# The Promise and Peril of 3-D PRINTING

By Gideon Grudo, Digital Platforms Editor

The military has been salivating over the potential for additive, or 3-D, printing for a number of years. No need for warehouses full of parts or an elaborate logistics system that flies crucial components to forward locations. Theoretically, just take a 3-D printer along on a deployment and any spare parts needed can be whipped up in a matter of hours.

Industrial futurists have speculated that entire systems—such as munitions or unmanned aircraft—could be produced using additive techniques, potentially abolishing the need even for factories.

Well, not quite yet. While 3-D is already being used successfully in a wide variety of low-tech applications, there are still a lot of fundamentals to be worked out in order to use it in flight-critical or mission-critical applications.

Repeatability, consistency, and quality are the keys to reliable components that lives depend on, and those are the focus areas in additive printing now. Once those issues are solved, there's genuine potential to realize the 3-D vision.

Additive printing uses a machine to convert a digital, computer model of an item into the real thing. Using a variety of techniques involving heat, chemicals, and lasers, and on materials ranging from plastics to aluminum to stainless steel, the machine lays down cross-sections of the item layer by layer. Depending on the quality required, the process can take as little as a few minutes or several days. Each layer bonds with the previous one; in metals, the process can be performed so the resulting piece is a continuous medium without line breaks or cleavage points.

When finished, the result is a physical representation of what had been an intangible digital model.

The technology goes one better than computer-aided casting or machining, which starts with a block of material and whittles away everything not wanted. Three-D printing inherently uses only as much material as needed and no more, reducing the cost and cleanup of machining.

## Print in Plastic

There are "realizable, near-term impacts for using additive manufacturing for sustainment applications," said Jon Miller, a materials research engineer with Air Force Research Laboratory's Materials and Manufacturing Directorate.

Sustainment applications are items like fixtures, jigs, masks, tooling, and design aids. The latter is a printed prototype that engineers can work with to rapidly and inexpensively refine a design.

"I can print that geometry with a CAD [computer-aided design] file that didn't exist 50 years ago. I want to make sure it fits. I can print it in plastic. I can issue that reprocurement. This prevents rework," Miller told *Air Force Magazine*. For most parts, USAF spends "a lot of money," he said, to have fabricators work up prototypes, and they arrive months later. If a part is defective, that means more delay and more money.

Right now, Miller said, if he needs to cover the lights on an aircraft, he can just 3-D print some covers. Drill holes can be mapped out on a 3-D-printed sheet of plastic, their location precisely aligned, and a permanent template rapidly produced. For all of these small applications, 3-D printing presents what Miller calls a "very simple, easy fix."

These examples are for noncritical and nonstructural items, though. An airplane won't crash if one of these items fails. It's the critical safety items, or CSIs, that challenge 3-D's utility.

"We have to know what the worst one" in a run of 10,000 pieces will do, Miller said. The Air Force isn't "confident enough yet" about 3-D printing's ability to handle CSIs.

For some items, there's no doubt the technology will mature to the point of mission-critical reliability. For others, it may long remain an "if."

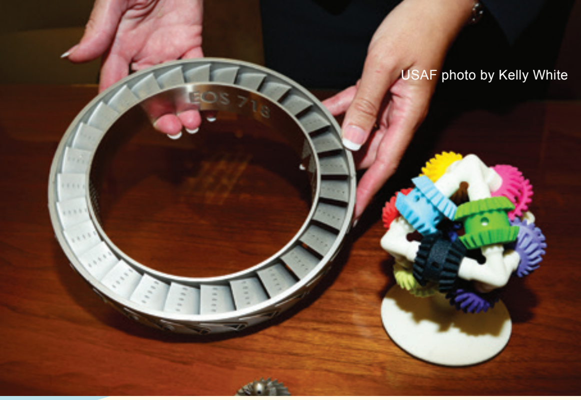
Only research can answer those questions, and Miller and his team are focusing on three areas: variability, quality assurance, and material integrity.

A recent example with a B-52 part illustrates the state of the art. Boeing has not made B-52s since 1962, and it stopped making "life of the airplane" parts not

# Can high-tech additive manufacturing solve USAF's parts obsolescence problems?


*Three-D prints of blower motors and impellers for B-52 avionics.*

Image courtesy of Elevate Systems



USAF photo by Kelly White

*Left: Additive manufacturing with a laser created the titanium part at left, while a 3-D printer made the colorful "Brain Gear" in one piece. Right: A typical 3-D printing setup, including a 3-D printer, a computer, and some examples of 3-D printed objects.*

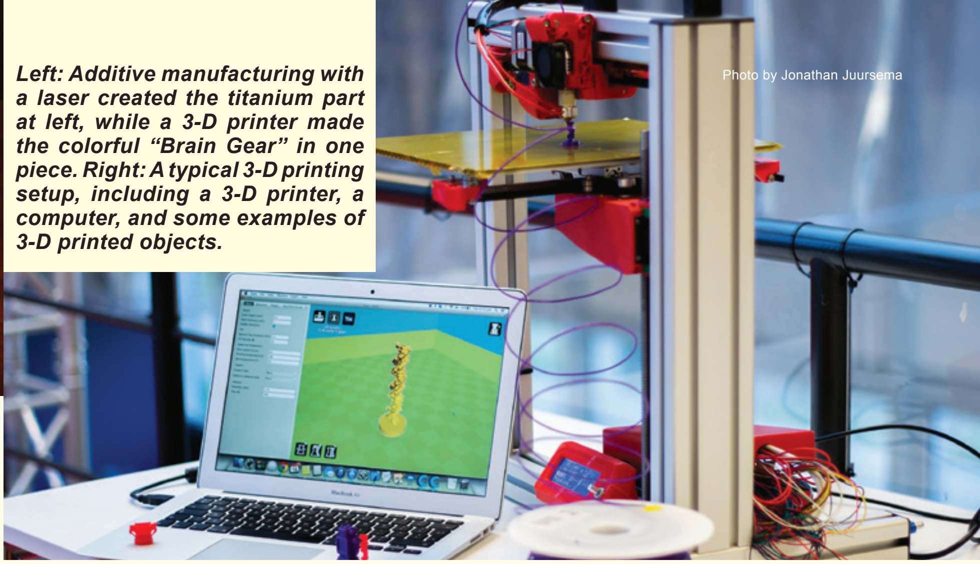


Photo by Jonathan Juursema

long after, because the B-52s were never expected to serve upward of 50 years.

Under contract with Tinker AFB, Okla.—the overhaul depot for B-52s—Elevate Systems reverse-engineered a part for the B-52.

Company President Scott Gray wanted to print it, he said in an interview, but didn't have a 3-D printer. His business then was creating blueprints used by other fabricators to make replacement parts.

Gray knew the College of Engineering at the University of Texas-San Antonio had recently purchased a 3-D printer. Once Elevate engineers made Gray a stereolithographic, or digital, model of the needed part—a blower motor assembly that cools the B-52's radar avionics during engine startup and taxi—he "just emailed it" to the university. Students at the school printed a thermoplastic (acrylonitrile butadiene styrene or ABS) model for him. It took four hours and cost about $150. They didn't charge him.

After Gray's model got tested and reprinted by different, and more sophisticated, printers, Elevate was able to get its blower motor onto 15 B-52s between January and October 2015. He expects there'll be more.

Elevate Systems now has three 3-D printers.

There's still some variability in the technology, and eliminating it is the key to printing CSI parts. The reality is that different printers—and sometimes the same printer—can create different products from the same CAD model and materials. That's unacceptable, Miller said.

AFRL needs a method to "prove that we can inspect the part sufficiently to prove that none of those defects exist," he said. Material integrity in this respect means figuring out how much variation in a part is allowable.

Once AFRL eliminates these and tangential unknowns, "the value of these opportunities depends strongly on the specific part geometry, part requirements, availability of engineering data, and economic factors for the conventional manufacturing approach," Miller said.

In the example of the B-52 component, after Gray had his $150 ABS plastic model in hand, he wanted a prototype print of the impeller (a component of the blower) in metal and sent the STL file to a company that printed a second prototype out of stainless steel. (This process uses stainless steel powder mixed with an aluminum alloy, called direct metal laser sintering or DMLS). The cost was about $600.

## LOWER COST

He then wanted to "bump it up a notch" and had a third prototype print made out of aluminum (in a process called selective laser sintering or SLS). That one cost $3,500.

This was getting expensive.

Tinker officials originally wanted the impeller made from aluminum, but Alex Villareal, Elevate Systems chief engineer, knew it could be made cheaper and lighter.

He thought of looking at thermoplastic, which could meet USAF's requirements and lower the cost. A material called Ultem 9085 fit the bill. Each impeller would now cost $350 and take between six and seven hours to print.

"We got that into our office and thought, … 'This is crazy,'" Miller said. Ultem 9085 isn't like aluminum exactly, but it's chemical- and heat-resistant.

Everything had to meet milspec—in this case including torque, vibration, volumetric airflow, and revolutions per minute. "Everything fell in line," Miller said.

It took a fraction of the usual time and cost. Traditional methods to reverse-engineer the part, do the production engineering, build jigs and fixtures, and establish a manufacturing capability would have cost about $10,000 and taken months to produce, by his estimate.

The real beauty of Gray's motor, however, became apparent when it failed in the early phases of development. Gray's people were scratching their heads when the finished motor wasn't doing its job. They had reverse-engineered the part exactly as it had been made 60 years before. What could be wrong?

"We didn't know why it was failing," he said, but his company had been given only the part—and no data about it.

It finally became apparent that the part they'd been given to model was, itself, defective. "The spacing of the vanes on the impeller was so close together, it was suffering restrictions of airflow in the housing," Miller said. That caused a torque problem, in turn "causing an over-amping issue, causing the motor to burn out," he explained.

Working this out through the traditional procurement methods would have cost "a lot of money," Miller said. With 3-D printing, Gray's team fixed the trouble in 20 minutes.

"I had it in my hand the next day," he said. It passed all the tests.

This successful failure, so to speak, exemplified the intrinsic value of having what Miller calls an "alternative manufacturing process."

Additive manufacturing, he said, is another tool in the industrial toolbox and "may offer an alternative manufacturing process for improvement in lead time, cost, or component performance, depending on the specific application."

Asked about its role in how USAF designs parts for future systems, he said there's "strong potential." ✪