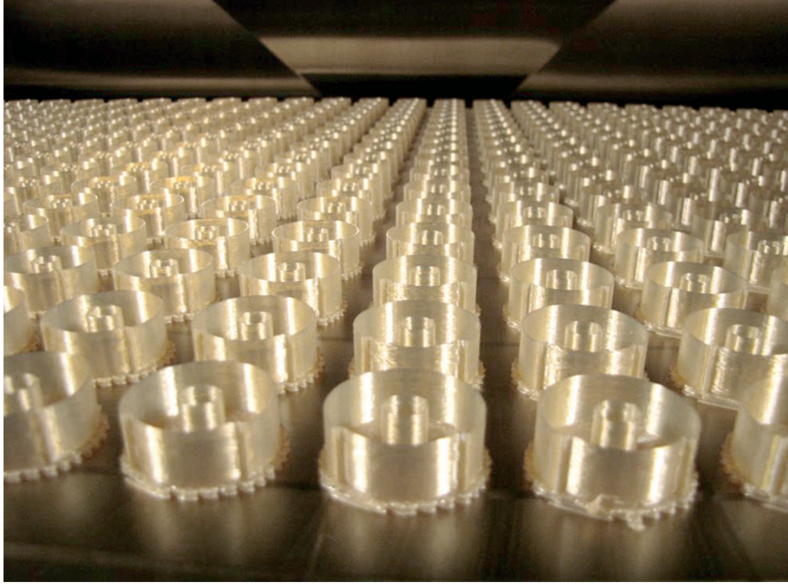
UAS production is a rapidly growing segment for additive manufacturing because of the complex systems, manufacturing iterations, low-volumes, structural complexity, absolute requirement to save weight and absence of passenger safety regulations to hinder deployment.

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

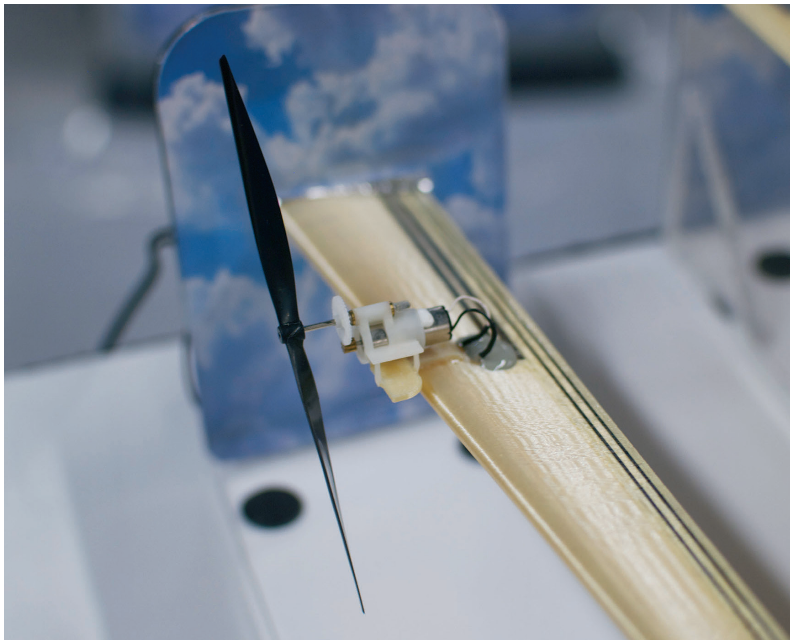
This manufacturing approach reduces the design constraints engineers face when using traditional fabrication techniques. The design of the wing's structure was optimized to reduce weight while maintaining strength. "The success of this wing has shown that 3D printing can be used to rapidly fabricate 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 also sheds light on 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 additive manufacturing can allow UAVs to be built more quickly, with more customization, potentially closer to the field where they're needed.



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



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

Ground support systems use AM.

Additive Manufacturing Trends In Aerospace

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.

Conformal electronics printed directly onto the structure frees up space for additional payload.

Leptron produces remotely piloted helicopters. For its RDASS 4 project, AM allowed Leptron 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, all thanks to additive manufacturing. And for this project, there were multiple designs for specific applications, such as eight variations for the nesting integrated fuselage components. If it had used injection molding, as it had in the past, tooling expense would have exceeded $250,000 and production parts would have arrived six months later.

Additive Manufacturing Trends In Aerospace

CONCLUSION

In aerospace, additive manufacturing has become a tool for designing, testing, tooling and production that extends beyond the aircraft manufacture into ground support systems and repair.

According to Sybrant, additive manufacturing does not discriminate. There are reasons that large organizations, like a Boeing can benefit from additive manufacturing — but also for smaller companies, it allows them to compete with the 10,000-pound gorilla in their space, if you will, because they can actually be more agile and possibly be quicker to market than their competitors are.

In a lot of cases — and this cuts across both large companies and small companies — it can lower their cost to get to market and improve the quality of the designs. It helps both ends of the spectrum compete much better than they could otherwise".

The pattern of adoption and outcomes from implementation are clear; additive manufacturing is accelerating change in aerospace manufacturing, and companies should embrace and learn to leverage this technology.

Additive manufacturing is helping aerospace manufacturers become more cost effective, more agile and more efficient in bringing new products to market. Whether used in prototyping, tooling or shortrun manufacturing, additive manufacturing is an essential capability to be agile and remain competitive in this rapidly changing world.

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

goengineer
www.goengineer.com