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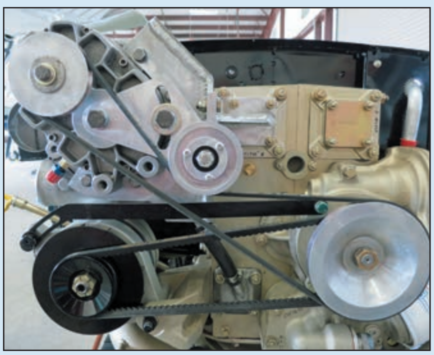

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DYNON INSTALLS: HOW'S IT WORKING?

Last year Dynon Avionics took a different approach to avionics installations by approving A&P mechanics to install its SkyView HDX Certified integrated avionics. To review, the capable SkyView Certified equipment is essentially the same basic platform as the company's experimental SkyView HDX, but has an AML-STC for certified aircraft. Instead of setting up a large dealer network of avionics shops (generally FAA repair stations), Dynon leaves it up to the aircraft owner to nominate a qualified A&P mechanic with IA credentials to do the installation (or install it themselves if qualified). Once Dynon verifies that the mechanic has a valid IA certificate, he or she is listed in the STC as the official installer. The AML-STC has grown to over 600 models, which was initially limited to Cessna Skyhawks. I followed a Dynon project in a Cessna and you can link to the video at tinyurl.com/v66jykb and read about it in the July 2019 *Aviation Consumer.*

The approach had many in the industry skeptical. After all, many A&P mechanics will admit they don't have the experience to complete a complex integrated avionics install in the amount of time that a customer might demand. But there are plenty of skilled A&P/IA mechanics who have installed Dynon and other avionics in experimental airplanes and these are the ones who have tackled these projects. And yes, some have taken a long time to finish them because of shop workload and the learning curve. I talked with Dynon's Michael Schofield who told me that Dynon has been building its installation network (there are 20-something shops—not necessarily avionics shops—set up as HDX Certified centers) with the goal of increasing install volume, which to the end customer means a more affordable upgrade. One way to do that is make install easier.

"We realized we weren't advancing the second part of the HDX Certified product, which was the affordability and simplicity of the installation," Schofield admitted. That should be easy to do because after all, Dynon has years of experience catering to homebuilders who don't have the experience and skill of a professional avionics installer. It already provides prefabricated wiring harnesses that connect the SkyView displays and it's something that's being expanded on for more components in the certified version of the SkyView network, including Dynon's transponder and radios. I like the idea because it could take someone twice as long to pin a connector than it would an avionics tech. Eventually Dynon might have more harnesses that are completely prebuilt and ready to go. Bench time spent wiring the input/output serial data ports, power and ground connections and troubleshooting pin connections adds up. Dynon is also working to reduce the time it takes to mount remote components (the ADAHRS and ARINC modules, as two examples) by providing mounting trays that are pre-drilled to accommodate them, so the installer won't have to make room for them elsewhere behind the panel. Install kits will come with more small parts, including bolts and fasteners so the installer won't have to provide them. Schofield used the IKEA furniture example, where many products come with everything you'll need for a quick assembly. It's also reworking manuals for more efficiency.

Dynon realizes that it can't do much for the challenge every installer will face and that's removing old components (without hacking up the harnesses so the owner can resell the equipment) and prepping the airframe for the new Dynon suite. But streamlining the install to make up for that time spent will help. Worth mentioning is that Dynon acquired Advanced Flight Systems, which fabricates complete panels for homebuilts using its Advanced Control Module, or ACM, which is a power and wiring distribution hub with electronic circuit breakers. This makes for a plug-and-play installation of the Dynon SkyView and third-party components, including GPS navigators. This hub concept will work in certified installs, too.

I think Dynon's SkyView Certified system has been a success and the improvements it's making to curtail the install process will give it the competitive price edge in a sales climate now facing serious challenges. —*Larry Anglisano*

CARDINAL RG ENGINE MOD

How come you guys left out the Lycoming IO-390 STC performance mod in the March 2020 *Aviation Consumer* Used Aircraft Guide for the Cessna Cardinal 177RG? Please publish as us aviation performance nerds would like to know what that engine does for climb and cruise performance in this airplane. Love the magazine and all that you report in sister publication *AVweb.com*.

Brian Burton
via email

We're not sure how we missed that. It's been a while since we've flown one, but in general you can expect shorter takeoff runs, an extra 130-FPM climb rate and a couple of extra knots in cruise from the 210-HP four-cylinder Lycoming IO-390-A1A6.

The beauty of the mod is that it's pretty much a plug-and-play upgrade, meaning you can use the engine mounts, exhaust, fuel lines and even the original propeller left over from the removed 200-HP IO-360. It even fits under the old cowling, although cooling issues left 1971 and 1972 model-year RGs out of the STC. You will need some other hardware, including an oil cooler and lines, which add to the cost and the installation effort.

As for pricing, this could easily be a $50,000 mod for a new IO-390, which includes a Unison Slick Start ignition booster. But an IO-390-equipped 177RG should fetch more money at resale, plus the engine has been reliable.

GARMIN G3X TOUCH COMPATIBILITY

I took the big plunge and am currently having a Garmin G3X Touch integrated avionics suite installed in my Cessna TR182, saying goodbye to my old King KCS-55A HSI.

Part of my upgrade decision was that I already had a Garmin GNS 430W navigator and a Garmin-AT SL 30 navcomm in the plane, and understood (according to Garmin sales material) that they would both play with the G3X Touch. I also have an S-TEC 55X autopilot.

Apparently, somewhere along the road there has been a software change and with a third-party autopilot the G3X Touch will no longer support both the GNS 430W and the SL 30 nav. It supports the SL 30 comm, but not the nav. Purportedly, somewhere down the road a software revision will be released to correct this. Deep in a revision of the installation manual it states this new non-compatibility. My avionics shop told me they found this out the hard way after previous installations had compatibility issues. My shop is wiring up the SL 30 nav to the G3X Touch in anticipation that this will eventually get corrected.

Still, I found this out mid-installation and don't have a good taste about the whole thing. I love *Aviation Consumer* and it's been a major influence on quite a few of my purchases. Keep up the good work.

WD Lewis
San Carlos, California

We asked Garmin about this and were told the G3X Touch does not support nav source selection for non-Garmin autopilots. Therefore, when a non-Garmin autopilot is interfaced to the G3X system, only one external navigator (GPS and/or VHF) can be connected to the G3X Touch. A second external navigator, if installed, must retain its own dedicated CDI display.

The main reason for the limitation is that the FAA won't allow a scenario where the autopilot is flying from a nav source that is different from what is being displayed on the G3X PFD (in other words, the autopilot is flying something different from what you're looking at on the display).

USED HOMEBUILTS

Thank you to Larry Anglisano for sticking up for purchasing used homebuilts—and for promoting local EAA chapters—in his First Word column in the April 2020 issue of *Aviation Consumer*. I've built my own and purchased existing completed kits and he's right that you need a good eye when buying something someone else built.

He's also correct that a Van's Aircraft RV-6A can make for a good used homebuilt because there are a ton of them in the field. But he botched the model line, or at least got the models reversed. The RV-6A is the one with the tricycle landing gear, not the straight RV-6. Thanks for your good work.

Herman Fishmann
via email

On The Cover: **That's a Cessna Skyhawk instrument panel sporting some of Garmin's new GI 275 retrofit electronic flight instruments. The idea behind the GI 275 is an easy upgrade of mechanical round-dial instruments without having to cut the panel—or the plastic overlay that covers it. We cover them and other choices in the budget IFR upgrade article starting on page 4.**

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That's one of our test beds sporting a pair of Garmin G5 flight instruments, a pair of Garmin GI 275 flight instruments, a Garmin GNX 375 GPS navigator with ADS-B transponder and uAvionix AV-20.

IFR On A Budget: The $15K Upgrade

Take a modern but utilitarian approach. That means downsizing the EFIS and scaling back nav capability. Garmin's GI 275 is a compelling choice.

by Larry Anglisano

It used to be that equipping for legal instrument flight meant buying radios with glideslope and adding pitot heat. And while the equipment requirements in the FARs have changed little over the years, the technology sure has. These days entry-level EFIS and GPS navigators come well-equipped and approved for IFR, and even if you don't actually plan to fly IFR, the equipment you bought is up to the task. In some ways, that makes the buying decision easier.

On the other hand, the market for retrofit EFIS and GPS navigators is crowded, and it's easy to over-equip (which means overspending) for basic IFR flying. In this report we'll backstop the buying decision and focus on the latest entry-level gear you might use for instrument training, light IFR, flying GPS approaches and as a bonus, also adding a healthy dose of digital reliability to an aging analog panel. The goal is to keep the total buy-in to a realistic $15,000 price point. (We'll never say avionics upgrades are cheap, but they may be cheaper than ever before thanks to competition.) To prepare you for gathering installation price quotes, herewith are our top-pick options to consider.

SMALL-SCREEN EFIS

Since the goal is a utilitarian, money-saving approach, settle on smaller displays. As appealing as a big-screen EFIS retrofit may be, it won't be low budget or easy to retrofit because of the metal work that's required to fit the display. But several entry-level EFIS models tame that dragon with a form factor that slides into the existing round-gauges cutouts. Let's start with Aspen Avionics, a company that pioneered the idea of a no-cut EFIS upgrade.

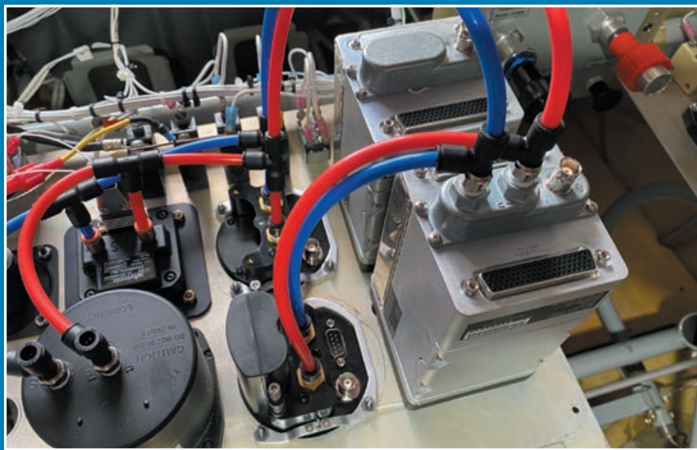
The budget-priced Aspen EFIS is the Evolution E5, which trickles down from the company's flagship Evolution Max system. While it's de-featured to save money, it still comes with Aspen's new and improved display technology that's years ahead of the original Evolution display. It's brighter, the onscreen data is easier to read and it has more failsafe backup.

Aspen was able to bring the price of the E5 down to $4995 (compared to $9995 for the flagship Evolution 1000) by sidestepping the TSO process in favor of an STC with approved model list (AML-STC), which is a blanket installation approval for hundreds of aircraft models. That STC, when installed per the manual, also includes the green light for removing the aircraft's vacuum system—a popular trend for obvious reasons.

But this isn't an all-glass makeover. An E5 installation means you'll retain the airspeed indicator, altimeter and turn and bank instruments, while the E5 instrument will occupy the 3-inch attitude and DG instrument holes. The E5 (like all of the Aspen displays) is one self-contained instrument that can be installed in most panels without cutting or modifying the metal. But installation won't be a while-you-wait affair. It requires the installation of a remote sensor module (RSM), which is an external heading and position sensor that's mounted much like a GPS antenna on top of the airframe.

The E5 is intended for basic IFR panels and as standard it won't have autopilot interface without buying Aspen's optional ACU, which is an analog converter unit that converts the autopilot's signal inputs to a digital format. This will add $1000 to the price, not counting installa-

SPACE MATTERS



One of the goals with any modern avionics upgrade—especially in aircraft with avionics that haven't been touched in years—is tidying up the space behind the instrument panel. Any avionics tech will agree that time and money spent to do that now will save time when they have to get back in to the suite to add wiring and components as the interface potential matures. From a cleanup standpoint, nothing frees up space more than removing the vacuum system, and that's just what you can do with any of the budget EFIS systems we cover in this article. The photo in the upper right is the vacuum plumbing removed from a Lycoming O-360, which shedded nearly 15 pounds from the aircraft including the instruments and the pump. The other photo to the left shows the chassis of these new instruments. Moving from right to left, the larger ones are Garmin G5s, the ones in the middle are Garmin GI 275s and to the far left is a mechanical airspeed indicator and uAvionix AV-20. The blue and red tubes plumbed in are pitot/static lines.

tion. This component is included in the Evolution 1000 Max because that model was designed for more advanced interfaces.

The E5, on the other hand, is intended to interface with a single GPS navigator over its digital databus. Maybe a legacy Garmin GNS 430W/530W or any of Garmin's current navigators, plus Avidyne's IFD series navigators. For connecting analog VHF nav radios and multiple GPS navigators, you'll need the optional ACU for the signal converting.

What we like best about the E5 is the added failsafe in case of a compromised pitot source input—something that's been a weak link in previous Aspen systems. Like most EFIS models, the Aspen requires pitot static air input for the flight instruments and if the pitot tube is iced or clogged, the E5 reverts to GPS assist mode from the connected navigator. This displays the GPS groundspeed (instead of indicated airspeed) and warns you to turn on the pitot heat, while the attitude data still stays alive instead of flagging like it does without GPS assist.

Like the high-end Evolution, the E5 has a one-hour backup battery in case the electrics go down. The feature set is bare bones; there's no touchscreen or synthetic vision. The E5 screen is divided into three parts: an upper attitude display, a lower navigation display and a data bar between the upper and lower halves. Unlike other Aspen displays, the E5 only has one page, so you'll always view attitude and heading data, and of course EHSI when connected to an external navigator—something the E5 didn't have when it was released last year. An E5 can be upgraded to a full-featured Evolution 1000, and you can still use the installed RSM and some of the existing wiring when upgrading.

GARMIN G5

We've covered the popular Garmin G5 in great length in previous articles so we'll review the basics here. Sized to fit a 3 1/8-inch instrument cutout and sporting a 3.5-inch QVGA color LCD display (no touchscreen or synthetic vision), the G5 can be purchased as a primary attitude indicator and also paired with a second G5, which is a digital DG/EHSI that works with the GMU 11 external magnetometer for magnetic

That's a Garmin GNX 375 budget IFR navigator displaying its integral ADS-B Out/In transponder and traffic display. It packs a heavy punch for its $7995 price, but has no VHF nav.

Garmin's GI 275 round-instrument form factor (top) saves installation effort, but multiple GI 275s quickly add to the bottom line. That's a pair of G5s, middle, in an older Cessna panel, and the uAvionix AV-30 digital instruments at the bottom.

heading display. Without the magnetometer, you'll see GPS track. When two G5s are paired together, the G5 DG/EHSI works as a reversionary attitude indicator if the primary G5 goes down. Both instruments have four-hour backup batteries.

The G5 DG is equipped for instrument approaches with its electronic HSI, but is limited to VHF nav and GPS sources with digital databuses, mainly Garmin GNS 430W/530W, GTN 650/750 and Avidyne IFD navigators. The G5 can also work with Garmin's discontinued SL30 navcomm and the current GNC 255 digital navcomm through an RS-232 serial interface. See the sidebar on the next page for more on interfacing VHF radios.

If you have a third-party autopilot (we're talking about S-TEC, BendixKing and even Century and ARC/Cessna models) the G5 EHSI can provide heading command with the GAD 29B converter.

Like Aspen's E5, the G5 is utilitarian, but displays all of the flight data you'll need for flying IFR and the STC allows for removal of the aircraft's vacuum system. There's airspeed, attitude, altitude, vertical speed, slip/skid, turn rate, configurable V-speed references and altitude select (for reference or for interface with Garmin's GFC 500 autopilot).

To comply with the STC, even a dual G5 setup can't replace the entire six-pack of flight instruments. They'll replace the AI, DG or the DG attitude instrument can replace the rate of turn instrument.

The G5 is an integral component of Garmin's GFC 500 autopilot because it provides pitch and roll outputs to drive it, while also displaying autopilot mode annunciation and flight director command bars. It has a basic altitude select and alerting feature that's useful for IFR flying. For instance, when passing within 1000 and again at 200 feet of a selected altitude, the set altitude value flashes for five seconds. Bust the altitude by 200 feet and the selected altitude data box changes to yellow text against a black background. It's a good backstop for keeping you honest.

The base G5 AI is $2299; the G5 DG/EHSI is $2599 and $3125 with the GAD 29B converter. All in, a dual G5 installation might run around $7000, maybe less, maybe more depending on the panel.

GARMIN GI 275

A suite of digital GI 275 flight instruments might not yield an entry-level upgrade—Garmin still purposes the non-TSO G5 for that. But with a form factor that directly replaces most 3 1/8-inch round instruments, the product could make sense for incremental upgrades.

The GI 275 series are independent multi-function instruments that have TSO and STC certification, a 2.69-inch diameter (active screen size) color capacitive touchscreen and an extremely flexible electrical interface potential. They can function as a primary flight instrument, EHSI, CDI, an MFD with synthetic vision, traffic and terrain display and an engine monitor. Let's break it down, starting with the $3195 GI 275 Base model.

In the most basic form, a GI 275 can solve a dilemma faced by many when upgrading to an IFR GPS, which requires an external CDI because it works with a variety of GPS navigators that require an OBS course resolver—including legacy

WHAT ABOUT VHF NAVCOMMS?

Face it, the latest budget navigators from Garmin, and even used legacy ones, have all but made the traditional navcomm radio extinct. But that doesn't mean you can't save some money by interfacing one with a budget EFIS. For IFR flying (and training) you'll need glideslope approach capability and you can get just that with a properly equipped navcomm. Garmin offers the GNC 255, upper right, and it interfaces nicely with both the GI 275 and G5 EHSI shown at the left. But at $4495, we think any of Garmin's budget navigators makes better long-term sense if you can live without VOR and ILS in favor of WAAS GPS. Many can, especially for training.

You can cut the cost in half by scoring a used BendixKing KX155 (around $2000 for a good one), shown in the middle, but you need a good eye when shopping. Some versions don't have glideslope and all are voltage specific—14 or 28 volts. The analog radio will work with Garmin's new GI 275, but not with the G5 since it doesn't have analog inputs. Perhaps the most versatile of all is a used Garmin-AT SL30, shown at the bottom. It has RS-232 serial output and works with the GI 275, G5 and Garmin's GI 106 series mechanical indicators. The SL30 sells for around $2500, is a good performer and could be an interim money-saver for IFR equipage.

GNS 430/530 navigators. BendixKing KLN-series navigators also require an OBS resolver, but Garmin told us it doesn't recognize this interface even though it might work. The instrument can accept and switch dual GPS inputs and dual VHF nav inputs for localizer and glideslope display. It can also be toggled as an MFD.

A step up is the $3995 GI 275 ADAHRS, which is the one for use as a primary and standalone EFIS because it has the sensors for displaying all primary flight data. When used as such, however, it's locked to display only the flight data—no MFD. Synthetic vision is a $995 option and is downloadable, so you don't have to bring it to a Garmin dealer for installation should you add it later.

As second GI 275 ADAHRS can be installed to replace a round-gauge directional gyro and it connects with an optional GMU 11 magnetometer for heading resolution. It can be configured as an EHSI, works with a variety of third-party nav sources and has mapping, traffic and weather overlay. A GI 275 ADAHRS with the magnetometer is priced at $4295.

One benefit of dual GI 275 ADAHRS units is failsafe redundancy. If the primary AI goes down, the one functioning as an EHSI reverts to primary flight data. The instruments have backup batteries and the STC allows for removing the vacuum system in this configuration. When used an EHSI, the GI 275 ADAHRS is locked, but also displays mapping.

For providing pitch and roll reference for driving attitude-based autopilots, the $4995 GI 275 ADAHRS+AP is the version you'll want. There's also an interface where a GI 275 can function as an engine monitoring system.

We've installed the GI 275 in our test aircraft and are preparing a full inflight performance report in an upcoming issue of *Aviation Consumer.*

BUDGET IFR NAVIGATORS

No matter which small-screen EFIS you choose, we think the interface is complimented by a WAAS GPS navigator. For WAAS on a budget, Garmin's new line of navigators—which aren't equipped with VHF nav receivers—make good sense. But

That's a Garmin GI 275 ADAHRS model with optional synthetic vision at the upper left. Yes, a lot of data packed into a small screen. That's the GI 275 EIS displaying engine and fuel data at the right.

the choice isn't necessarily easy. We covered the units in the navigator market scan article in the September 2019 issue of *Aviation Consumer* and determined that the GNC 355 was a winner, but not exactly a slam dunk. There are sacrifices, and those include settling for relatively small screens (4.8 inches) compared to Garmin's GTN-series navigators, while also doing without ground-based VHF nav capability.

To review, the base navigator is the $4995 GPS 175. It's strictly a GPS, but it does have built-in wireless for connecting with smartphones and tablets running the Garmin Pilot app. At $6995, the GNC 355 adds a 10-watt comm radio, and at $7995, the GNX 375 has no comm, but instead a built-in ADS-B transponder.

All of these navigators work with Garmin's G5, GI 275 and even with Aspen displays. They are approved for Class I/II aircraft weighing under 6000 pounds and are approved under a 700-model AML-STC.

How you choose will depend on how the panel is currently equipped. For many equipping for IFR, we think the GNC 255 will make the most sense because it has the comm radio. You may or may not be comfortable flying IFR with a single comm, so you might retain an existing radio or install a standalone comm, which could add around $2500 to the project.

If you aren't comfortable with ditching VHF nav capabilities, you'll have to install Garmin's GTN 650 (priced at $11,995) or Avidyne's IFD440, for $11,999.

There's also a fairly lively market for used navigators, mainly Garmin GNS 430W and GNS 530W units. These are long out of production, of course, but they are still supported. We searched the market and found that good ones (with recent factory service and in good cosmetic condition) have high resale value. Plan on paying around $7000 for a GNS 430W (the W nomenclature is important because it means it has WAAS) and upward of $9000 for a larger-screen GNS 530W. The GNS 430W/530W have VHF navs, but older processors and older displays compared to newer navigators.

We suggest working closely with your shop before striking a deal on any used unit. You'll need an installation kit, mounting tray, navigation datacard and GPS antenna, which might not be included. The shop will also have to include FAA Form 8130-3 airworthiness paperwork to support the installation.

THE BOTTOM LINE

At press time uAvionix was working toward certification of its AV-series flight instruments, including the full-size, 12-in-1 AV-30. This is a highly configurable digital instrument that fits in a 3 1/8-inch round panel cutout and has primary attitude, slip, directional, airspeed and angle-of-attack data, plus battery backup.

As we reported in the March 2020 issue of *Aviation Consumer*, the AV-30 and smaller AV-20 are also used to control the uAvionix tailBeaconX ADS-B transponder. But until it's certified, the AV-series units can only be installed in experimentals. The AV-30-C (pending certified model) is currently priced at $1995. We'll keep tabs on these products.

If your plans include removing the vacuum system and you're struggling between a pair of Garmin G5s or a pair of Garmin GI 275s, our advice is to get a hard quote for both options. The GI 275, with its round form factor, can fit exactly as an old round gauge did. This means no modifying the Royalite plastic overlay on many panels (the G5 fits a round hole, but has a square bezel that will require either modifying the plastic or doing metal work and removing it). But a GI 275 suite, or at least two of them, will be pricier than dual G5s.

It's possible that a Garmin GNC 355 GPS/comm ($6995) and dual Garmin G5 flight display ($4900) install could sneak out the door for around $15,000 in basic interfaces. Of course that doesn't include an autopilot or a transponder/ADS-B system. In that case, you might substitute the transponder-equipped GNX 375 navigator for an additional $2000, but that doesn't include a comm radio. Maybe you retain an existing radio, search the used market for a standalone comm or install a separate ADS-B solution. Dual GI 275s and a GPS 175 navigator is $13,285, which is substantially more than the same package with dual G5s by nearly $3500. But again, there could be some savings in the installation, and the map and overlay capability on the EHSI (which doesn't exist on the G5) could be worth it.

One way to prioritize and save a lot is to take an incremental upgrade approach by simply installing one Garmin GI 275 Base model and interface it with a Garmin navigator as the primary indicator. Keep the traditional flight instruments and install a second GI 275 as your budget allows. That's pretty much what Garmin intended, since the GI 275's form factor doesn't require cutting the instrument panel—wire them up and drop them in the hole.

Last, get a side-by-side demo of a GI 275 and G5. The decision might be easier when comparing them, as the GI 275 simply does more.

ENGINE UPGRADES

Supercharging: Bolt-On Power

It's hot. The airplane's heavy. The strip is high and short. Wouldn't sea level power be nice to have right now?

For less than half the price of aftermarket turbocharging, a supercharger can improve rate of climb and cruise performance.

by Rick Durden

They've been around since before airplanes walked the planet. They're simple—an air compressor that shoves more air into the engine so it can burn more fuel and produce more power. They were staples of many of the engines that gave World War II fighters, bombers and transports their impressive performance. Yet, for all their value, superchargers have largely faded from the general aviation scene.

Almost.

One company, Forced Aeromotive Technologies (www.forcedaeromotive.com), has been providing a bolt-on supercharger system for a gradually increasing variety of airplanes for more than 18 years. Currently it offers its mod for most Cessna 182s through the R model (including those that have a number of engine mods), Cirrus SR22s and Diamond DA40s as well as some homebuilts. The belt-driven supercharger provides sea level power up to 7000 feet density altitude. We took a look at the company and the system and liked what we saw.

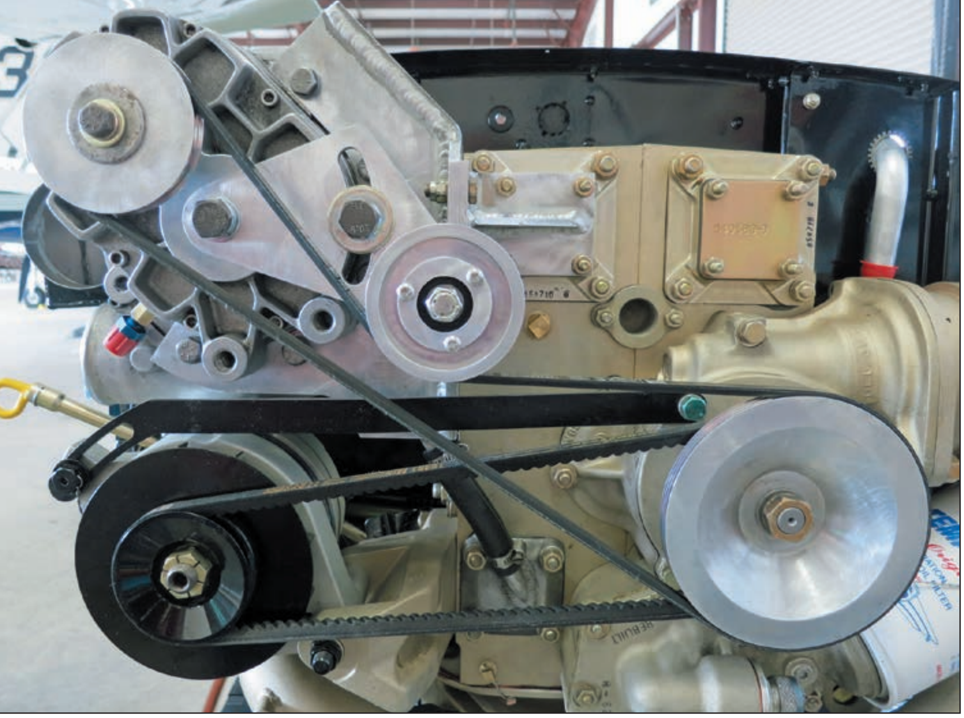
BACKGROUND

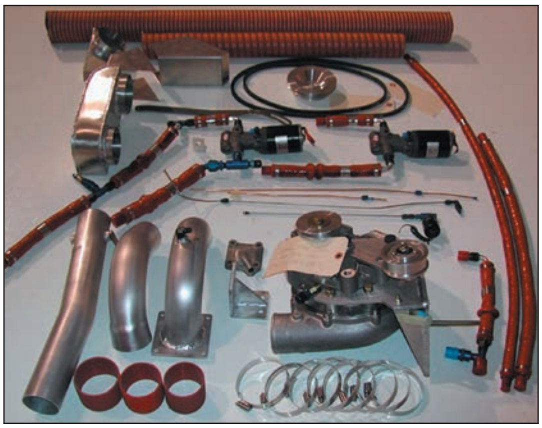
Superchargers are air compressors directly driven by the engine via a belt, gears or the crankshaft. If the compressor is driven by a turbine spun by engine exhaust gases, the assembly is technically a turbosupercharger. Being American, we've shortened that name to turbocharger or simply turbo. The value of supercharging and turbocharging for airplanes has been recognized for over 100 years. In 1920 for example, the altitude record for airplanes was 33,114 feet, set by a World War I LUSAC-11 fighter with a turbocharged Liberty engine.

For general aviation airplanes, Cessna led the way into "blown" engines when it came out with the turbocharged Model 320 twin for the 1962 model year. It set the tone by increasing the horsepower above that of the normally aspirated version of the engine. Turbocharging proved popular quickly and all of the major manufacturers soon offered it. In return for big performance gains and the ability to operate in the flight levels, owners happily put up with the increased maintenance costs of a turbo system, largely a result of the heat involved with substantially compressing air as well as placing a turbine in the exhaust stream. A turbocharger at speed glows brightly enough to read a newspaper in a darkened dynamometer room.

Forced Aeromotive's founder, Rod Sage, took a slightly different approach to boosting engine power for increased performance. His research indicated that the vast majority of owners of turbocharged airplanes never flew them above 12,500 feet. He also looked at performance numbers for turbocharged and normally aspirated versions of the same airplane and saw that, because of the back pressure in the exhaust system, the turbocharged airplanes did not perform as well as their normally aspirated brethren below 10,000 feet.

Sage was looking for the best of the normally aspirated and blown engine world when he developed a belt-driven (off of the accessory drive) supercharger that would





Looking forward at a Forced Aeromotive supercharger (upper left in photo) installed on the back of a Cessna 182 engine, top. Test run of the supercharger mod on a Cessna 182, middle. Cessna 182 supercharger kit, bottom.

allow the engine to develop its sea-level horsepower up to 7000 feet and 75% power at 12,000 feet. That meant that the supercharger would not be compressing the charge of air going into the induction system nearly to the degree that a turbocharger does on a system that allows full power to be developed to some 20,000 feet and increases the temperature of that air by over 200 degrees, often necessitating an intercooler to feed the engine air at an acceptable temperature.

INDUCTION AIR

Sage's supercharging system increases the induction air temperature by no more than 60 degrees, providing a relatively cool, dense charge to the engine. As one person we discussed it with commented, "It's gentleman's supercharging." That sounds right—the system doesn't use the brute compressive force superchargers and turbochargers are capable of, so we think that it's much less likely to cause the engine and exhaust wear common to more intensely boosted engines.

On that subject, Sage told us that in the 18 years he's been providing the supercharger mod, no owner has reported the need for a cylinder change. The system is also much lighter than a turbocharger system: depending on the airplane, one-fourth to one-third the weight and about half the price.

Forced Aeromotive does installs at its Denver Centennial Airport home base as well as shipping complete kits for those who want to have the work done at their home shop. Sage told us that about half of his sales are overseas. He also said that buyers tend to be those who want the ability to operate in the mid-teens but don't need to get into the flight levels. The substantially improved rate of climb has caused skydiving operators to be some of his best customers for the Cessna 182 mod.

The Diamond DA40 mod has only been out a little over a year, but Sage said that it's proving popular in the West where the unmodified airplanes do not perform well in high and hot conditions.

PERFORMANCE

Forced Aeromotive's website gives some performance data for the various mods, with cruise airspeeds improving 10 to 20 knots. Climb rate goes up as much as 500 FPM. Sage told us that airplanes with the supercharger mod outclimb normally aspirated and turbocharged models of the same type from sea level to 10,000 feet. That doesn't

AFTERMARKET SUPERCHARGING: ONE OWNER'S EXPERIENCE

James Buck bought his G1 Cirrus SR 22 when he was living in the Midwest. In a fashion similar to that of numerous owners, he progressively upgraded the avionics and generally personalized the airplane until he had it equipped the way he wanted it.

Then he moved to New Mexico where his new home airport, Double Eagle II, has a field elevation of 5837 feet.

Buck told us that he was suddenly looking at a maximum of 24 inches of manifold pressure on takeoff and hot day performance was not impressive. In addition, he regularly needed to fly in to Durango, Colorado, which lives at 6689 feet.

Dealing with the altitude realities of the West, Buck said he considered selling his airplane and buying something turbocharged. He discarded that option because he doubted that he could find something equipped as he desired and didn't want to face the cost of upgrades to another airplane. He then looked at aftermarket turbocharging but was put off by the price.

After doing some research, Buck decided to have the supercharger system developed by Forced Aeromotive installed. He said that he was lucky enough to get a used system, so he did not pay the new price. The airplane was down for less than two weeks for the installation. It added 30 pounds to the empty weight but did not have a noticeable effect on balance.

Buck described operating his airplane with the supercharger to us as moving sea level up to 7000 feet. He gets a full 29.6 inches of manifold pressure on takeoff from Double Eagle II. No matter what the altitude, takeoff procedure involves simply going to full throttle—the supercharger system takes care of itself; it automatically limits manifold pressure to 29.6 inches.

Once the airplane reaches critical altitude—7000 feet—in climb, the manifold pressure begins to decrease at one inch per thousand feet just as with a normally aspirated engine.

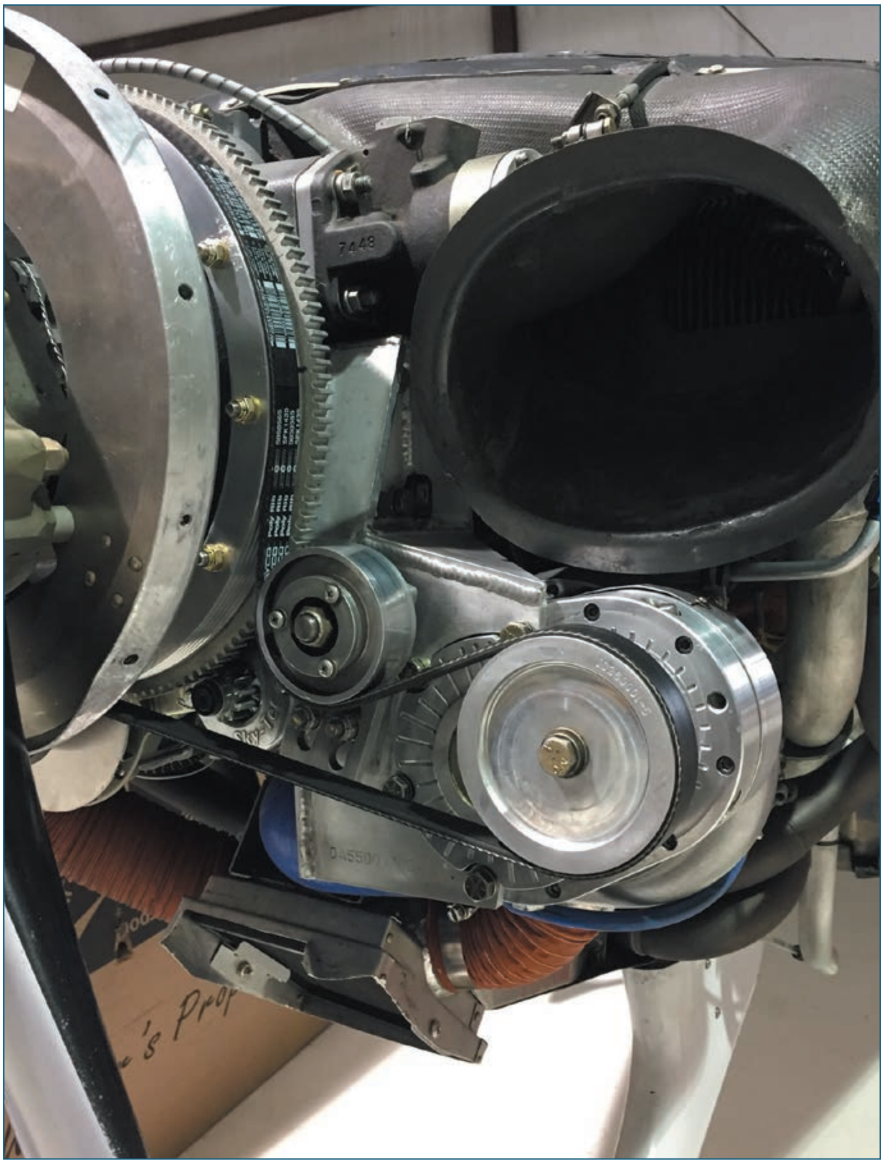
Initially, Buck said that the engine ran hotter than before the mod and CHTs were sometimes a problem. With the fuel injectors that were in the engine, it could not be run lean of peak. When he had the engine overhauled he had GAMIjectors installed and has been running the engine lean of peak. High CHTs are no longer a problem.

From a performance standpoint, Buck says that he sees takeoff manifold pressures 4 to 5 inches higher than before the mod at the airports where he normally flies. Fuel flow at cruise is 2 to 3 GPH higher than before simply because he can get more power at any given altitude. He told us that his cruise speeds are up by 20 knots at all altitudes, and he normally cruises above 10,000 feet. For example, he said that at 12,000 feet the airplane originally cruised at 160-165 knots TAS. Now he sees 180-185 knots TAS.

Buck sent us the photos above from a flight he made in March of this year. At 14,500 feet, TAS is 194 knots with a fuel burn of 14.5 GPH.

Since the system was installed, Buck told us that he has had a belt failure. He blamed himself for it because he did not buy a new belt when he installed a used system. He said that the failure was no big deal—the engine just became normally aspirated. He flew to his destination, landed and had the belt replaced. He now carries a spare.

According to Buck, maintenance is no big deal. There's a 50-hour check of pulley torque and the supercharger oil is changed every 100 hours.



Looking aft at the supercharger installation on the front of a Diamond DA40 engine, above. Supercharger installation on a Cirrus SR22, below.

surprise us as the supercharger requires only modest horsepower to turn, so it exacts little climb penalty where the exhaust backpressure in a turbocharged system significantly hurts performance below 10,000 feet.

The normally aspirated airplane will initially climb with the supercharged one, but within about 2000 feet of sea level, its power loss becomes noticeable. The supercharged machine continues to develop full power to 7000 feet, so its rate of climb increases with each 1000 feet above sea level until it reaches 7000 feet.

OPERATION

Operation of the supercharger system is dirt simple. No matter what the altitude, on takeoff the pilot firewalls the throttle. An electromagnetic valve (with a second acting as backup) opens when the target manifold pressure is reached: 29.6 inches in the Cirrus SR22, 28 inches in the Cessna 182.

Once the airplane reaches critical altitude—that altitude where the supercharger will not provide enough air for the engine to maintain sea-level power—the electromagnetic valve closes and all of the "charge" is directed to the engine. Manifold pressure then begins to drop at a rate of one inch per thousand feet.

Put bluntly, the supercharger system moves sea level to 7000 feet for an airplane with the mod.

The supercharger system is completely self-contained. In fact, it has its own oil system, so there is no need for a the supercharger to "spin down" after landing to avoid cooking it when the engine shuts down and its oil pressure goes to zero.

Installation takes 10-14 days. There is a few days' lead time in ordering a kit as Sage's company makes some components, such as hoses, at the last minute. The only additional maintenance requirement for an airplane with the mod is a 50-hour check of pulley torque and a 100-hour oil change.

DIAMOND DA40 MOD

We were particularly curious about the Diamond DA40 mod, primarily because we think supercharging smaller-engined airplanes can go a long ways toward bumping up their otherwise modest high and hot capabilites.

Californian Chris Keck recently went through the supercharger STC on his Diamond DA40. His comments: "I commute in the summers from San Carlos to Truckee, California. The cruise altitudes are 9,500 or 10,500, based on direction of flight. Before the install I didn't get to altitude until almost Sacramento after takeoff from San Carlos.

"Now I am able to maintain a climb rate in excess of 800 FPM and get to altitude in one-third the time. Cruising at 11,500 feet with 24 inches of manifold pressure and 2400 RPM results in a TAS of 153 knots. Before the mod cruise was 135-140 knots TAS. Cruise at 17,500 feet, an altitude I never used until the mod, is now 135 knots TAS.

"The install was a problem as a piece provided by Forced Aeromotive did not provide enough room for the unit and needed to be fitted a second time. The install ended up costing $6000. I recommend contacting Forced Aeromotive as they say that they can do the install for $2000.

"Cylinder head temperatures have increased and require close monitoring. Overall, I'm glad I went forward with the mod."

WARRANTY AND PRICING

The system comes with a six-year or 1800-hour warranty. Sage told us that he has never had to rebuild a supercharger—of some interest to those who figure on about 1000 hours before a turbocharger needs work, often teardown and rebuild.

For the Cessna 182 system, the price is $21,850. It weighs 31 pounds. The majority of the weight is between the firewall and the engine, so the balance change is minor.

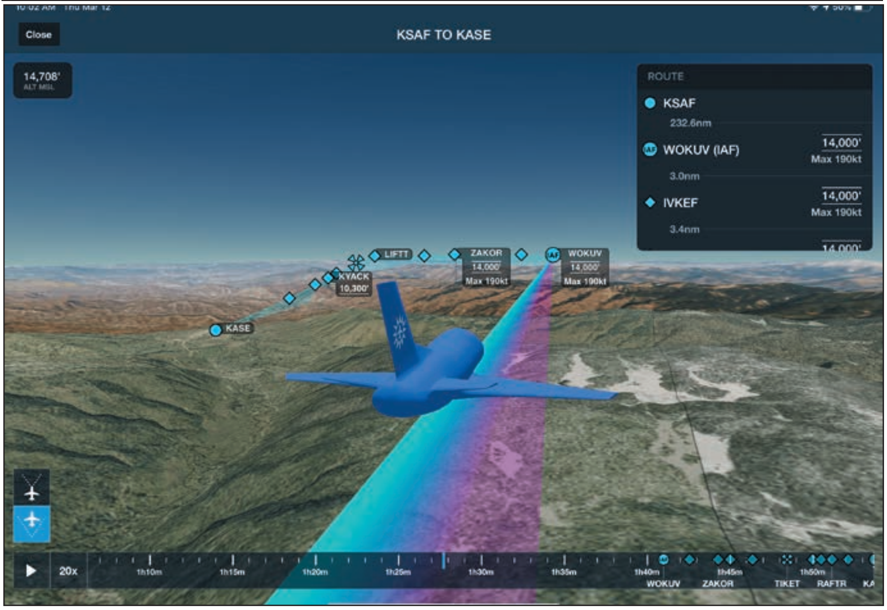
For the Cirrus SR22 the price is $39,500 and the weight is under 40 pounds (how much under may vary depending on the individual airplane). The company also offers a replacement MT composite prop that mostly offsets the weight addition of the supercharger system.

The Diamond DA40 kit is priced at $30,150 and weighs 18 pounds.

Forced Aeromotive sells its supercharger mod for Cessna 182s that have had bigger engines dropped in them. It can be installed on the Continental O-470L, R, S and U, IO-550 and the PPonk engine mods.

CONCLUSION

Frankly, we think the Forced Aeromotive supercharger conversion is quite attractive for those who operate in the high country. It boosts performance nicely without the maintenance challenges of turbocharging.



That's a screen grab at the top of ForeFlight's 3D Approach utility inbound to Santa Fe Regional Airport. Notice the timeline at the bottom of the screen for advancing through the flight, including the approach segment.

ForeFlight 3D Approach Preview:

ForeFlight's latest approach graphics are useful for briefing the approach during preflight. A missed approach preview would make it better.

by Larry Anglisano

ForeFlight introduced its 3D Preview feature awhile back, but now version 12-2 is enhanced with 3D Approach Preview, standard on Performance Plus subscriptions.

The idea behind 3D Approach Preview is to better visualize what the approach segment will look like (down to the runway threshold) because it creates onscreen markers for each waypoint in a route, plus labeled approach fixes for a given instrument approach.

If you haven't used ForeFlight's 3D Review feature, it essentially lets you follow the path of a planned (or recorded) flight overlaid over high-res aerial imagery and terrain. The feature uses parent company Jeppesen-sourced high-res worldwide terrain data.

The new 3D Approach Preview displays an interactive nav log at the bottom of the screen for viewing each waypoint and the distances between them, and you're able to advance to any leg in the planned flight for preview. Think of it as a timeline of a planned flight.

The first step is to create a route on the Maps or Flights view in the app, and select the 3D button. The utility then displays each waypoint along the route using the identical markers that are shown on the map. Each leg is color coded to indicate past, current and future legs in

The screen grab at the left shows how 3D Approach/View depicts altitude and speed restrictions for specific waypoints in the flight plan and approach procedures. The timeline playback at the bottom is set for 20 times the normal speed to quickly advance through the segment. The image at the top is what the high-resolution base map looks like with mountain passes turned on. The white arrows point to the Loveland and Berthoud passes in Colorado.

the route. There's orange for where you've already been, magenta for your current leg and blue for where you'll be next.

The interactive nav log is for viewing the distances between each waypoint in the flight plan. The nav log is in the Route window and you can tap a waypoint to advance to that leg in the flight. If there's an approach that's part of the flight plan, you'll see speed and altitude restrictions for each waypoint associated with the approach. For example, if you need to be at 9000 feet and at maximum speed of 190 knots at the initial approach fix, these restrictions will be included in the IAF waypoint label, and for others in the approach.

As for virtual imagery, the app now includes the altitude restrictions in 3D. The benefit here is a realistic depiction of the approach's glideslope in relation to the surrounding terrain.

It's important to stress that this data is really intended to be previewed and not used as you would when flying with a synthetic vision utility. Plus, you'll need an internet connection to download the data. But you can use it in flight once it's downloaded.

To access and brief a 3D approach detail within the app, go to the route editor in the FPL menu and tap the approach bubble for the one you want to brief. Then select 3D Procedure Preview. This will open the 3D Preview utility at the beginning of the approach without having to advance through the entire route.

One thing we wished 3D Approach had was a depiction of the missed approach procedures. This would be a pretty useful tool whether you're familiar with the approach or not. We suspect ForeFlight is working on that next.

MOUNTAIN PASSES AND HIGHWAYS

ForeFlight version 12-2 also includes mountain passes in its high-resolution base mapping. This mapping includes Jeppesen-sourced terrain and highway labels for enhanced VFR mountain flying. Labels for major highways and roads apply to U.S. interstates and federal and state highways. In the Map Settings menu, you'll see a Cultural Elements and Major Roads tab to turn them on.

Some users have contacted us reporting that they couldn't access the mountain pass feature, but you need to download the high-res mapping first. To access it, download the high-res base map for any region in the app's Downloads section. Once the appropriate high-res base map is downloaded you'll have mountain passes for the U.S. and Europe, and mountain pass icons are oriented on the map based on direction, plus they indicate the pass name and elevation. For Europe, the base mapping feature even depicts gondolas and cables, including their maximum elevation.

You can turn the mountain passes depiction on or off through Map Settings and Terrain menus. Also keep in mind that the Base map is what you'll see with no other charts or maps enabled other than the Aeronautical Map.

The ForeFlight Performance Plus subscription is $299 per year, which is what you'll need for 3D Approach. The Basic Plus is $99 per year.

Visit www.foreflight.com.

CHECKLIST

- (+) Both Hero 7 and 8 have impressive image stabilization and shooting options.
- (+) Hero 8 has simplified mounting frame, but battery door is a kludge.
- (~) Both cameras suffer from poor battery life and overheat shutdowns.

Which GoPro? As Always, It Depends

The Hero 8 has impressive image quality and stabilization, but also some warts. Overheating causes both models to shut down.

by Paul Bertorelli

In the cockpit, POV or action cameras have become as common—if not more so—as handheld radios. Driven by the action sports and social media markets, competition in these cameras is white hot and new models and accessories proliferate. For the purpose of this review, the choice is between the GoPro Hero 7 or Hero 8.

Yes, the Garmin VIRB Ultra 30 is still an option as are the Osmo Action and Sony FDR-X3000. And while the VIRB is better populated with aviation accessories, including filters and wireless integration with an onboard intercom, the GoPro imagery and stabilization is the one to beat, in my view. Despite some quirks, the footage these cameras are capable of is stunning.

NO EASY CHOICE

All of these cameras have similar capabilities and performance, but there's enough difference between them to complicate the choice. I'd like to say picking one is a no-brainer, then cite the reasons. But it's not that simple. It depends on how you're going to use the camera in and around the airplane and what else you're going to do with it, such as extreme sports, diving, skiing and whatever else you think you might want to video. And, of course, if you don't have footage of it, it didn't happen, so that's basically everything.

First, let's dispense with the simplest problem. If you have an old GoPro 4 or 5 or a VIRB Elite, the GoPro 7 or 8 is a significant upgrade. The image quality, color fidelity, audio and operability are far superior, in my estimation. When GoPro introduced the 7 in the fall of 2018, it kept its homegrown GP1 chip that first appeared in the Hero 6. But this model also added a feature called HyperSmooth stabilization, giving it a performance improvement over the Hero 6, or any other POV camera, that was stunning. Before the Hero 7 appeared, the Garmin VIRB Ultra 30 crushed the GoPro 4 and 5, as we reported in the November 2016 issue of *Aviation Consumer.* But time and technology march on and now the Hero 7 and 8 hold the upper hand. While the VIRB's stabilization was impressive, GoPro's HyperSmooth is noticeably better.

It's not quite gimbal quality, but for a hard-mounted camera, it's difficult to tell the difference. HyperSmooth removes the minor shakes the airframe will subject the camera to and it's effective to make handheld shots almost shake free. It's done in the software by sacrificing a small amount of the image area in favor of manipulating it to suppress movement. In the GoPro 7, it's applicable to resolutions up to 2.7K and 60 frames, but not 4K.

That's not much of a sacrifice

Hero 8, left in top photo, has a new frameless mount. Its non-removable lens cover, lower photo, is a weak point.

For the Hero 7, top, the Artman Protective Case is a good option to contain both the camera and the mic adapter. But it won't work with the Hero 8, below. The camera is larger and has built-in foldable fingers that fit standard GoPro mounting accessories.

because 2.7K is a good compromise between 1080 and 4K and takes less card space and battery capacity. I rarely use any other setting.

The Hero 8's improved HyperSmooth 2.0 was done with the same GP1 chip, but also with software tweaking. Side by side on the same mount, the Hero 8 is marginally smoother, but certainly not night and day.

MECHANICAL DIFFERENCES

The cameras are similar mechanically, but the Hero 8 introduces a new basic frame, or more accurately, the lack of one. When GoPro introduced the Hero 5, it featured a rubberized metal case that fits into a skeleton frame with the standard GoPro mounting fingers. The Hero 8 does away with that in favor of a frameless case with two folding fingers.

Although this simplifies the accessory load, it has been met with mixed reaction in the field. The fingers appear to be somewhat tender and if the camera is whacked, the small screws can shear off, necessitating a repair trip to the factory, if you don't lose the camera.

While the Hero 7 had two doors in the case—one for battery and SD card and a second for cable/charger access—the Hero 8 has one for everything. Again, a mixed bag. The door tends to come off when you open it, requiring a fussy reinstallation.

Another complaint about the Hero 8 is that its lens is fixed, not removable, as on the Hero 7. Two issues with that: One, if it gets scratched, back to the factory it goes and second, you can insert neutral density film into the removable Hero 7 for a prop filter. The Hero 8 requires a dedicated filter.

AUDIO OPTIONS

If you plan to use the camera inside the cockpit and you want to record intercom/radio audio, it gets … complicated. Both the 7 and 8 require a mic module to match audio input to the camera. For the Hero 7, this is the GoPro mic adapter ($49) that accepts a 3.5-mm jack. But the module is clunky and you need to find a place for it. The best solution I've found is the protective case from Artman Protective Housing ($15 on Amazon) that has a slot for the module, a case for the camera and a cold shoe mount for an external mic, if you need that. This lash-up adds weight to the camera and also almost an inch of height, which reduces mounting flexibility on a tight glareshield, for example. The mic adapter will work with the Hero 8, but the Artman case won't because the 8 is slightly larger. Ulanzi has the G8-5 case with an optional mount for the mic adapter ($39.95 and $9.95 respectively). Again, it adds weight and size to the overall camera so it's not a perfect solution.

In early 2020, GoPro introduced the Media Mod, an external case for the Hero 8 that incorporates onboard mics and jacks for an external mic, charging and HDMI output. The camera slides into this $80 accessory and a latch secures it so it's smaller than the Artman and Ulanzi solutions. As of press time, the mount is on backorder, but early reviews on it have been mixed.

It does, however, have one nice feature useful for aviation: It offers a line-in setting for audio, meaning you can plug the intercom directly into the camera. I've had unhappy results in using audio cables designed for this purpose, plugged directly into the camera. There sometimes appear to be impedance matching issues and in one shoot, the cable picked up noise from an avionics source, producing an audible click on a one-second beat on the recorded audio. The line-in option may help with this. As soon as one is available, we'll give it a try.

INSIDE/OUTSIDE

Either camera is suitable for mounting inside the airplane or on a wing, strut or fuselage mount. The HyperSmooth in both does an excellent job of eliminating airframe buzz, yielding a crisp image. Inside mounts, however, have one large wart.

Both the 7 and 8 will overheat and shut down, especially if placed on a glareshield mount in direct sunlight. In warm conditions, I've had both cameras shut off after about 20 minutes. After cooling for five minutes, they'll come back for another 15 or 20. Don't be surprised if you don't see continuous operation.

Mounted outside the airplane, there's sufficient airflow to prevent this from happening. Shooting 2.7K at 60 frames, either the 7 or 8 appear to run for 40 to 50 minutes before exhausting the battery. For reference, the Hero 4 and 5 will run longer, as much at 90 minutes on a full charge, but at lower resolutions. Batteries matter, too. GoPro's latest branded battery is rated at 1220 mAh and is identifiable by a blue band along the bottom.

At $20, these are expensive batteries and for any kind of serious shooting, you need at least two or three. For $35.99, Artman from Amazon offers a three-pack battery system that includes a charger that will accept USB-C or USB micro cables. And the batteries are rated at 1480 mAh. So, more power, less money. What's not to like, right?

Hold up. Despite the higher capacity, the Artman batteries consistently yield less endurance than the GoPro batteries. And although it doesn't seem to affect camera function, they will sometimes throw an error code indicating incompatibility. Considering the price, they're worth the purchase if you need extras. Just know they don't work as well as the GoPro originals. The charger is a plus and works well, even for the GoPro branded batteries.

RECOMMENDATIONS

Because of market demands, prices on these cameras have been fluid. The Hero 7 is currently selling for $330, plus $50 for the mic adapter, if you need it. The Hero 8 is retailing for $400, plus $80 for the Media Mod if you want audio capability. It doesn't make any sense to buy it with the older mic adapter then add the price of a case to that.

So, we're talking about $100 price delta here between the 7 and 8 for cameras that are functionally quite similar. The Hero 7 has a marginally easier-to-use menu system, while the Hero 8 has marginally better stabilization and some additional shooting modes. It also has menu presets of which I'm not a fan.

The price/value equation is so close that my advice is if you're buying purely on price, go with the Hero 7. If you want the latest features and don't care about price, the 8 is the better choice. If you have an old clunker Hero 3 through 6, GoPro will give you $100 on a trade-in for a Hero 8 and that makes it the hands-down best choice.

And by the way, the trade-in doesn't even have to work. I suspect going into early summer, we'll see more downward movement in price for both models.

ADS-B UPGRADES

Trig GPS/Txp Combo: Small-Space ADS-B

When panel space is tight, the Trig Avionics TN70 standalone GPS and TT22 compact transponder is a worthy pairing.

by Larry Anglisano

In aircraft with limited panel space—maybe small aerobats, motorgliders or ultralights—equipping for the ADS-B mandate could be a challenge. Scotland-based Trig Avionics has that market covered with a line of compact avionics, including 1090ES ADS-B transponders. But to comply with the mandate, those transponders (and third-party ADS-B 1090ES models not equipped with internal GPS) need connection to an approved position source. The TN70 WAAS receiver is one option.

The TN70 remote receiver is a GPS/SBAS/WAAS engine that's approved via TSO-C145c, which meets the 2020 ADS-B mandate spec, and there's an STC for interfacing it with the BendixKing KT74. It comes with the companion Trig TA70 external WAAS antenna, which is TSO-C190 certified.

The TN70 is compact and measures 1.6 by 4.1 by 6.5 inches and weighs 1.06 pounds, making it good for mounting in tight spaces.

And for tight panels that can't accommodate a rack-mounted transponder, Trig sells the TT22. This is a two-piece Mode S ADS-B model that has TSO approval and a 250-watt output. The transponder's control head fits a 2 1/4-inch instrument cutout and the entire system weighs 16 ounces. With the rear connector, the control head is 3.5 inches deep.

The TT22 also has a built-in altitude encoder, a backlit LCD display and the control head is splashproof, making it a player for open cockpit seaplanes and ultralights. No electrics? The unit can run off an external battery.

If you have an LSA or experimental, Trig sells the TN72 GPS receiver and it packages it with the TT22 for $2999, shown below. You can also buy the TN72 by itself for $399. The certified TN70/TA70 WAAS receiver/antenna is street-priced at $1995.

Visit www.trigavionics.com.

Smart Batteries: True Blue Power, EarthX

Lithium-ion aircraft batteries far outperform lead-acid ones, but initial costs and FAA approval are major obstacles.

by Phil Lightstone

So many buyers are removing their vacuum system in favor of all-electronic instruments, but neglected electrical systems—including the battery—are the weak link. Reliability isn't helped when the typical lead-acid model sits for long periods in harsh temperatures.

AIRCRAFT ACCESSORIES

Meanwhile, battery tech for the consumer electronics market has changed for the better, and that includes smart lithium-ion cells with better tolerance for demanding electrical loads and temperature extremes. So what about smart batteries for aircraft? Two companies—Mid-Continent Instrument's True Blue Power division, and EarthX—have been leading the charge with models for limited applications. Let's take a close look.

MANY PROS, SOME CONS

Lithium-ion and lithium iron phosphate cells seem well suited for small airplanes. Consider that these cells are roughly 80 percent lighter than lead acid and nickel cadmium cells, have a 4000-charge cycle life (versus 350 for a typical lead acid battery), will not corrode or sulfate, can't freeze or boil, plus they can be mounted in any position other than inverted. They have a low self-discharge rate (which means they can hold a charge during long winter storage) a wider operating temperature range, sustain higher starting voltage while the engine is cranking (ideal for hot and cold starts) and their discharge voltage is constant. But they deliver a steep drop-off at total discharge, which isn't good. To contrast, conventional batteries are good at dying slowly, giving you enough time to get on the ground before you've lost the last bit of power.

Last, applications are limited by regulatory approval and the buy-in for current STC'd models only makes sense for high-end aircraft.

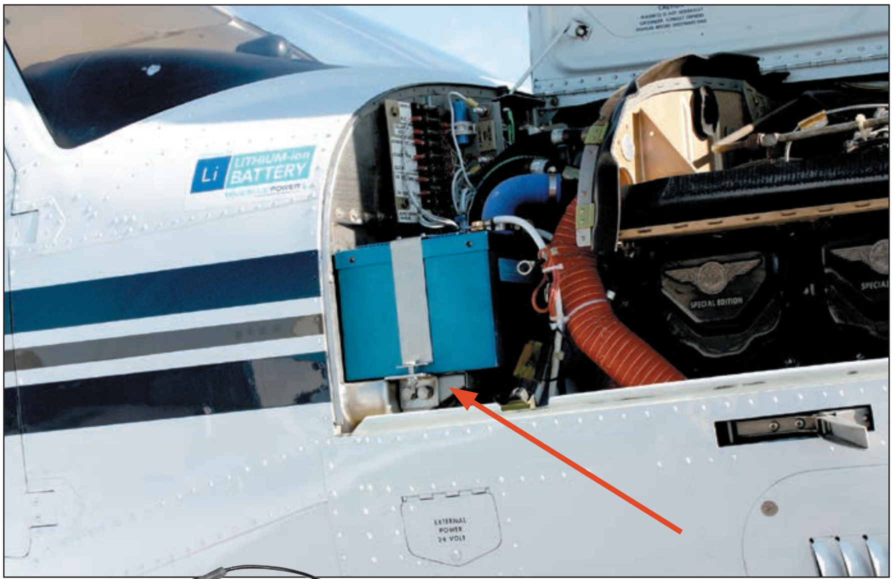
TRUE BLUE POWER

Mid-Continent Instruments and Avionics, through its True Blue Power division, has been working on smart-battery tech for the better part of 10 years and holds both TSO and STC certification for its TB-series NanoPhosphate Lithium-ion batteries. The STC list partially includes Beech Bonanza and King Air models, Robinson R44 helicopters and Pilatus PC-12 turboprops.

True Blue worked to make the batteries safer for the aircraft environment because thermal runaway is a major concern with lithium-ion batteries. Search YouTube videos showing the catastrophic failure of a consumer-grade battery in a smartphone and you'll see what we mean. The NanoPhosphate cell chemistry used by True Blue Power is said to be significantly more stable and less reactive than other chemistries. In the event of an internal short circuit to a cell (or thermal runaway) in a True Blue Power battery, the electrolyte vapor is directed outside the aircraft and away from cabin occupants and critical components. The company says its lithium-ion batteries are tested to withstand a scenario in which all redundant levels of protection are disabled and over-current/overcharge is applied. In that case the battery is proven to deliver 100 percent containment and reach a max temperature of 204 degrees C—something that's proved during the rigors of TSO testing.

True Blue Power has a number of batteries in different sizes and

The True Blue TB17 battery, inset image above, is STC'd for some 28-volt Beech Bonanzas and has an eye-widening $6500 price tag.



That's the TSO- and STC-approved True Blue Power smart battery installed in a Beech A36, top, and experimental-only EarthX ETX900-TSO battery at the bottom. The black wire is a serial output line for connecting to an EFIS.

amperage for limited piston and turbine aircraft. The TB17 is a 17 amp-hour battery (nominal at 23 degrees C), weighs 16 pounds, requires about 30 minutes (at 34 amps) for a complete recharge when fully discharged and will work in extreme temperatures (-40 to 158 degrees F). It's a smart battery designed to protect against overcharge, over-discharge, over-current, short circuit, over-temperature, under-temperature and has charge current limiting protection. It also delivers higher voltages during engine start.

Integrated in the battery is a switchboard for enabling and disabling charging or discharging, depending on cell health. It also has charge-limiting and current-monitoring functions. In addition to the switch board there's a control board, which is the heart of the Battery Management System or BMS. This discrete logic circuitry monitors the battery functions and protects against short circuit, over-temperature and over-discharge. The control board also generates the battery status signals for output through the 7-pin interface connector for cockpit monitoring and heater control via Mid-Continent's MD41 annunciator control unit, or ACU. It displays fault, temperature, charging and heating status, and a push-button switch turns the heater on and off.

The TB17 produces no emissions unless there's a failure. But the TB17 still requires venting to ensure that any gaseous emissions are vented overboard, and it's up to the installer to install the vent where emitted gases would not be directed toward any of the aircraft's cabin air intake points.

With its internal, self-powered heater circuit, the TB17 operates at extremely low temps (-40 degrees F) and is designed to support an engine start down to approximately 23 degrees F. Below this temperature, the performance of the battery begins to decrease in current and energy delivery as the electrolyte in the cells begins to thicken and the internal impedance increases to retard ion flow. In order to address this, each battery module contains an individual heater that is powered by the cells themselves, even at low temperatures.

When enabled, the cell heater automatically turns on (including during flight) when the temperature of the battery is below 50 degrees F and turns off when it reaches 59 degrees F. The unit will continue to monitor its temperature and turn the heater on again as needed any time the temperature drops below the threshold.

The estimated life for the TB17 battery is eight years, it has a two-year warranty and it has reliably demonstrated over 20,000 engine starts and subsequent charge cycles. The cells themselves are designed for a useful life of up to 10 years. The price? $6594, not including the $1110 MD41-1817 ACU.

Worth mentioning is that True Blue Power also offers its Gen5 series larger smart batteries, which include the TB20, TB30 and TB40 batteries (20, 30 and 40 amp-hour ratings) and these are proof that True Blue's tech has been maturing over the past 10 years with better onboard electronics for providing proactive data, alerting and command-control operations of the battery cells. With USB connectivity, data can be retrieved from the battery by plugging in a USB data stick. Added benefits of the TSO-certified Gen5 batteries include wider operating temperatures (than even lead acid or nickel cadmium), more power per battery weight, more engine starts per charge, plus automated built-in preheaters for controlling battery temperature. They also have data integration and control through an annunciator panel. They have on-condition maintenance and an extended service life of eight years, on average, before replacement.

But all that tech—and rigors of FAA certification—come at an astonishingly high price. The 46 amp-hour TB44 used on the Pilatus PC-12

EarthX ETX series batteries come in a variety of sizes, top, and are gaining sizable popularity in the experimental aircraft community. Part of that is because of the company's thorough quality control and testing process, shown bottom.

turboprop single is $17,404. Contact www.truebluepowerusa.com.

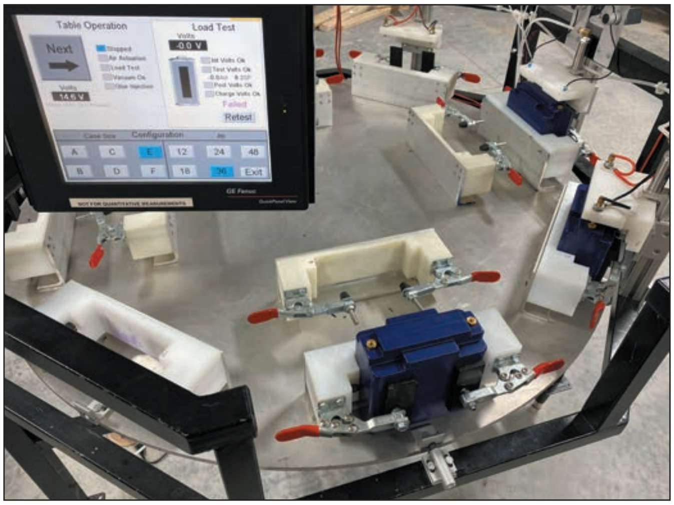
EARTHX BATTERIES

Colorado-based EarthX Batteries was founded in 2009 and its batteries are focused on applications where weight savings are critical. We're talking about powersports and racing, but its non-certified batteries have been popular in the experimental aircraft market, and included by some OEMs.

EarthX batteries are based upon lithium iron phosphate chemistry, or LFP. LFP has gained market acceptance due to its low cost, non-toxicity, natural abundance of iron, excellent thermal stability, safety characteristics and electrochemical performance. Its use as a battery electrode was first described in published literature by Akshaya Padhi and coworkers of John B. Goodenough's research group at the University of Texas in 1996. Then, researchers at MIT introduced a new coating, called the Beltway Battery, which allows the ions to move more easily within the battery. The MIT scientists discovered that by coating lithium iron phosphate particles in a glassy material called lithium pyrophosphate, ions bypass the channels and move faster than in other batteries.

EarthX began manufacturing its batteries in 2011 and designed an aircraft-specific battery in 2013. The company began the FAA certification process in 2017, receiving the first ever issued FAA TSO-C179a in April 2019 for a 12-volt LFP battery system, the model ETX900-TSO.

The installation guidelines stipulate that the aircraft must have a battery fault monitoring indicator installed (via an annunciator light or displayed on an EFIS), the battery must be vented, the electrical system must have a maximum charge rating of 80 amps and the battery must be replaced after six years in service. The maximum voltage output from the aircraft's charging system shall not exceed 16 volts for greater than 100 msec. An automatic over-voltage protection device (OVPD) is required on the aircraft charging system.



The ETX900-TSO weighs 5.4 pounds (compare it with a Gill G35 weighing 27 pounds), measures 6.5 by 3.1 by 6.6 inches, and has a 15.6 Ah capacity, an operating temperature of -30 to +60 degrees C and a self-discharge rate less than 3 percent per month.

The cells used in EarthX batteries are made in China to EarthX specs and are stored for three months before being assembled at the company's Colorado plant. This allows each cell to mature, while ensuring there are no defects (the defect rate is 0.2 percent, according to EarthX) before being placed in service.

Each ETX900-TSO battery has two 8-cell packs and a Battery Management System (BMS). The BMS is built in-house, using surface-mount electronics. The BMS circuit board conducts a startup and self-diagnostic check when it is attached to the battery cells. This test takes one hour, ensuring that each cell's voltage matches the other cells in the battery. After final assembly, the battery goes through an eight-step testing and quality assurance process. Each battery is provided with a unique serial number, with manufacturing and testing data stored for 10 years—an FAA requirement.

The EarthX batteries do have over-discharge (a complete drain) protection, excessive cranking protection, high-temperature protection and short-circuit protection. It also balances the charge between each cell and can alert for low voltages or high voltages (above 15.2 volts). Think of the BMS as backup to the aircraft's voltage regulator and over-voltage protection. There's a lot at stake.

As an example, the charging system on a Lycoming IO-360 has the ability to generate more than 100 volts (based upon a defective voltage regulator and over-voltage protection device). With greater than 100 volts feeding the battery, and if the battery's over-voltage protection failed,

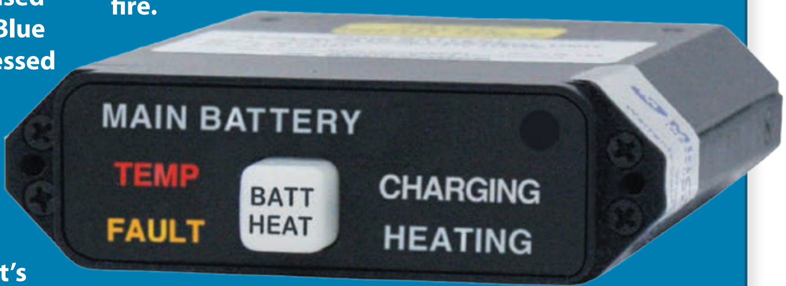
BMS: BACKSTOPPING SMART-BATTERY SAFETY

Talk about lithium-ion smart-battery technology for aircraft and inevitably the discussion will turn to safety—as in, what happens if the thing goes into thermal runaway, like that string of smoked smartphones that made the news a couple of years ago. That's why BMS, for Battery Management System, is a key element to smart aircraft batteries. True Blue Power and EarthX batteries have sizable protection built in, including the ability to monitor the battery's health status on the fly.

For instance the EarthX ETX900-TSO has a serial communications output (a black wire on the outside of the battery) for interfacing with an EFIS or a panel-mounted annunciator light, and is designed to monitor and alert that something is outside of normal parameters. Same with True Blue Power. That's the MD41 annunciator control unit (pictured right) used with TB-series smart batteries. The BMS in True Blue Power batteries stores health data, which is accessed with an external drive.

The EarthX batteries don't log or store data, but do have over-discharge (a complete drain), excessive cranking, high-temperature and short-circuit protection. They also balance the charge between each cell and can alert for low voltages or high voltages (above 15.2 volts). That's a good thing—an over-voltage smoke show is not. Without a failsafe, the battery's cells would vent and the aircraft's electronics will likely be damaged beyond repair from a voltage spike. Think of the BMS as backup protection to the aircraft's voltage regulator, over-voltage protection device and charging system fault indicators.

As a last line of defense the EarthX and True Blue batteries have a thermal runaway containment system to safely vent vapor and smoke to the outside of the aircraft. It's rare, but the EarthX battery's chemistry could enter a thermal runaway condition, however, as the battery heats up and the iron phosphate chemistry starves the combustion process of oxygen. This results in the creation of fumes, which are vented overboard, but in theory there wouldn't be a fire.



then a thermal runaway could be triggered. See the sidebar above for more on BMS circuitry.

For further protection, EarthX designed a thermal battery box that's designed to protect a battery from heat in the engine bay after shutdown and from radiant heat during flight. The battery box is stainless steel with a mirror finish and has a high-performance insulating foam layer between the box and battery to reduce the effect of convection heat. There is a hold-down tab with a mounting fixture that can hold up to 1-inch-diameter cooling air ducts. The battery box was engineered to be strong enough to withstand 30 G's and is compatible with EarthX's existing E-case battery models—which are the ETX680/900/1200.

EarthX has a variety of battery sizes and weights. The ETX900-TSO battery is for replacing 25 or 35 Ah lead acid batteries. The good news: EarthX is working toward FAA (and Transport Canada) certification for installation of its batteries in certified aircraft, beginning with the Cessna 182 series, which house the battery outside of the engine bay. Separate approval will be required for models that have batteries housed in the engine bay. EarthX is hoping for certification sometime in 2020.

Until then the only way to legally support an installation in a certified aircraft is through an FAA field approval. In Canada the field approval process will require engaging a TC design approval representative. Still, the price looks promising.

EarthX is offering the ETX900-TSO at a pre-STC price of $699, and the expected retail price for the certified version is currently $899. For international aircraft (non U.S. registered), EarthX uses a third party to provide an FAA Form 8130-3 for an additional $150. EarthX also sells battery chargers, vent tubing and LED panel annunciators direct and through Aircraft Spruce. Contact www.earthxbatteries.com.

A MARKET TO WATCH

We're impressed with True Blue Power's batteries, but they're limited to 28-volt electrical systems and are high priced for lower-end GA pistons.

Concorde Aircraft Batteries has been developing a series of lithium-ion batteries with lithium iron phosphate cathode material, but says the batteries won't be retrofittable due to the integrated BMS and required external monitoring. It says the cost of the battery will be up to six times higher than an equivalent size lead-acid battery (plus high shipping costs), a premium "which is hard to justify with regards to replacement batteries." It's holding short for now.

We agree, but if EarthX certifies its ETX series models and prices them sub-$1000—a price we feel is palatable—it could be a compelling upgrade for a lot of buyers.

CHECKLIST

- + The tech in smart batteries beats lead-acid aircraft batteries in every way.
- + EarthX LFP batteries have been performing well in experimentals.
- ~ But they're off limits to certified aircraft without a difficult field approval, at least for now.

TRAINING

Lycoming Engine School: Not Just For Techs

There's plenty for the average aircraft owner to learn from Lycoming's factory engine training course.

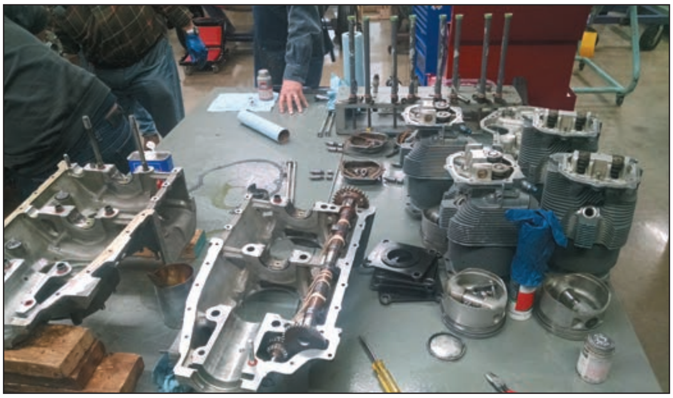
by Paul Pelletier

I recently attended Lycoming's factory engine training course and found that the curriculum isn't limited to mechanics. As expected, the students were predominantly A&Ps but there was only one airplane owner (of a Pitts S1) who simply wanted to learn more about his engine. I think more owners should take his approach, and many don't realize that Lycoming tailors the course to owner/operators and mechanics alike. As an educator and a practicing A&P, it was obvious to me that 70 percent of the material covered is appropriate to aircraft owners willing to learn proper engine operation and simply want to build on their knowledge of what's going on underneath their cowlings.

The five-day, 40-hour Lycoming program is taught at the Pennsylvania College of Technology in Lycoming's hometown of Williamsport, Pennsylvania, by Mike Damiani—a former Lycoming factory representative with a passion for small airplanes.

The first half of most days is spent in the classroom and the second half is in the lab with a teammate disassembling and reassembling a four-cylinder Lycoming O-360 engine. For the average owner, it's likely the first time they've seen a piston aircraft engine scattered on the table (see the main image above), which in itself could make them better prepared to talk the talk with their mechanics.

The course begins with the history of Lycoming and its engines, and includes a review of service publications and manuals, engine construction, theory of operation and service. While the O-360 was used primarily for hands-on, Damiani discussed all Lycoming engine models and their different applications. Some time is also spent dissecting an engine's data tag—an important thing.



The course becomes more technical after discussing the infamous Lycoming camshaft and its strengths and weaknesses. Important for the owner/operator, additional time is spent discussing good operating habits to help with cam life. Damiani reminded everyone that inactive engines pose a problem for Lycoming cams, as do high RPM starts and cold starts without preheating.

We learned that although the engine design is old, Lycoming's new production techniques do make newer engines more robust and safer. I'm a believer, especially after a complete factory tour led by a factory rep. The number of multi-axis CNC machines on hand is impressive and can consistently ensure the accuracy of parts tolerances.

The crankshafts are hardened using a state-of-the-art hardening process where electrical ionization forces nitrogen into the metal, hardening the surface. Time is spent discussing how hollow cranks can influence dirty engine oil. There's also valuable advice on dealing with propeller strike inspections and crankshaft gear bolt installations.

But for me the lesson on cylinder heads was the most interesting, particularly as Lycoming wants compressions tests to be within 5 psi of each other. We learned the symptoms of sticking valves (rough-running engine for first startup of the day, and short-duration roughness that clears up in climb or cruise). Symptoms also can be high mag drops and intermittent rough idle. To cure sticking valves, Damiani discussed valve guide care and reaming valve guides. There's also valve spring inspections and proper installation, plus proper valve adjustments.

For the owner, the topic of oil filtration should be a popular subject. In fact, if I had an older engine with an oil screen I would upgrade it to a filter. Damiani discussed oil pressure, oil pumps, oil temperature and the trends Lycoming sees. The course smartly covers the proper troubleshooting techniques for high oil temperatures—pointing out the relationship with oil coolers and thermostatic bypass valves.

The course covers spark plugs (and a spirited discussion on plug selection), ignition leads and magnetos, plus spark plug maintenance and proper cleaning techniques. I was particularly interested in reducing lead fouling on my own three O-235 engines and the course helped.

Last, if you're building an airplane with a Lycoming engine there's plenty of value in this $1640 course, which can be a good supplement to joining a local EAA (Experimental Aircraft Association) chapter.

Visit www.lycoming.com/contact/training for a schedule of 2020 training courses.

Contributor Paul Pelletier is Aviation Consumer's resident A&P, an airplane owner and operates A&P Paul at Windham Airport in Connecticut.

DIY MAINTENANCE

Tire Inspections: Pressure, Wear, Damage

And those are just a couple of items on the hit list when preflighting tires. Think like a tech to make expensive rubber last longer.

Staff report

Face it, aircraft tires are expensive, so why not do everything you can to make them last? Unfortunately, tires are one of the most neglected items on the preflight checklist. You can likely be doing more to increase their life and more importantly, help avoid a trip into the weeds—or worse—if they fail. Start with the FAA's AC-43-13-1B chapter 9-14, which deals specifically with tire and tube maintenance. It states the obvious: that a program of tire maintenance can minimize tire failure and increase tire service life. Start with the basics.

• Tread wear. Put your eyes on the tread. Tires should be removed when tread has worn to the base of any groove at any spot, or to a minimum depth as specified by the tire or aircraft manufacturer. Tires worn to fabric in the tread area should be removed regardless of the amount of tread remaining.

• Uneven wear. This doesn't necessarily mean you need to shotgun the tire. If tread wear is excessive on one side, the tire can be dismounted and turned around, providing there is no exposed fabric. But sort of like on a vehicle, you should dig further to find out why the tires are wearing unevenly. Gear misalignment causing this condition should be corrected.

• Tread cuts. If you find suspect damage, do not probe cuts or embedded foreign objects in an inflated tire. Instead, mark them with a crayon or chalk. Remove tires that have any cuts into the carcass ply. Also remove them if you find cuts extending more than half of the width of a rib and deeper than 50 percent of the remaining groove depth. You're also looking for weather damage—cracking, cuts and snags extending down to the tire's carcass ply in the sidewall and bead areas. See the main image below. Look for bulges in any part of tire tread, sidewall or bead indicating a separation in structure. Cracking in a groove that exposes fabric or if the cracking undercuts the tread ribs? Time to pull the tire.

• Flat spots. Yeah, we've all done it. In general, you might not have to shotgun a tire blemished from skidding and hydroplane burns unless there's exposed fabric.

• Beads. Inspect bead areas next to wheel flanges for damage due to excessive heat, especially if there has been brake drag or severe braking. Stay off the brakes during taxi, and heels on the floor during landing.

• Surface condition. The surface condition of a tire can be inspected with the tire on the aircraft. The tread should be checked for abnormal wear (don't forget to roll the plane forward to check the entire tire). If the tread is worn in the center of the tire but not on the edges, this indicates that the tire is overinflated and the operational air pressure should be reduced. On the other hand, a tire worn on the edges, not in the center, indicates underinflation. Keep a tire gauge in the cabin and use it.

• Inflate properly. Underinflation will cause excessive tire wear and imbalance and overinflation stresses the tire.

TREAT 'EM RIGHT

Other than inspection, use common sense and extra care to keep tires healthy. When washing the aircraft, protect the tires from any fluid (including harsh soaps and degreasing agents) other than plain water.

Also, pay attention to simple operational techniques such as moving the aircraft forward to straighten the nosewheel before setting the parking brake, or before pushing the throttles forward during an engine runup or takeoff roll. This can reduce the stress on the nose tire and wheel.

Bottom line is that checking the tire pressure often, inspecting them carefully during each preflight and using extra care to avoid unnecessary stress during ground ops (and landing) are easy ways to make them last.

Cessna Conquest I:

A 425 Corsair/Conquest I is still a good choice for moving into the world of turboprop twins. Be ready to train and write big checks.

CHECKLIST

- + It has sturdy handling, a roomy cabin and reliable PT6A engines.
- + At around 250 knots it's not blistering fast, which makes it a good step-up turbine.
- ~ The hardened insurance market means high premiums—if you can even get a policy.

Talk about the current market of new million-dollar piston singles and inevitably someone will argue that you could buy a twin turboprop for less. The Cessna 425 Conquest I is one of them.

The current *Aircraft Bluebook* pegs a 1981 425 at $620,000 (down $200,000 from ten years ago), and for those looking to move into the world of Jet-A-burning twins, the Conquest is worth a look. The airplane has a reputation for being a relatively easy step-up turbine—if not a logical step—for eventually moving into a Cessna Citation jet.

The Cessna 425's strengths are relative economy with good performance, including balanced-field numbers, excellent handling characteristics, a well-designed cockpit for flying single-pilot, good CG, good loading options and a comfortable bizjet-like cabin.

Of course we don't have to mention that a Conquest ownership (or any twin turboprop for that matter) won't be cheap—from fuel burn to maintenance to engine swaps ($350,000 per)—but we will anyway. But among twin turboprops, a Cessna 425 "baby turboprop" may be one of the least expensive ways to get into the world of turboprop twins. Its direct competitors might be the Piper Cheyenne I, a Beech King Air 90 and even some turboprop singles. Here's a fresh look at the market.

A properly maintained 425's dispatch reliability is high, and operational simplicity makes it comparatively undemanding to fly.

HISTORY LESSON

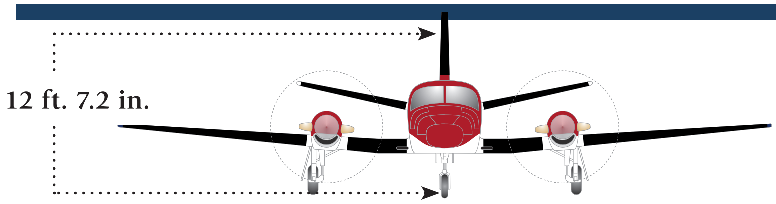
Before the Conquest, Beech had been busy cranking out its King Air line since the mid-1960s, while Piper gained FAA certification of its first Cheyenne model in 1972. Cessna, perhaps nodding to Beech's preeminence in the market, leapfrogged turboprops altogether, preferring to put its development dollars into the Citation line, a move that's paid off nicely. But the 1970s were almost ready to yield to the 1980s before Cessna type-certificated its first turboprop, the Model 441, in August 1977.

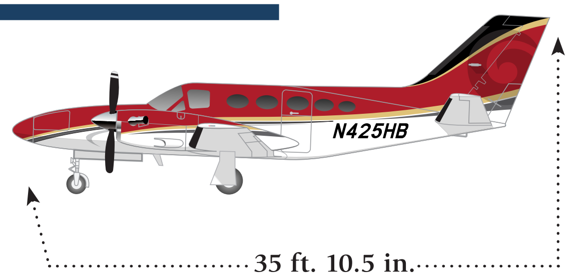
Now known as the Conquest II, the Model 441 was an evolution of the Model 404 Titan, a piston-powered twin, powered by Garrett (now Honeywell) TPE331-8 series turboprop engines. Confusingly, the Model 425—eventually dubbed Conquest I—earned its type certificate almost three full years later, and started life as the Cessna Corsair. Itself an evolution of the very successful Model 421, the 425 was powered by venerable Pratt & Whitney Canada PT6A-112 engines.

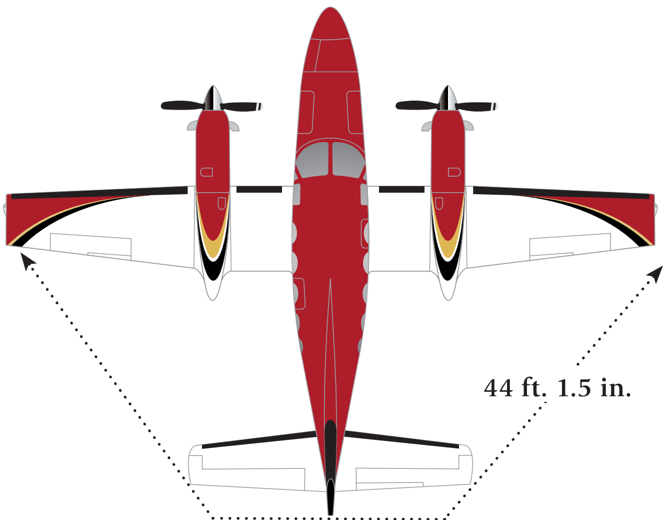
Before production of Cessna's "baby turboprop" ended in 1986—along with a lot of other models from among the GA manufacturers—some 236

The handsome 1983 425 Conquest I in the main image sports four-blade MT propellers and a modern paint scheme.

CESSNA 425 CONQUEST I





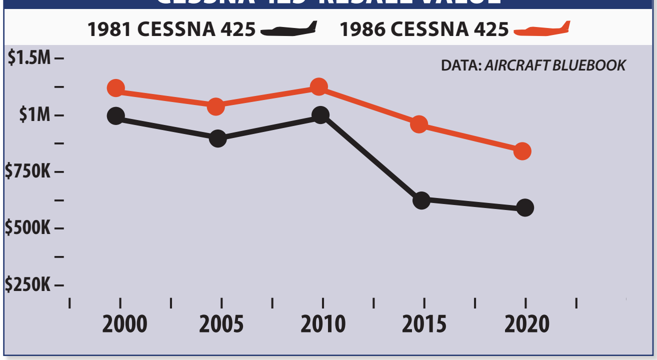


Drawings courtesy www.schemedesigners.com

CESSNA 425 MODEL HISTORY

MODEL YEAR	ENGINE	TBO	OVERHAUL	FUEL	USEFUL LOAD	CRUISE	TYPICAL RETAIL
1981 CESSNA 425 CORSAIR	PT6A-112	3500	$350,000	366	3285 LBS	251 KTS	±$620,000
1982 CESSNA 425 CORSAIR	PT6A-112	3500	$350,000	366	3285 LBS	251 KTS	±$675,000
1983 CESSNA 425 CONQUEST I	PT6A-112	3500	$350,000	366	3652 LBS	251 KTS	±$720,000
1984 CESSNA 425 CONQUEST I	PT6A-112	3500	$350,000	366	3652 LBS	251 KTS	±$750,000
1985 CESSNA 425 CONQUEST I	PT6A-112	3500	$350,000	366	3652 LBS	251 KTS	±$820,000
1986 CESSNA 425 CONQUEST I	PT6A-112	3500	$350,000	366	3652 LBS	251 KTS	±$870,000

CESSNA 425 RESALE VALUE

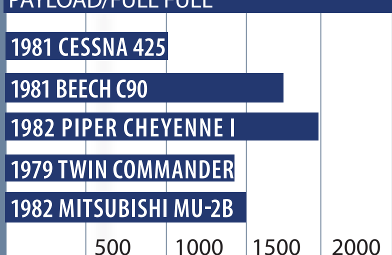


SELECT RECENT ADs

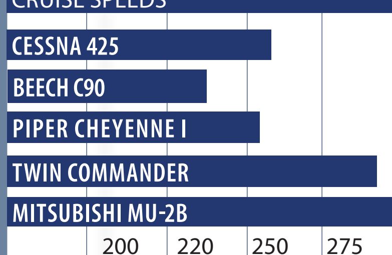
AD 2005-20-25	AVIONICS BUS CIRCUIT BREAKER SWITCHES: INSPECT/REPLACE
AD 97-01-13	FUEL, OIL AND HYDRAULIC HOSES: INSPECT/REPLACE
AD 91-25-08	FRONT WING SPAR UPPER CAPS: INSPECT, INSTALL REPAIR KIT
AD 1984-20-02	NOSE LANDING GEAR: REPLACE ROD ENDS

SELECT MODEL COMPARISONS

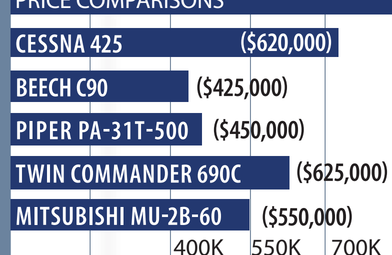
PAYLOAD/FULL FUEL



CRUISE SPEEDS



PRICE COMPARISONS



Like all big twin Cessnas, a Conquest deserves lots of avionics. The one at the top has dual Garmin G600 primary flight displays and big-screen engine monitors. Look carefully at the suite of mechanical instruments in ones that haven't been upgraded. Working on the aged SPZ-500 autopilot is time-consuming and expensive.

Model 425 Corsair/Conquest Is were produced.

By the time Cessna was able to certify the Corsair/Conquest I in July 1980, general aviation production had peaked, and Cessna itself had been going through some very difficult years. Several of its high-performance twins were suspected of design errors that led to inflight airframe failures. These included the 441, its piston-powered kin the 404 Titan and the Model 340. Expensive ADs were applied while the company tried to fix the problems: All early Model 441 airframes were upgraded to a later configuration by the factory, at its expense. Meanwhile, the 340's empennage had to be inspected every 10 hours of operation for a period of time.

IT'S NOT A TURBINE 421

One of the elemental strengths of the 425's design is the nearly bulletproof Pratt & Whitney Canada PT6 free turbine engine. The A-112 version originally installed in the 425 is a fairly unsophisticated one that is not highly stressed. It is flat rated at 450 SHP. For pilots transitioning to turbine power and for operators at smaller airports, PT6 power is the right choice and is easy to support. The inflight shutdown rate is impressively low, which is why so many pilots call the engine bulletproof.

The Conquest is not a model 421 with PT6As—not by any stretch. The 425 is its own airplane, even though a handful of Continental GSIO-520N-powered Cessna 421 Golden Eagles have the Riley 421 Prop Jet conversion. This includes Honeywell LTP-01 engines and winglets. But there are a number of distinctions, and very different systems were installed in the Conquest. It would make about as much sense to call a 421 a pressurized 411, or a 414 a wide-body 340. But make no mistake, all are products of the same basic design and engineering philosophy, and the later 400-series airplanes reflect many of the lessons learned in designing, developing and building the 500-series Citations.

The wingspan of the 425 is about three feet wider and the wing area is 10 square feet greater than the 421 wing. The 425's horizontal stabilizer has a distinct dihedral (and, as a former senior Cessna official later said, it really should have been a cruciform tail to negate the adverse effects of propeller wash, now often called whirl-mode vibration, but the company did not want to spend the extra bucks). Still, the aft fuselage structure is much beefier than that of the 421. Just count the rivets from the cabin door aft on the two airplanes.

True, many performance numbers are fairly close for the two types. But that is at a takeoff weight of 7450 for the 421 and 8600 for the 425—more than half a ton of difference. Basic empty weights are about 250 pounds different, but the 425 lifts nearly double the fuel weight of the 421 (2452 versus 1236, or 1572 with auxiliary fuel on the 421). Both all-engine and single-engine rates of climb are fairly close (1950/345 for the 421 and 1875/380 for the 425). The 421 wins the accelerate/stop race (3630 to 3800 feet), but the 425 runs away in accelerate/go (4960 for the 421 to 3360 for the 425). For the love of turbine power.

The 425 also has the advantages of propeller reverse and autofeathering—a no-go system, by the way—the latter of which greatly simplifies aircraft control in the event of an engine failure.

At comparable weights, of course, the power and higher aspect ratio wing advantages of the 425 enable it to run away and hide from its piston-powered cousin. Then, compare the inflight failure and unscheduled removal/repair rates of the two engines. It's no contest: The turbine is far superior.

For the properly trained pilot of a well-maintained airplane, the superior systems and performance of the 425 result in greatly reduced workload compared to the 421 or any other piston twin.

MAKING IT BETTER

At its introduction as the Corsair, the 425 had a maximum takeoff weight of 8200 pounds and a basic empty weight of 4870. Full usable fuel weight of 2452 pounds (366 gallons) and average optional equipment weight of 375 pounds left a pretty miserly 503-pound payload.

Maximum takeoff weight was increased to 8600 pounds in 1983; basic empty weight increased by 52 pounds, leaving most of the increase for payload. At the same time, the 425 was formally inducted into the "Cessna Propjet" family and was renamed the Conquest I. No more privateering.

Earlier 425s could be modified to the new weights quite easily, and all have been. Zero-fuel weight increased from 6740 to 7000 pounds; maximum landing weight remains 8000 pounds. Most other changes to the 425 are system or operationally related, such as improved static wicks and additional avionics options.

Probably the most important of the latter is the optional Sperry (and later Honeywell) SPZ-500 flight control system. Even for its $75,000 cost at the time, it was a big improvement over the ARC (Cessna) 1000 FCS, which has been one of the weak links in the 425 and other Cessna twins. Some 425s were equipped with the ARC 800 series autopilot, which is even less desirable than the 1000. One owner told us the 800 in his airplane had a mind of its own despite many attempts to correct its abrupt pitch excursions. We've had our hands in these systems enough to know labor and parts costs for troubleshooting and repair can be a big number. Evaluate them carefully during a prepurchase run-through.

From the beginning, Collins avionics have been an option worth the price differential over the standard ARC system. To be fair, it should be noted that a number of operators had good experience with their ARC avionics (and a Cessna technician, when asked about his early experience with the 425, said everything was great except for the (expletive) Collins radios. If you find one with Collins or ARC avionics, we would budget $100,000 to start for a full-up avionics retrofit, and likely more if you replace the autopilot. Common upgrades, including the Garmin G600 TXi primary flight display, S-TEC digital autopilot and Garmin GTN navigators. Don't forget ADS-B transponders.

It may be time for some panel work, too. As a requirement for British certification, a master caution warning system was added. This is a useful addition because the annunciator panel can be hard to see in direct sunlight, even though it is mounted at the top of the panel, under the glareshield.

A noticeable improvement was made in the later run of 425s: better interior design, fit and finish. Appearance, comfort and durability all were improved. Redesigned cabinetry also provided more legroom for passengers in the principal four club chairs.

Another factory option made available in 1982 was Cessna's Cescom maintenance program, which recently was turned over to CAMP Systems. A genuine programmed maintenance scheme in its later form, Cescom provided more flexible inspection options that could reduce total hours and cost for those who scrupulously followed the recording and reporting requirements. A service life recorded on Cescom would be a strong plus for any used 425. Regular readers of aircraft resale

A Conquest cabin has a business jet feel and it's a dwelling that passengers should like. There's plenty of storage in the cabin and nose baggage area, middle. Yes, that's a potty seat, bottom.

We wouldn't kick either one of those big Cessna twins out of the hangar. On the left is a 421C and on the right a 425 Conquest.

advertisements will note that such programs as Cescom, various engine maintenance programs and good service bulletin compliance history are considered sales advantages.

A number of improvements have been missed by operators who do not carefully review product information and improvement and service bulletins from Cessna and component manufacturers. These include glass replacement windshields (although some technicians claim this change has not completely solved cracking and delamination problems), replacement of troublesome torque gauges with electric ones, water drains to control circuit breaker and avionics systems contamination and shorting, plus a number of engine modifications.

The best Conquest I is one fully up-to-date on hourly, cycle and calendar maintenance, ADs, service bulletins and kits, product improvements, updated electrics, current avionics and a sound pressurization and climate control system. This could run into real money. How much?

When shopping, consider that *Aircraft Bluebook* suggests dinging the price by $112,000 if the SIDS (Cessna Supplemental Inspection Documents) aren't complied with. It should also pass the most meticulous, every-nook-and-cranny inspection by an experienced 425 technician. The best-looking Conquest I, with the newest interior and latest paint job, may be a beast in disguise.

Cosmetics are appealing, but they are the least important part of any airplane purchase, especially something as complex as a Conquest. There are many thousands of buyers who were lured by good looks thinking the airplane was good to go, only to find they had bought hangar queens.

PERFORMANCE, LOADING, CABIN COMFORT

While the 425 does not have the payload capacity of a C90 King Air, it is nearly a fill-the-seats airplane. With lots of lard and luggage toward the rear of the airplane, CG has to be checked carefully, but the loading range is quite wide.

Zero-fuel weight dictates that anything between 7000 and 8600 pounds has to be fuel, but that still leaves a healthy payload of crew, passengers and baggage or freight of 1673 pounds for a typically equipped airplane.

The average 425 can seat eight: two in the cockpit, four in club seats, and two in the additional full seat on the left rear side of the cabin and belted potty seat. Even with the maximum number of seats, there is a generous baggage area in the aft cabin (about 30 cubic feet and up to 500 pounds). The cavernous nose houses another 22.4 cubic feet of baggage area with a maximum load of 400 pounds. It's a big airplane.

There is a lot of cubic space in both the cabin and baggage areas that could tempt those lacking caution and experience to exceed load limits. Yield not to that temptation. Aside from CG concerns, exceeding maximum loads can cause serious performance deterioration, especially in high density altitude conditions.

With sea-level, standard-temperature conditions and gross weight the (well-flown) 425 can clear a 50-foot obstacle after a run of 2420 feet and land over the same barrier in 2120 feet. With the already mentioned accelerate/stop and accelerate/go distances of 3800 and 3360 feet, a properly qualified pilot can safely operate from 4000-foot runways with room to spare. If you are used to flying a Skyhawk or a Cherokee, that may sound like a lot of runway. For a nearly 9000-pound airplane, however, that's pretty good.

Rate of climb is good enough to make it practical to climb into the flight levels for even relatively short trips. The 425 operates best between FL230 and 280. While maximum speed of 260 knots comes at 18,000 feet, fuel burn is high. At FL260, max cruise power produces 251 knots and 1240-NM still-air range. In the mid-20s, the 425 is a five-hour-plus-reserves airplane. With a maximum operating speed of 230 KIAS and max gear operating of 175 and approach flaps of 174, the 425 can return to pattern altitude quite quickly when necessary.

A Conquest with well-balanced rotating components and a fully functioning propeller synchrophaser can be relatively quiet and comfortable at cruise power settings, especially at propeller RPM of less than 1900. Each airplane has an ideal, low-vibration RPM that can be determined with practice. Good propeller balancing makes it even better. For a number of 425s, the best compromise of noise and vibration occurs at propeller settings of between 1825 and 1850 RPM. Experimentation pays off, because once cruise power is established, vibration is more of

TWIN TURBOPROP PRICES PLUMMET

We looked hard at *Aircraft Bluebook* values for same-class turboprop twins—the 425 Conquest I, Piper Cheyenne I and Beech King Air C90—and discovered an eye-widening pattern of depreciation over a 10-year period. The Conquest was introduced in inauspicious times. Since then, single-engine turboprops like the Pilatus PC-12, Daher TBM series and Piper Meridian/M-Class singles have come onto the market, offering similar performance (except when an engine fails), fully integrated avionics and autopilots, similar cabins and around half the burn of Jet-A. All of which nearly drives a new turboprop twin to extinction, evident by the huge slide in resale values of twin turboprops starting around 2009. The 425 Conquest wasn't the only turboprop that took it on the nose, and that's all good for buyers in 2020.

According to *Aircraft Bluebook*, even the Beech C90 King Air book value has steadily declined in big numbers. Ten years ago a 1981 C90 had a typical retail of around $900,000. Today it's published at $390,000. A 1981 Piper Cheyenne I once valued at $550,000 currently lists for $230,000.

These are starting values, of course, because major upgrades and refurbishment are a huge factor in ultimate fly-away pricing. Just as it is in the lower end of the market, planes that have been upgraded with modern avionics, paint and interior end up selling for a lot more. The same goes for the Conquest, where major renovations aren't uncommon. We looked at the respected aircraft sales website Controller.com and found wild price swings. For instance, a 1982 Conquest I with 7400 hours on the airframe and 1100 hours on the PT6A-112 since major overhaul was listed at $690,000—which is in line with *Aircraft Bluebook* suggested retail prices. On the other end of the spectrum, there was a 1983 model listed for $1.4 million. It sported fresh Blackhawk XP135A engines (PT6A-135) with four years/2300 hours remaining on the warranty, relatively low airframe time (5800 hours and 4500 landings), new Garmin glass avionics with ADS-B, cabin Wi-Fi, paint from 2002 and incremental interior upgrades including new cabin seating. The Blackhawk mod has a factory-new list price of $750,000, and core engine credits can be up to $35 per hour per engine for every hour remaining on the factory TBO, which for the PT6A-112 is 3500 hours. Blackhawk advertises that nearly every Blackhawk-powered aircraft that has been resold within 500 hours of the upgrade has sold close to or higher than the combined investment of the airframe and engines. That's pretty much what we saw in our research.

The other thing we see is that despite the comparatively small population, the market for used 425s remains active and, for the most part, the airplane is favorably regarded. For a properly maintained airplane, dispatch reliability is high, and operational simplicity makes it comparatively undemanding to fly. With prices now stable, we think the right Cessna 425 Conquest I is a good used market value.

a noise-generating factor. The two major sources of noise both involve propeller vortices: hitting either the nose cone or the tail, and then being transmitted to the cabin (the fuselage acts like a megaphone).

The 425 is a good airplane with respect to noise and comfort.

SINGLE-PILOT CAPABLE

But only if you are. Our accident scan uncovered a surprising number of issues in IMC, proving that while the Conquest 1 has a reputation for being an easy turboprop to fly by yourself, bring the A game.

The reward for doing so is a cockpit with decent ergos, made even better by modern electronic displays that bring lots of data in a centralized location. The cockpit dwelling is also comfortable for most pilots of average to large size. Visibility is good. Control harmony in flight is fair. Pitch is the heaviest force, and this is by design. Appropriate trim input is a key to flying the 425 smoothly.

Even so, pitch changes resulting from configuration adjustments are modest. They are more obvious with power changes—particularly major

CONQUEST I CRASHES: IMC ISSUES

We dug into Cessna 425 accident reports back through 1985 trying to find 100 so that we might do some meaningful analysis into problem areas with the fleet. We found a grand total of 27 mishaps of widely varying severity, including one poor pilot who had another airplane taxi into his turboprop.

We found no engine-failure-induced accidents, a tribute to the Pratt & Whitney PT6 powerplant.

One pilot did think he had an engine problem—a chip light illuminated—so he shut the engine down. He then landed short of the runway and tore off the gear. An inspection of the chip detector revealed that it was defective and had given a false chip indication.

There were only two fuel-related accidents. In one case the fuel was contaminated, leading to one engine going quiet, followed a few minutes later by the other. The pilot was almost able to glide to an airport and survived a landing in trees. In the other, the pilot noted a split between the left and right fuel gauges although he was certain that there was an equal amount of fuel in the tanks. He chose to believe the gauge that showed more fuel.

You got it, it was the other gauge that was correct. He was, however, right about the tanks having the same amount of fuel, as the engines quit at almost the same time. The accident investigator found that the left gauge showed empty while the right indicated 290 pounds of fuel.

Icing played a role in four accidents, including aviation's version of a fender bender when a 425 slid off of an icy taxiway and hit a sign at low speed.

One pilot reported that after collecting ice, he was able to remove most of it with the deicing boots, but still chose (probably wisely) to tack on extra speed on approach to landing. He hit turbulence in the flare, which rolled the airplane in both directions. He attempted to go around, but stalled the airplane and a wing hit the ground.

To the extent that there was a common thread in 425 accidents, it was problems associated with flying IFR in IMC.

One 425 pilot collected so much ice that he stalled the airplane and spun it in.

The post-crash investigation into a 425 that was seen to emerge from cloud bases in a diving spiral before it broke up revealed that the left pitot heat switch had been damaged sometime prior to the flight. The pilot had turned it on prior to entering icing conditions, but it did not activate the system. The right side pitot heat was on and functioning. The pilot lost control after the left pitot tube froze up and he tried to deal with discrepancies between the pilot and copilot airspeed, altitude and VSI indications.

Of five accidents in IMC, three involved pilots who lost control of their airplanes and postmortem exams found significant levels of disqualifying prescription drugs in their bloodstreams.

Another pilot broke out of clouds on an ILS at 100 feet in a left turn, which he continued to ground impact.

A pilot who had his passenger crouch beside him to "help find the runway" on an ILS went well below minimums before missing the approach. Rather than climbing, he then flew level into obstructions. The passenger survived. The pilot, who was not wearing his shoulder harness, did not.

Two pilots got things wrong with the power controls. When one brake failed on landing, the pilot feathered the props rather than commanding reverse and went off the end of the runway. Another, meaning to pull the power to idle before flaring to land, commanded reverse and hit hard, short of the runway and collapsing the gear.

power changes as when transitioning from approach to missed approach or go-around.

There are no peculiar tricks, however. From both the pilot eye-level perspective and physical/reaction demands, the 425 probably is the simplest of all the turboprops to transition to. Thus the nickname "baby carriage." Pilots transitioning from light twins will have to get a feel for control pressures, trim use, aircraft performance and weight (inertia). But good training and a bit of experience quickly lead to confidence. Engine management, from startup to shutdown, is as important as how well you can fly (or program it to fly) a busy approach in the clag. And you better mind those PT6As. Poor power management can lead to premature failure or, at the least, much higher hot-section inspection and overhaul costs. They cost big bucks.

Flying the airplane entails extra time and extra care during pre- and post-flight operations. There are good tricks to learn. For instance, if a quick landing and turnaround is planned, shutting off the bleed air source from one engine about 15 minutes out, then starting that engine first on the turnaround, means lower start temperatures and lower stress on both engines.

On the ground, both before and after flight, the airplane needs special care, and operations such as ground towing and refueling must be closely monitored.

MAINTENANCE, SUPPORT

This is not the kind of airplane to use for on-the-job training for technicians for your local or favorite but unqualified shop. That's a major reason for unhappiness with the 425 and similar airplanes for many operators. Selecting the wrong shop can be as expensive as neglecting proper maintenance altogether. The best approach is to talk to other Conquest I operators to get their recommended service and information sources. Keep meticulous records, too. Get involved in an information-sharing network of operators and service/support organizations. It can serve as effective early warning and help keep operational readiness up and costs down. With all that in mind, any serious Conquest I buyer and owner should absolutely join the Twin Cessna Flyer organization (www.twincessna.org).

The known maintenance record of the 425 fleet, consisting mainly of service difficulty reports (SDRs) and airworthiness directives (ADs), has highlighted some shortcomings of the design. While there has been no overwhelming weak point, several problems identified in the field have resulted in ADs. There are a few that suggest careful inspection in hard-to-get-at areas is required. These areas include control cables at pulleys, fairleads and pressure vessel seals, and window retainers.

Service difficulties that resulted in ADs include wing spar cap cracks caused by landing gear loads (AD 91-25-8, repetitive inspection or replacement), windshield attach point failures (84-3-4, repair or replace the windshield), nose landing gear actuators (84-20-2) and horizontal stabilizer attach fittings.

On Sept. 1, 2007, Cessna introduced the Supplemental Structural Inspection Program (SID) for the Model 425, after working with Model 300/400 operators and the FAA. The program consists of the current structural maintenance inspections, plus supplemental inspections, as required, for continued airworthiness of the airplane as years of service are accumulated. The current inspection program is considered to be adequate in detecting corrosion and accident damage. The SID program's emphasis is to detect fatigue damage whose probability increases with time.

Approximately 60 percent of the active 425 fleet (approximately 240 aircraft worldwide) has had the SID inspections accomplished, which are due on all aircraft over 20 years old (i.e., the entire fleet). The initial inspection requires the entire series to be completed, which is a sizable task and not to be accomplished by the average maintenance shop. The complete series of inspections involve 943 labor hours, plus nondestructive testing if completed simultaneously. Individually, there are 1685 labor hours of inspections, plus NDT.

Once the initial SID inspection is completed, additional inspections will only come due again over the course of 10 years or 5000 hours of operation. Only one minor inspection has been added to be accomplished every 200 hours of operation or 12 months, whichever occurs first. The vast majority of the inspection series repeats again in five years or 2500 hours of operation, or 10 years or 5000 hours of operation. A comprehensive explanation of the program is available from Textron Cessna technical support or an authorized service center.

At least the Conquest is not an orphan. Despite the fact no 425s have been produced for a few decades, operators tell us that Textron/Cessna support is commendable, particularly when compared to most other manufacturers or former manufacturers. Cessna service centers specializing in 400-series twins also can be a good source of research materials for determining what the proper maintenance status of a 425 should be. The few bucks (or hundreds of bucks for all materials) represent a worthwhile investment.

So, too, it pays to get to know someone in customer service at Pratt & Whitney (PWC). While the PT6A-112 is a fairly old and mild version, there is much to learn about modifications and recommended procedures. For instance, one reader who bought a 425 awhile back had a nearly $55,000 shock when discovering the original cobalt inlet guide vanes had been replaced by nickel vanes (that large payment included hot section inspections).

Basic changes have occurred—which operators on Cescom or on the mailing lists at Cessna and PWC would have known about—that increased propulsion system serviceability and durability (and reduced major maintenance costs). Among these are compressor washes. A mod was introduced that adapted a fitting much like the one on a garden hose to make compressor washes easier to perform.

The Conquest I's PT6A-112 engines have a 3500-hour TBO and a typical overhaul cost of around $350,000. If you're going to re-engine one, consider the Blackhawk XP135A mod for more speed and efficiency.

PWC has a lot of eye-opening information for operators. Among these are some of the reasons for regular compressor washes. You might accept the necessity in a high salt-content environment. Pratt specialists can show you maps of concentrations of contaminants such as sulfur that occur at cruise altitude in parts of the North American continent, where you might expect the air to be pristine. Among the relatively simple modifications that can be made to the 425's engines is one that reconfigures the inlet nozzles to reduce temperatures in the combustion section of the engine during starts.

What some operators of turbine engines never learn, and others learn only after expensive inspections and overhauls, is that heat is both the friend of performance and the enemy of endurance. Going for maximum performance all the time means running temperatures to the

VAN'S RV-6/A

You asked, so we'll deliver by covering the used Van's RV-6A series in an upcoming Used Aircraft Guide. We want to know what it's like to own arguably the most popular experimental model out there, how much it costs to operate, maintain and insure and what they're like to fly. If you'd like your RV to appear in the magazine, send us any photographs (full-size, **high-resolution**) you'd like to share to the email below. We welcome information on mods, support organizations or any other comments. Send correspondence on the RV-6/A by Aug. 10, 2020, to:

Aviation Consumer
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Used Conquest I

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recommended limits. Given the vagaries of most gauges and the benefits of just a few degrees lower temperature, a little touch of conservatism can mean literally thousands of dollars of reduced cost during a hot-section inspection or overhaul, not to mention diminishing the stress that could result in one of those rare inflight failures.

Of course, much the same can be said for piston engines, from a big Pratt radial all the way down to a Briggs & Stratton.

OWNER EXPERIENCE

We have owned our 1983 Conquest I now for six years. With 10,500 hours on its clock it has full Garmin glass, including dual Garmin G600 displays, GTN 750 navigators, Garmin traffic and radar systems and an S-TEC 2100 digital autopilot. This Conquest was in fact the Garmin STC plane. Prior to the Conquest we owned a Cessna 421C for nine years and we still do, and we bought a Cessna Citation 501 three years ago so the Conquest I sits firmly in the middle. For speed, we tend to fly the Conquest at 18,000 feet and get 260 knots with a burn of 475 PPH, moderately loaded.

We're sold on the Conquest being an easy turbine upgrade from the 421. It was a very easy transition as so much felt very familiar, and because so much of the airframe and the cockpit is similar. I've heard that Cessna upped the build quality, but we haven't really noticed much between the two. The difference between the Conquest and the Citation, however, is significant and it is clear that the Citation 501 from the same era is built to a much higher standard in all respects.

This said, components seem to hold up much better in the Conquest. The turbine-powered airframe flies much smoother than the piston, and thus it's not shaking itself to bits!

We have MT props on the airplane and they are definitely smoother than the alloy four- blade props they replaced, and quieter, too. We notice little difference in performance, although perhaps a bit slower in cruise (roughly 4 knots) and a slightly better climb rate.

The props were upgraded mainly for two further reasons. The plane originally had three-blade props and must have been upgraded to four-blade props due to harmonics, and the NG idle setting had to be turned up. The result is the plane pulls away on the ground during taxi and you are constantly either on the brakes, or in reverse. The five-blade MT props are set at the ordinal idle, so there's no issues. Also the blades are about 9 inches shorter and can be ordered with titanium leading edges. We fly on a lot of country strips, sealed and grass, and the edges and length are a major help in avoiding FOD in the engines and chipped blades on the props. They are expensive, but probably the most important upgrade we've made to our 425.

Stuart Clumpas
via email