Case Study

Achieving the Promise

How General Atomics Maximizes the Potential of Additive Manufacturing

When Orville Wright coaxed his kite-like flyer up into a brisk North Carolina wind, marking the first flight of a heavier-than-air machine, it was 1903. The "flight" covered 120 feet and reached a top speed of 6.8 mph. A mere 44 years later, another pioneer in a more aerodynamic craft reached 700 mph, fast enough to break the sound barrier. Since then, humans have been to the moon, and aircraft no longer need onboard pilots, highlighting the breakneck speed at which aerospace has evolved. Considering the technical accomplishments needed to attain this, these milestones show what can be achieved with a willingness to experiment and a disciplined, dedicated focus.

GENERAL ATOMICS AERONAUTICAL

stratasys DIRECT MANUFACTURING

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That same technological trajectory also describes how General Atomics Aeronautical Systems, Inc. (GA-ASI) brought additive manufacturing (AM) from an experimental technology to one of the pillars of its manufacturing processes. GA-ASI is a world leader in developing and producing unmanned aircraft systems, notably the MQ-9A Reaper and MQ-9B SkyGuardian, to name just two. In just over a decade, GA-ASI's adoption of AM has advanced from a few desktop printers to a fully evolved ecosystem of AM technologies and applications, resulting in thousands of parts flying on multiple GA-ASI unmanned aircraft platforms today.

Built on a Sound Formula

GA-ASI's accomplishments with additive manufacturing didn't happen by accident. They are a result of a systematic approach developed over time that meshes with the company's business objectives. GA-ASI has refined the process to enable a "rinse-and-repeat" methodology and applies it when evaluating new AM technologies and applications. In condensed form, the process contains the following elements:

- Development of an AM ecosystem
- Establishing the business case for AM application
- Forming a center of excellence dedicated to implementing and expanding AM use
- Partnering with industry to learn, grow, and strengthen the supply chain

Although GA-ASI developed this recipe, there's no reason why other manufacturers in industries beyond aerospace can't use the same methodology for success.

A visual representation of the GA-ASI Additive Manufacturing Ecosystem.

The AM Ecosystem - The Foundation of Success

In 2018, General Atomics' leadership saw value in centralizing the implementation of AM with dedicated monetary and human resources. Three years later, GA-ASI established its Additive Design and Manufacturing Center of Excellence, which has become mission control for AM evaluation and deployment.

Steve Fournier is a senior manager at the center and has been instrumental in establishing the company's AM "ecosystem" – the framework of elements that comprise a successful AM program. In Fournier's words, the ecosystem is the recipe that guides the organization for each AM application the company pursues. "The benefit is that it's a template for us to work through what we need to work through and brings credibility to what we do," Fournier says.

Essential elements of an AM ecosystem include material properties, printer and material OEMs, contract manufacturers, software solutions, specifications, standardization organizations, and a team skilled in the development and application of AM. The more developed the ecosystem, the greater the likelihood of a successful AM program.

A well-developed ecosystem is also essential for significant applications like qualifying flight-worthy AM production parts and establishing new additive technologies.

At a minimum, the ecosystem establishes a standard of operation surrounding a particular AM application family that shares similar technical requirements and criticality level. It provides efficiency by avoiding reinventing the wheel for each use case. Fournier stresses that it can also start small and grow as a company gains more experience with the technology. "One of the challenges I feel many companies face is that they're trying to do too much before they start doing anything, as opposed to identifying the right application that fits into an ecosystem that is manageable," Fournier says. He offers advice, saying, "Go after the low-hanging fruit and build the ecosystem for that class of applications, and then increase the depth of the ecosystem over time to increase the criticality of the components and the application space overall."

Start With the Business Case

Among all the elements of the ecosystem, the keystone is the business case, which, according to Fournier, should be the starting point that guides the go/no-go decision on each AM application. He adheres to the tenet of "printing because you should, not because you can." Fournier believes a good business case is supported by groups of components – part families – vs. single one-off use cases. The idea to use AM may start with a single part, but Fournier encourages looking for similar parts and applications in that category. "In a high mix, low volume business environment, you likely will not interest leadership with a part that saves a few hundred dollars. But if you have hundreds of these parts which accumulate millions of dollars of savings, they start paying attention," he says.

Achieving wins by starting small makes it easier to develop the ecosystem and ultimately evolve to higher-requirement applications like production parts and flight hardware. These low-hanging-fruit applications include shop aids, mock-ups, and form-and-fit check tooling. For example, GA-ASI used 3D printers co-located at the point of use and on the shop floor to achieve time and cost savings of up to 85% with these applications compared to non-AM approaches.

> "Print because you should, not because you can."
>
> Steve Fournier
> **Sr. Manager, GA-ASI Additive Design and Manufacturing Center of Excellence**

Ground-support equipment manufactured with FDM additive technology.

The GA-ASI Certifiable Ground Control Station contains parts previously made with laminated composites that are now 3D printed.

At a higher level, the company has achieved significant cost savings by converting from laminated composite parts to 3D printed alternatives. GA-ASI used AM instead of laminated composites to build elements of its Certifiable Ground Control Station (CGCS), designed for its remotely piloted aircraft systems. Over the initial course of the program, GA-ASI achieved over $2 million in recurring cost reduction in addition to over $300K of tooling savings. A significant portion of these savings resulted from avoided labor to manufacture the tooling and the subsequent lay-up, curing, and final trim work on the composite parts.

Fournier points out that, at times, the technical case may not be fully vetted for a particular application – what he calls being in the "yellow" zone. But with the business case as the key arbiter, the technical challenges can usually be overcome. Fournier relates, "Our goal is to get it to a green business case and yellow at a minimum on the technical side. We can then push the yellow to green if we have a big enough business case and incentive. That's the strategy we adopt."

Leverage the Power of a Dedicated Center of Expertise

GA-ASI's AM program reached an inflection point when the company invested in a department dedicated to the technology's implementation and advancement. The Additive Design and Manufacturing Center of Excellence followed a few short years later, a direct result of leadership recognizing the value of a centralized approach to AM, with a team dedicated to its successful implementation.

"Through our AD&M Center of Excellence, we're using a structured and stringent qualification process for AM applications that delivers a positive business case for us over conventional manufacturing methods," GA-ASI President David R. Alexander says. "Our team of AM professionals are working to increase the adoption of AM parts for the benefit of our aircraft and ultimately, our customers." A synergy is achieved with a team that understands additive technology, the company's products, and how to best integrate the two. Without leadership's support, an organization's AM implementation may be fractured and unfocused, unable to realize the full benefit of the technology.

Fournier is explicit about the value in-house AM talent provides. "A key success point we've experienced over the last few years is to have dedicated additive application engineers and technicians onboard. They know our product, they know the people, they build the connections, and they get ahead of the design," Fournier says. He adds that successful implementation of AM can be a long road without that internal expertise. In fact, when asked to sum up the key ingredient to success for its AM program, Fournier is quick with his response: people. "The key to success with additive at GA-ASI is to have the right team driving the bus, beyond having an ecosystem, beyond having money for R&D. Without the team, you really don't go anywhere."

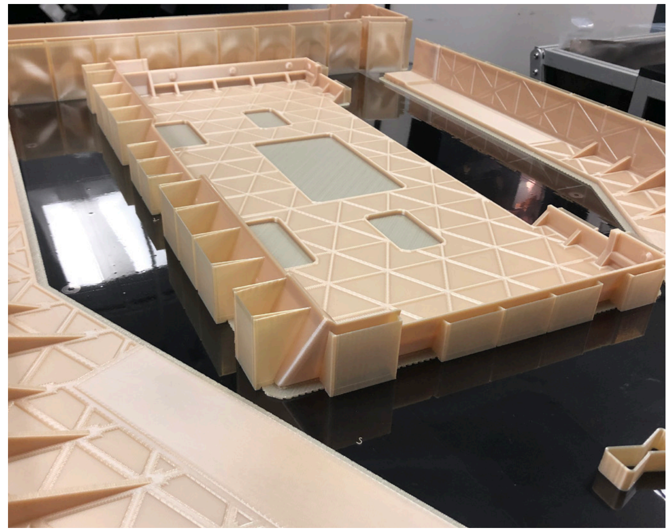
Partner With Industry to Accelerate Success

Orville Wright didn't go it alone, nor did Wilbur. They were partners and together birthed an industry that has taken their initial creation to heights that they probably couldn't even imagine. Needless to say, the right partnerships have fueled the success of countless organizations, from Hewlett-Packard to Microsoft to Apple.

It's a philosophy that's not only shared but promoted by GA-ASI. One of the company's key AM partners is Stratasys, which includes its contract services arm, Stratasys Direct Manufacturing®. A substantial portion of GA-ASI's polymer AM activity is achieved with Stratasys FDM® technology applied across prototyping, tooling, and production-part applications. Once GA-ASI validates the application in-house, it turns the bulk of manufacturing AM parts, approximately 75%, to vetted and validated contract manufacturers, including Stratasys Direct. The remainder stays in-house to maintain expertise, ensure production supply vertical integration capability, and handle low-volume/high-mix production for early-stage aircraft developments.

> “The industry partners are essential for multiple reasons. Number one is acceleration.”

Fournier advocates the engagement of AM partners for several reasons, particularly if a business doesn't have a well-developed internal AM ecosystem. Key among them is speed. “The industry partners are essential for multiple reasons. Number one is acceleration,” says Fournier. In his view, the business partnership helps speed the process of achieving any particular AM objective. In addition, it expedites the assimilation of knowledge, lessons learned, and best practices.



These 3D printed parts replace assemblies that were previously made using a more resource-intensive composite laminate process.

Not every element of the AM ecosystem can be accelerated, such as AM knowledge transfer to internal personnel, but many others can be through partnerships, among other means.

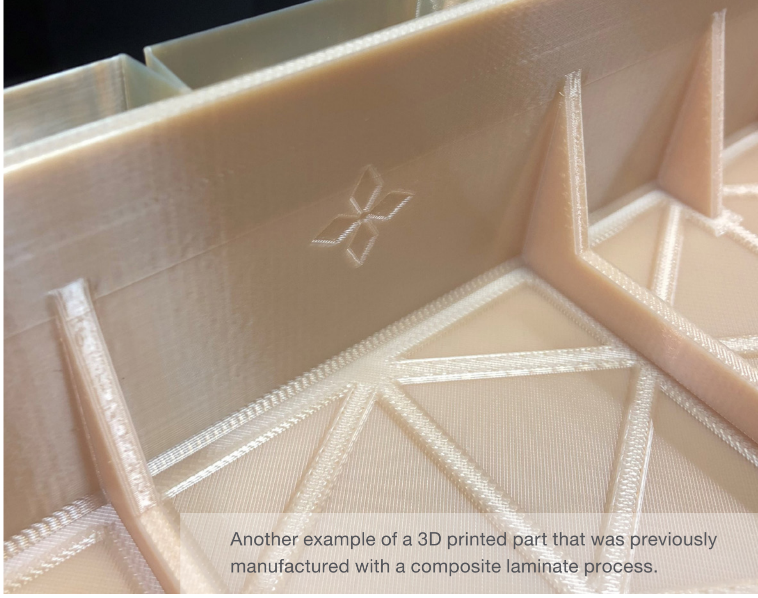
One example includes the collaboration between GA-ASI and Stratasys to produce 3D printed flight hardware. Stratasys performed the preliminary legwork for qualifying 3D printed aircraft parts by establishing additive process and material specifications with regulatory and testing organizations. From there, GA-ASI leveraged those tools to certify its internal process and qualify 3D printed parts for its certified aircraft programs. This working-together relationship allows GA-ASI to dramatically streamline the qualification process, which otherwise would be more costly and time-consuming.

Just as significant is how Stratasys Direct's contract manufacturing services benefit GA-ASI, an integral part of GA-ASI's AM ecosystem. For example, GA-ASI outsources thousands of parts to Stratasys Direct, which allows GA-ASI to grow the number of AM parts it installs on aircraft much faster and for a lower cost than producing them all in-house at a capital-intensive cost. In this way, Fournier sees GA-ASI's internal capabilities as the brains (or capabilities) of its additive program and contract manufacturers such as Stratasys Direct Manufacturing as the muscle (or capacity).

This philosophy is also highly suitable to the variable nature of GA-ASI's business, which includes high-mix/low-volume and repetitive production demands. "That's the reason we go outside for about 75% of our recurring manufacturing," says Fournier, "because it allows us to have enough capacity for the low-volume, one-off, early-stage development flight hardware work."

In the end, GA-ASI's formula for success includes a blend of internal AM capabilities and reliable partners for outsourcing. In-house AM capabilities let GA-ASI respond to rapid-reaction development efforts where designs are in flux, and AM provides the right tools for a high level of iteration. In contrast, outsourcing to qualified, reliable contract manufacturers like Stratasys Direct Manufacturing delivers the best solution for overflow and forecastable production. In Fournier's words, "You have to partner with the Stratasyses of the AM world to understand the best practices, the best lessons learned, and assimilate and share knowledge in a win-win situation." To put meaning behind that statement, GA-ASI consults with Stratasys Direct Manufacturing's engineers, and the two companies' workflows emulate each other.

Fournier also makes distinctions between contract manufacturers like Stratasys Direct and service bureaus. "They're not the same," says Fournier. "A service bureau will deliver something, but there's no quality clauses or the rigor of manufacturing to deliver a fully functional flight part repeatably, at least from our industry standpoint. A contract manufacturer will take responsibility for the quality and will be audited and take that level of stringency to deliver that hardware, not only once, but always to the same quality level," he says.



Another example of a 3D printed part that was previously manufactured with a composite laminate process.

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An aircraft duct 3D printed with ULTEM™ 9085 resin material.

Putting it All Together

In the relatively short time since adopting additive manufacturing, GA-ASI has attained impressive results. For example, in 2022, the company reported its MQ-9B SkyGuardian comprised about 240 AM parts, saving $2 million in tooling costs and achieving more than $300,000 in recurring cost avoidance. Those results will only increase over time, fueled by additional AM applications across other upcoming aircraft programs.

Reducing costs is one of the fundamental benefits of AM. Another is speed, which helps businesses accelerate time-to-market. Fournier is clear about AM's impact for GA-ASI on this aspect – it increases the likelihood of meeting challenging contract schedules, which could mean the difference between moving forward or losing to the competition. Fournier highlighted an example of a new aircraft contract that makes substantial use of AM: "If we don't meet that deadline, we're going to be at a disadvantage. The faster we can get that done, the more we're able to get data and confidence ahead of that deadline for the customer," says Fournier. And additive plays a vital role in making that happen by adding buffer to tight schedules, ultimately allowing GA-ASI to deliver on schedule.

But while cost reduction and time-to-market acceleration are worthy objectives, they don't paint the complete benefit picture of additive manufacturing. In Fournier's view, AM's other advantage is its ability to change the approach to design and manufacturing because it alleviates conventional manufacturability constraints. In an aerospace context, this freedom enables differentiation and departure from conventional concepts toward more complex designs and unitized structures. And that is when additive manufacturing can become the only solution because these structures can't be produced with any other manufacturing methods. Fournier relates, "Additive itself is not the end game - it's not what will change the industry and flip it on its head. Additive is a good fit in that it's an enabling force to manufacture designs that will be increasingly and exponentially complex and integrated at the system level. It is part of the full digital manufacturing end goal at GA-ASI."

GA-ASI clearly understands the role of additive and how to apply it for utmost effectiveness. However, it wasn't always this way. The company's embrace of AM started small but grew steadily by consistently following the basis of the ecosystem described earlier. The good news for other businesses is that this methodology is not specific to GA-ASI – it can also work for other companies interested in adopting industrial additive manufacturing.

Fournier points out that success with AM is less about reinventing the wheel and more about adapting the wheel. He attributes this approach to the speed at which GA-ASI has applied and structured its use of the technology. "We took the position to collaborate as much as possible to identify elements within the ecosystem that could be accelerated, for instance, by working with Stratasys on materials and material qualification, supplier qualification, and things like that. That accelerates our adoption of additive in the right way, in the right channels," says Fournier.

Undoubtedly, GA-ASI has developed a highly successful formula for maximizing the full potential of industrial additive manufacturing, and they are continuing their additive journey every day, one application at a time. And with the results achieved thus far, it's clearly paying dividends.

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