

DETAILS IN



**How Mike Lambert used technology
to make his airplane his own**

BY HAL BRYAN

"I DON'T KNOW HOW I would've built an airplane without access to a 3D printer," said Mike Lambert, EAA Lifetime 638976, who recently finished an RV-14.

I've known Mike as a friend and former colleague for many years. Even though we have technology backgrounds and early-adopter tendencies in common, that bold statement really caught my attention.

Mike's aviation story is loaded with full-circle moments, a collection of previews and payoffs.

When he was about 12 years old, he flew home to Seattle from visiting friends in Mexico as an unaccompanied minor. During that trip, the airline cabin crew walked him onboard and took him up to see the cockpit.

"That was my first moment where I thought, 'I want to be around this stuff, and I want to fly one of these,'" he said.

As I write this, Mike has been a pilot for a major airline for nearly 15 years. He is currently training as a check airman on the Boeing 787.

After that cockpit visit, unsurprisingly, he spent a lot of time immersed in early versions of Microsoft Flight Simulator. In his mid-20s, after graduating from the University of Hawaii with a mechanical engineering degree, he worked on landing gear systems at Boeing for three years. He then started a rewarding nine-year stint at Microsoft working on, you guessed it, Flight Simulator.

In high school, he worked on the line crew at Kenmore Air Harbor. As a teenager, he was hoisting de Havilland Beavers out of the (salt) water on forklifts so they could be washed every day.

"Probably the most stressful thing I've done in aviation," he said.

He came back to Kenmore years later and became chief pilot of the airline's landplane operations.

In between those bookends, he took his first introductory flight at Snohomish Flying Service at Harvey Field, northeast of Seattle, with the late Arnold Ebnetter. Arnold is a legendary instructor whose one-off E-1 set the record for the longest nonstop flight in a home-built. The airplane is now proudly displayed in the EAA Aviation Museum. Years later, Mike ended up working for Arnold, instructing and flying skydivers.

Several years ago, Mike's sons Chris and Nick started showing an avid interest in



flying. Mike decided it was time to build an airplane. He considered an RV-8 but ultimately selected the -14 because of the side-by-side seating that he preferred for flying with his sons. He ordered the tail kit and started building in May 2018.

"I got the tail kit right away," Mike said. "The build was going so fast, because Chris and I were building every day, that I thought that this was going to be super fast. And, so, I ordered the wing kit and fuselage kit within months of starting the tail kit."

Mike got the tail and fuselage joined within six months.

"That did go fast, but from then on, it didn't," he said. "Which is part of the story because that's when I started going down the path of customizations."

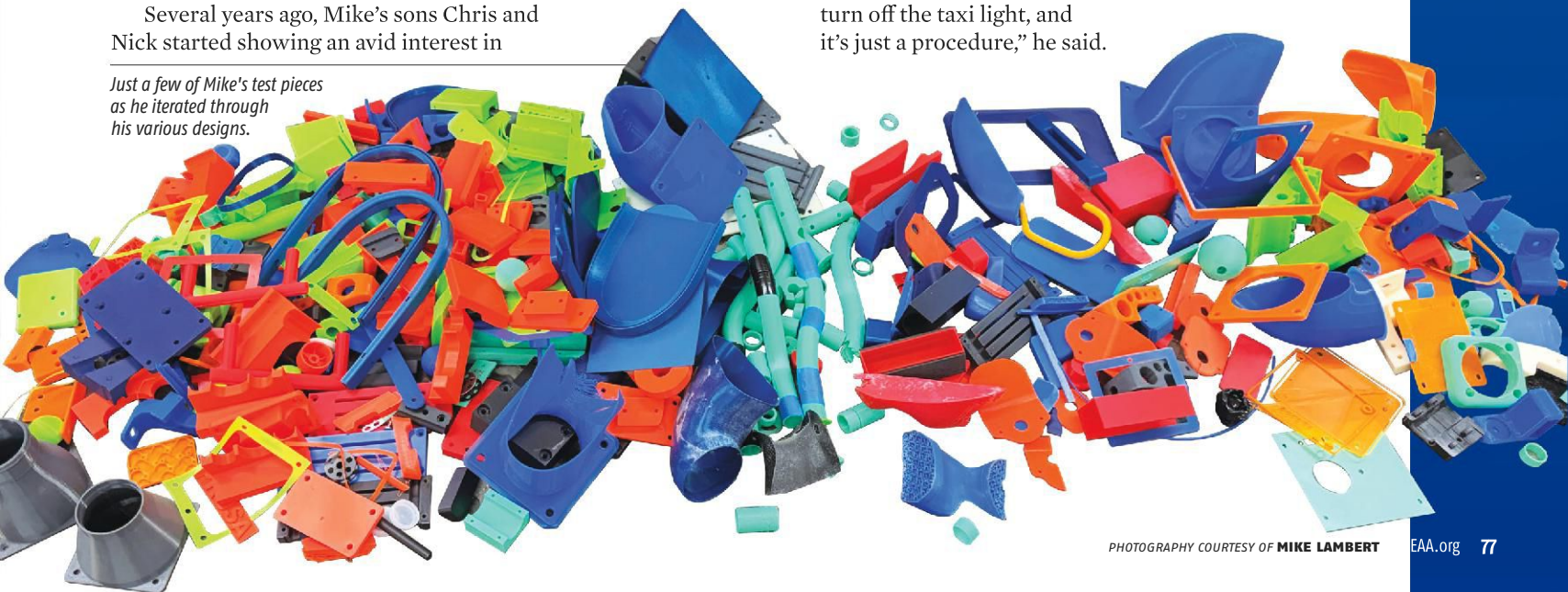
When Mike says "customizations," he's not talking about changing anything major on the airplane, nothing structural or anything like that. He has nothing but praise for Van's Aircraft, the quality of the kit, and the clarity and detail in the drawings and instructions. He just found himself with first the desire and shortly thereafter the means to make a series of detailed changes, some inspired by his airline career. He's the first to point out that his tweaks and bits of polish don't necessarily make the airplane better, they just make it more his.

"A lot is left to the planning and imagination of the builder," he said. "For example, the panel design is completely up to the builder, and all of the components behind the panel are up to the builder as well. So, in a sense, all builders have to do a lot of customization and personalization when it comes to the inside of the cockpit. Figuring out where things go and how to interconnect them is part of the fun."

One of the things Mike wanted in the RV-14 that not all builders opt for was a parking brake.

"[I was] motivated by airline things, like when you come to a stop, you always set the parking brake and turn off the taxi light, and it's just a procedure," he said.

Just a few of Mike's test pieces as he iterated through his various designs.



“So, I do the same thing with my RV-14. I come to a stop, I always set the parking brake, and turn off the taxi light.”

With a little help from his son, Mike got to work designing an internal mount for the mechanism.

“I designed the mount for the parking brake valve,” he said. “I designed it using SOLIDWORKS through EAA. Nick, my older son, he’s an engineer, so he knew how to run it.”

Once he had a design in mind, Mike reached out to fellow airline pilot and RV builder Steve Tschurwald of Aircraft Specialty Flightlines in Wisconsin. Mike had worked with Steve on a reoriented fuel selector and later beta tested several complete sets of fuel and brake lines Steve was developing. Mike sent the design to Steve, which led to the first half of an epiphany.

“The next thing you know, he’s printed something and put it in the mail,” Mike said. “And then here I am, a couple days later, installing it and testing it. And it finally hit me because 3D printing’s been around but kind of left me behind. I wasn’t into it until I saw the magic of it.”

It’s important — no, vital — to point out that what Steve sent Mike was a mock-up in plastic just to test the fit and placement of the mount.

Steve was using PLA, or polylactic acid. PLA is an easy-to-work-with plastic filament that is biodegradable and inexpensive — see sidebar on page 82.

“It was just prototyping stuff, not designed to be strong ... because ultimately it would be an aluminum part,” Mike said.

Mike refined the design, sent it to Steve, and Steve printed another prototype and mailed it to him. After a few iterations, it was perfected and off to the machine shop to be done in aluminum. The final iteration includes a microswitch to indicate parking brake status on one of his three Garmin G3X displays.

“It’s a lot cheaper to get it right 3D printing and then send it to the machine shop to be made from aluminum,” he said. “There’s no mistakes at that point. They’re really going to machine a part that will fit.”

Mike’s next project was driven by his desire to add small electric fans to the NACA intake-fed air vents on the instrument panel. The vents do a great job of keeping the cockpit cool when you’re flying, but they don’t provide much airflow on the ground when you’re taxiing. He didn’t have any interest in the added weight and complexity of an air conditioning system, just something to help during taxi.

“It’s just the test cases on the ground, where it’s miserably hot, and I’m about to take off,” he said. “I’d like to keep the canopy closed and locked; that completes the checklist.”

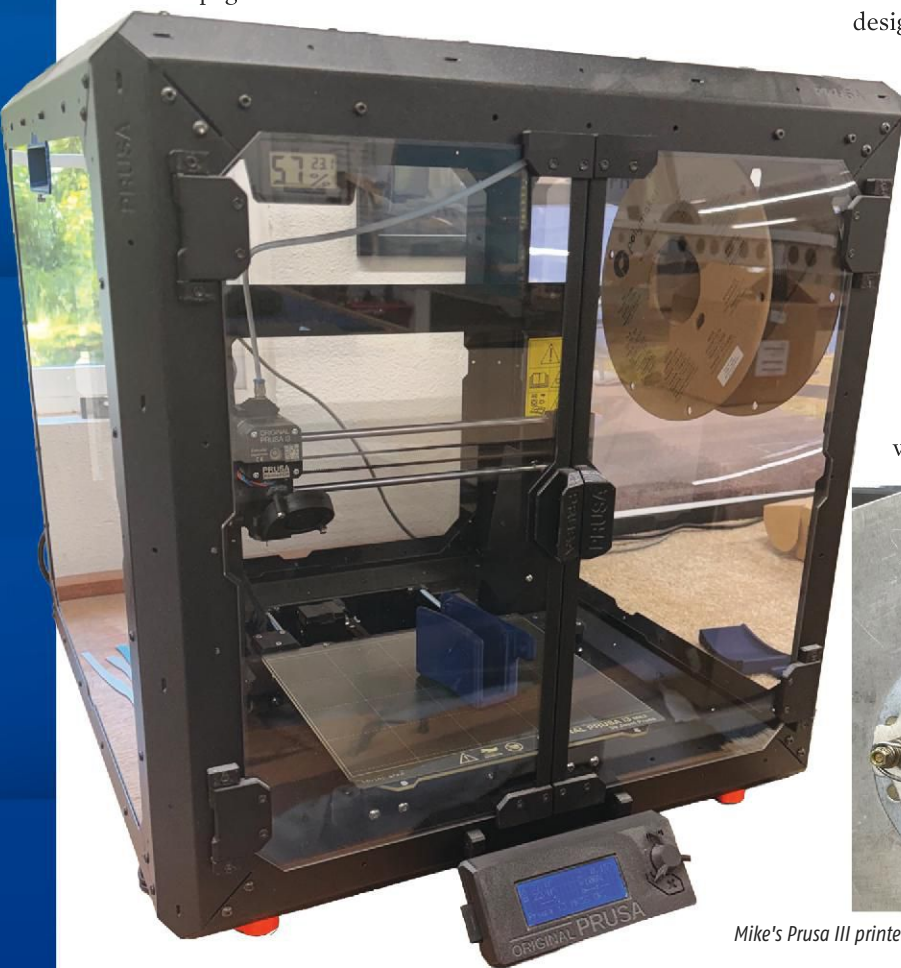
Mike sourced a pair of 50-millimeter DC-powered electric fans, but it’s not like he could simply plug them into the vents.

“It was like a round hole, square peg type thing,” he said. “So, I designed basically an adapter from a square fan to a round vent. And, so, that sounds easy, but that was a hard thing to figure out as far as the 3D modeling, and that was really good. I like the challenge of 3D modeling. It’s kind of fun.”

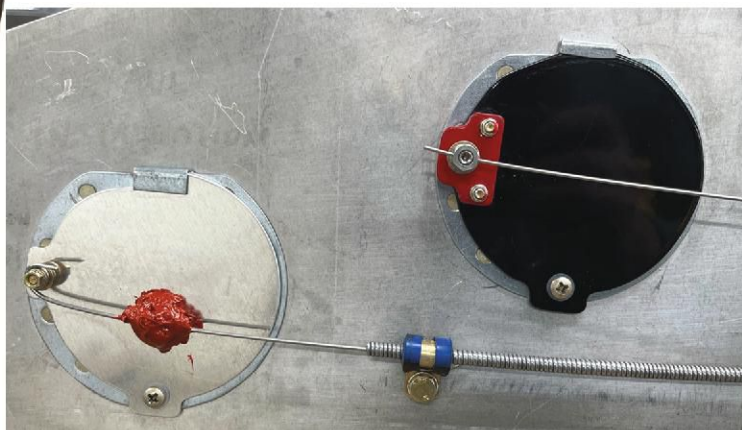
He and Steve started going back and forth again. Getting the adapter just right took three tries — and that’s when Mike asked himself a question that would change the rest of his build.

“How much are these printers? I don’t want to just keep asking Steve to send me everything I want to print,” he said. “I can just get my own and print my own mistakes multiple times until I get it right. So, that’s when I decided, yeah, I need my own printer.”

He decided to invest in a Prusa MINI printer. Prusa, along with companies like Bambu Labs, Creality, Elegoo, and others,



Mike's Prusa MINI printer



Alternate air door

has made great strides in making this technology affordable, accessible, and increasingly reliable.

“Out of the box, the thing is just solid,” he said. “Probably the best set of instructions I’ve really ever worked with.”

After he had the printer set up, he was off and running.

“Once I had my own, there was no limit to how many iterations I’ll print,” he said. “It helped me get things in hand and visualize things that eventually turned into things made out of metal.”

As his skills developed, Mike continued to find ways to use 3D printing to prototype and test-fit new parts, including a mold for an air intake, a hose pass-through for a smoke system, templates for access doors to wing-mounted cameras, and redesigned brackets for the alternate air door and a custom cooling flap. “I sometimes call it a cowl flap because that’s what it acts like, but it’s not on the cowl; it’s on the fuselage,” he said. “So, it’s technically not a cowl flap.”

One of his biggest projects also became his favorite.



SPECIFICATIONS

AIRCRAFT MAKE & MODEL: Van's Aircraft RV-14

CERTIFICATION: E-AB

LENGTH: 21 feet, 1 inch

WINGSPAN: 27 feet

HEIGHT: 8 feet, 2 inches

MAXIMUM GROSS WEIGHT: 2,050 pounds

EMPTY WEIGHT: 1,300 pounds

FUEL CAPACITY: 50 gallons

SEATS: 2

POWERPLANT MAKE & MODEL: Lycoming IO-390

HORSEPOWER: 210

PROPELLER: Hartzell two-bladed, constant speed

CRUISE SPEED/FUEL CONSUMPTION: 168 KTAS/9.5 gph

POWER LOADING: 9.8 pounds/hp

WING LOADING: 16.3 pounds/square foot

V_{NE}: 200 knots

V₅₀: 51 knots

V_X: 70 knots

V_Y: 95 knots



“Of my own innovations that I installed, the one I’m probably most proud of is the center console with the throttle quadrant,” he said. “I spent a lot of time just sitting in my plane when there was very little in the plane except seats, and just going through the concept of where should this be, where should this be? And nothing against Cessna push-pull throttle prop fixture, but the throttle quadrant is really what makes it feel right to me.”

He spent a lot of time iterating on the knobs, printing multiple prototypes until they felt just right in his hand before committing to the final design. That led to a flattering piece of feedback.

“They’re all anodized — black, blue, and red,” he said. “Steve, the guy that manufactures what I print or what I design, he says, ‘Well, if I’m going to make one set for you, I might as well make 100 and sell them.’”

Just aft of the throttle quadrant, the console and armrest add to the polished look of the cockpit.

“The storage portion of the console is built with carbon fiber, just my chance to get some experience building with carbon fiber, and then it’s molded together with a 3D printed bracket,” he said.

His sister Laura stepped in and stitched the leather covering for the armrest/lid. Her skills also came in handy when Mike wanted a custom glareshield.

“She’s been sewing professionally since high school, so she’s got industrial sewing machines,” he said.

After multiple iterations, the finished glareshield, complete with LED underlighting, adds a lot of polish to an already professional and well-organized cockpit. When one of Chris’ former professors heard about it, he wanted one, too. That experience ended up helping Mike learn a good lesson.

“I go down there, install a glareshield on his, and at the time I just had rings printed in 3D that held the glareshield in position, and they melted in Palm Springs,” he said. “So, well, okay. 3D printing is cool, but it doesn’t work everywhere. These should be aluminum, and look professional, and that was like, oh, okay. I found the limit there.”

As Mike progressed on the build, he upgraded his 3D printer to a larger Prusa Mk. 3.

“[It has] an enclosure, and so I can print more exotic materials that don’t melt in the sun,” he said.



Cockpit in progress



3D-printed knob prototypes in place for review



Headset module mount with wire track

“It’s a lot cheaper to get it right 3D printing and then send it to the machine shop to be made from aluminum. There’s no mistakes at that point. They’re really going to machine a part that will fit.”

— Mike Lambert

So, for noncritical components, including things like the bracket inside the center console, a headset hanger, and a little clip mount for the headset's volume control module, Mike is now able to produce the final product himself.

“What I’m using now for anything that goes in the airplane is ASA,” he said, referring to acrylonitrile styrene acrylate, a 3D printer filament that is extremely strong and highly UV-resistant.



3D Printing for Absolute Beginners

THE IDEA OF 3D PRINTING IS SIMPLE — creating an object that replicates a digital file through the precise layer-by-layer application of material. You can think of it like a computer-controlled hot glue gun precisely extruding a single strand of plastic multiple layers. However, it's only been in the last few years that the technology has become affordable enough to find its way into the homes of casual users.

While there's still a fair amount of trial and error, and printing a 3D object in plastic isn't as simple as printing a Word document on paper, it really has gotten remarkably accessible.

Before we go any further, bear in mind that, in our world, home-based 3D printing is meant primarily for rapid and iterative prototyping to test-fit components, making small jigs and templates, etc., and potentially creating some noncritical things like a phone holder or cable clip. It is not for producing actual aircraft-grade parts.

As with any new technology, 3D printing comes with its own lexicon and can seem overwhelming when you're just getting started. Here are some things to know if you're thinking about taking the plunge.

Material Types

Consumer-grade 3D printers generally use spools of plastic called filament that is fed into a heated nozzle that melts it at a controlled rate. In addition, there are some excellent printers that use liquid resin instead of filament, which offers finer detail but requires additional equipment and effort and is a lot more complex, so we'll focus on filament printers.

The most commonly used filament is polylactic acid (PLA), which is a good all-around biodegradable plastic that is inexpensive and easy to work with.

That said, PLA can deform in the sun. While we're not producing actual aircraft-grade parts, if you want to print things like tablet mounts or headset cable clips, consider something stronger and with better heat resistance than PLA, like polyethylene terephthalate glycol-modified (PETG), acrylonitrile butadiene styrene (ABS), or acrylonitrile styrene acrylate (ASA). These filaments work essentially the same way, but they offer more heat resistance and require different settings on your printer.

Size

The size of the objects you print is based on the printer's build volume. Popular and affordable entry-level printers like the Bambu A1 mini and the Prusa MINI+ have build volumes of 180 millimeters by 180 millimeters by 180 millimeters, which is slightly bigger than 7 inches cubed. The build volumes go up from there, as do prices.

Speed

While a simple square with holes in it to mark drilling locations may print in 15–20 minutes or so, most print times are measured in hours. Generally speaking, the higher the maximum speed of the toolhead (the component that moves the nozzle around and does the actual printing), the faster the print. An entry level printer's toolhead might max out at 500 millimeters per second, while the top

of the line unit hits 1,000 millimeters per second. Faster can be better, but it's always more expensive.

Colors

For our purposes, there likely isn't any pressing need to print more than one color at a time. However, even entry-level printers can be easily and affordably upgraded to do four-color prints, which lets you do fun things like make coasters with your chapter logo on them. And, of course, the more expensive units can do even more colors.

Nozzles/Hot Ends

3D printer nozzles, also known as hot ends, come in a variety of sizes and material types. Simply put, the larger the nozzle, potentially the faster the print but the lower the detail. It's primarily the nozzle that defines the "resolution" of the print.

Typical nozzles range from 0.2 millimeters up to 0.8 millimeters, with 0.4 considered the best tradeoff in terms of speed and quality.

Generally speaking, hot ends are made from either hardened or stainless steel. Hardened is more durable for specialty abrasive filaments while stainless generally offers better print quality because of its improved thermal conductivity.

Build Plates

This is a metal plate on which the printer actually prints. There are different varieties of textured and smooth plates that give a different finish to your printed parts, as well as plates with different adhesion properties, which are designed for different temperature ranges, etc.

Health and Safety

Obviously, when you're melting plastic, you're dealing with high temperatures — using PLA, the nozzle can range from about 375 degrees to 425 degrees Fahrenheit. The print bed is also heated, and while not as hot with a typical range of 120–140 degrees Fahrenheit, that's still hot enough to cause a second-degree burn in 3–5 seconds. Just wait until things have cooled down before removing your print or changing nozzles, etc.

Realistically, most people leave their printers unattended during long prints, so make sure they're plugged into surge protectors and set up on fire-retardant materials, in a room equipped with a smoke detector and proper fire extinguisher. A smart plug that you can turn off remotely is also a good idea, as is a metal enclosure, which several of the popular printer companies offer. Those enclosures offer some fire protection while also controlling the fumes and ultrafine particles that are released by the melting filament.

While PLA is considered to be extremely low risk, no matter what filament you use, proper and active ventilation, ideally exhausted to the outside or through a HEPA filter, is absolutely mandatory. Bear in mind that you might be sanding these parts as well, so take the usual precautions there, like dust masks, etc. Common sense rules the day.

Software

That briefly hits the high points of the hardware side of 3D printing, but that's only one piece of the puzzle. You also have to have something to print, and a way to prepare it for and send it to the printer.

When you get started, the first things you print will likely be files created by somebody else. The printer will include some test files so you can verify that it works, so at the very least you'll start there. From there, spend some time online and take a look at files that other people have designed and shared. Some printers, like the Bambu series in particular with MakerWorld, have their own large free online file marketplaces. Independent sites, like Thingiverse.com, are loaded with even more.

It all, of course, depends on what you're looking for. Thingiverse, for example, has a few interesting things for RV builders, including bell crank templates and various jigs, cradles, and support blocks that can be helpful during the build. A quick search of VansAirForce.com shows that a lot of their members have shared files there as well. In some cases, you could print the file yourself as a prototype to verify fit and, as Mike has done several times, have the part machined in a suitable material for actual aircraft use.

At some point, though, you'll discover that what you need doesn't exist, and it'll be up to you to design it. If you have some experience with CAD (computer aided design) software, then you're all set. Just about any current CAD program out there — including SOLIDWORKS for Makers, which is available to EAA members at a 50 percent discount — can generate files that can be sent to your 3D printer.

If you've never worked with CAD software, then check out Autodesk's TinkerCAD at TinkerCAD.com. This is a web-based CAD application that, in spite of the fact that it is targeted in part at kids, is robust enough to get you started on some basic parts. Perhaps more importantly, it will familiarize you with the overall concepts and tools involved in 3D design. There are multiple tutorials that start you at the beginning, and they're worth doing.

There are also a number of tools out there that can take a 2D image and convert that to a 3D-printable part. While this might work for simple things like a hole template, to really take advantage of your printer during an aircraft build, you're best off investing the time to learn CAD.

Finally, you'll need a piece of software called a slicer, which should be included with your printer. This is a program that imports the 3D file you've downloaded or created and then translates it into compatible instructions and sends those to your printer. The slicer is where you choose filament types and colors, and adjust settings for quality, speed, etc. You'll use the slicer to specify things like the density, and you'll learn how to orient the objects you print for strength and efficiency. You can also do some rudimentary editing in the slicer, such as adding simple shapes or text, resizing, and duplicating designs so you can print multiple copies in one session.



Camera holder

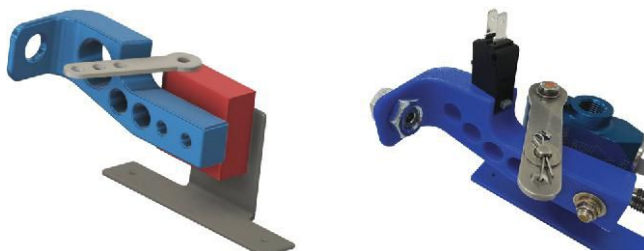
Wire pass through

For Mike, one of the biggest benefits of 3D printing on this project was also one of the simplest.

"If you were going to drill four holes into something and it was something custom, and you were going to take the tape measure out and get those four holes exactly perpendicular and parallel and lined up and all that," he said, "I could not imagine doing that without doing it first in CAD, creating a little plate of these four holes as a template, and then locking this into position and then drilling the four holes — and now they're perfect. Anybody can do that."

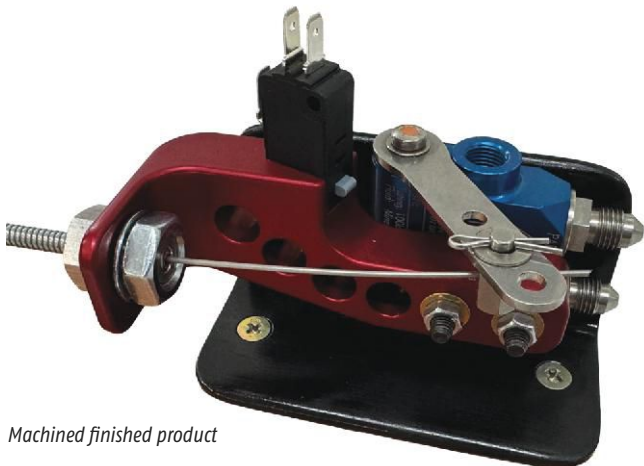
Finally, the printer went quiet, the last page of Van's instruction manual was reached, and the project became an airplane. Mike prepared for the first flight by doing two three-day sessions of transition training with Van's Aircraft's Mike Seager, EAA 371232, as well as flying with other RV builders, including his longtime friend Dennis

Parking brake assembly



CAD screenshot

3D-printed prototype



Machined finished product





3DP mold for air intake

“Once I had my own, there was no limit to how many iterations I’ll print. It helped me get things in hand and visualize things that eventually turned into things made out of metal.” — Mike Lambert

Jones, EAA Lifetime 414466. Dennis completed his RV-14A about six months earlier.

“I didn’t have a right-seater. I just flew by myself,” Mike said. “For the first flight, Dennis flew chase in his RV-14A, and then we met at Paine Field [KPAE]. I wanted my first landing to be on a long runway, so we landed at Paine Field, and then he and I flew nearly every test flight together for the 40 hours.”

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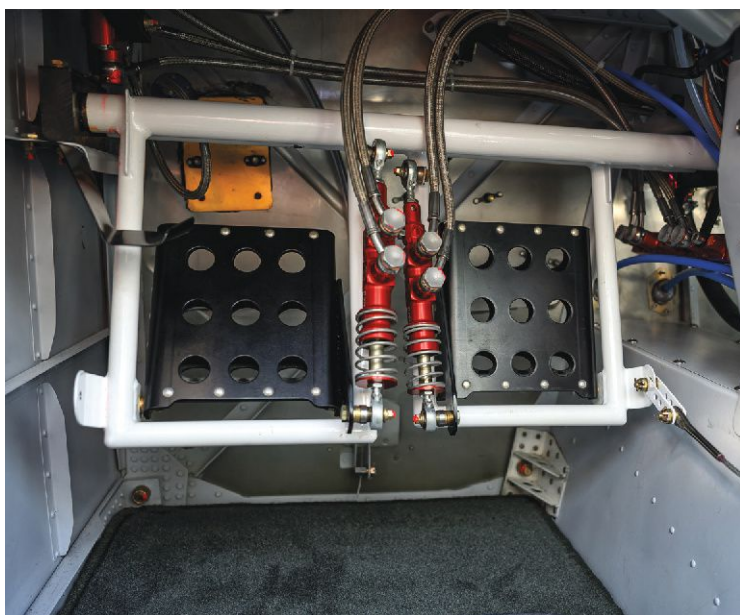
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As his skills developed, Mike continued to find ways to use 3D printing to prototype and test-fit new parts, including a mold for an air intake, a hose pass-through for a smoke system, templates for access doors to wing-mounted cameras, and redesigned brackets for the alternate air door and a custom cooling flap.



That first flight went the way all builders hope they do. “Everyone tried to tell me, ‘Make it as normal as possible, don’t tell anyone you’re doing it, don’t make a ceremony out of it, just fly the plane,’” he said. “So, my first flight was quite boring. Nothing happened.”

Once the hours were flown off, Mike worked with Evoke Aviation on the paint scheme, which was then applied by SunQuest Air Specialties. Now Mike and his sons spend their time enjoying the airplane, including bringing it to Oshkosh.

Do you actually *need* a 3D printer to build an airplane? Of course not. No more than you need a kit instead of just a set of plans, a magenta line to get from point A to point B, or anything other than an E-6B to figure out fuel burn and wind correction angles. But, as technology marches on, conscientious builders and pilots will at least consider all of the tools in their toolbox. Mike is hardly the first person to make use of a 3D printer when building an aircraft. In fact, some of the first commercial and industrial uses of the technology were to build tooling and jigs for aerospace manufacturing, as far back as the late 1980s. But, for him, the idea shifted dramatically from presumed novelty to seeming necessity as he built his airplane. “I didn’t even really do anything with 3D printers before I started building an airplane, and then by the end of the project, to me, it became as necessary as a wrench,” Mike said. “And 3D printing may not be the final solution, but it gets you to something that’s tangible. You can hold it in your hand and say, yeah, I like this. Or this should be like this, and with a little effort, I can modify it, and then just within hours I can have a new version of it. The satisfaction of that is super high.” *EAA*

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