BUILDER'S LOG

Alternative Realities

A from-the-heart discussion of an auto-engine conversion project.

BY LARRY SIMPSON

My transformation from semi-contented Mooney 201 co-owner to Van's RV builder/owner/pilot wannabe occurred somewhere high over southern Arizona in the summer of 1998. A polished RV-6 pulled up next to us, and the pilot offered a friendly salute before leaving us quickly behind. If you want to mess with a Mooney owner's head, that is precisely how you do it.

Builder and tinkerer, Larry Simpson.

The idea lay dormant until, early in 2004, I overheard a chance comment at an RV fly-in at Lakeland, Florida, and tracked down Bob Berube and Russell Lepre, partners in a local builders' assistance enterprise called Flight Crafters. My wife, Gene, and I liked the co-owners and their crew of experienced builders, and believed with their assistance we could probably finish an RV in a year or perhaps as long as 18 months. By February, we owned a Van's RV-7A empennage kit, and the quest to create our own unique Sky Dancer began.

Firewall Matters

The build process could have paralleled so many others but for our years in a Mooney partnership that were generally enjoyable except for a belly that was always oily from a leaking Lycoming. The possibility of finding an alternative powerplant that was smoother, quieter and cleaner, not to mention based upon more modern engineering and technology, was intriguing.

Gene and I were regular attendees at the Sun 'n Fun fly-ins, and each year I haunted the automotive conversion displays and read all I could find about the various V-8, Wankel rotary engine, RSN (real soon now) diesels and even small turbine alternative engines. I discovered the Eggenfellner Subaru conversions at about the same time that we were awaiting delivery of our first kit from Van's and decided that this firewall-forward package, as it was advertised, might be exactly what I was looking for. I had a good understanding of my own skills and desires, and part of the Eggenfellner attraction was the promise of a complete firewall-forward package; I would not have to become an engineer to make it work, and I liked that. After a demo flight with Jan Eggenfellner in March, I placed a deposit on one of the still-in-development H6 Subaru packages set to replace the familiar four-cylinder conversions.

Back to the Airframe

It took about four months to mostly complete the empennage kit and move on to the quickbuild fuselage kit that arrived in late April. The initial excite-

Photos: Kevin Wing, Rick Lindstrom, Marc Cook ment of building slowly wore off as the months passed with little significant progress seeming to be made. The Subaru engine was still months away, but planning for its installation was necessary, and integration of the engine computer, electronics and the engine monitoring equipment into the overall aircraft electronic design became a priority. The ultimate complexity of this task and the challenge of learning a whole new set of skills rekindled the creative juices. Fortunately, Pete Rafferty, a retired Air Force electrical engineer and member of the Flight Crafters family, was available to direct this phase of my education. Little did I know that working exclusively on the aircraft electronics and the panel would end up requiring more than a year.

The complicated panel and the significant differences in electronic considerations for an automotive engine conversion required that every decision made and every wire that we connected be carefully documented. I looked at several different types of CAD and electronic design programs, but ended up using a simple drawing program, Smart Draw, which offered more flexibility and a shorter learning curve. Every day that Pete and I spent working on the panel or wiring, I would take home our pencil sketches made on legal pads or scrap paper and convert them to schematics and electronic drawings that were carefully archived both electronically and in a series of notebooks for future reference. This slightly obsessive behavior proved its worth time and again as the project's timeline lengthened, and we would revisit a long-finished module to add to it or modify it as we came closer to completion.

The Generation 3 PSRU, like its predecessors, is a two-shaft, four-gear arrangement meant to put the prop shaft on the same plane as the crankshaft.

The modified water cooling system employs three small radiators around the prop; the current configuration has two larger radiators left and right of the PSRU.

Moving Forward

In the fall of 2004 the fuselage and wings were well along, and I was starting to focus on the engine. I had studied Eggenfellner's online installation manual for a 2003 four-cylinder Subaru and based most of my wiring decisions on those recommendations. We knew that adjustments would need to be made for the larger six-cylinder version that he was still working to complete, but these changes were difficult to predict, so we did the best we could and waited for the engine package to be available.

The winter of 2004 was spent making minor modifications and "improvements" to the airframe. These varied from a stiffener for the armrest to an automotive-type fuel screen in the wing tanks to replace the original primitive pickup. Each of these departures from the tried and true required careful thought and consideration, and each meant ounces that would add up, as I would ruefully discover with our first weight and balance two years later. The panel underwent another round of revisions, and we kept pulling wires. There seemed an endless number of complex and layered electrical connections that needed to be made, and my father, who grew up in the automotive business and returned to it after nearly 20 years with Eastern Air Lines, offered some sage advice that his father had given him: "Just take one wire at a time, Son, just one wire at a time." I would remember that every time the panel's wiring seemed to be getting out of control, and it did help.

Twin SuperTrapp mufflers quiet the normally raucous H6 Subaru.

Pete and I made slow but steady progress on the panel and the electronics, and they were ready when I brought the finally completed Eggenfellner Subaru conversion home in March of 2005, six months later than originally projected. Eggenfellner would not release engine packages until he was satisfied that they were right, so revisions of the delivery dates were not uncommon. I had brought some of the delay on myself and could not complain.

The process of hanging the engine on the firewall took only a day, but completing the firewall connections and integrating the engine electronics would take several more months. During that time I also redesigned the

external muffler mounting system to be more streamlined and started designing a tunnel cover for the cockpit-mounted fuel pumps. Once again I relearned the lesson that every design change translates into money, time and delays.

Modifications R Us

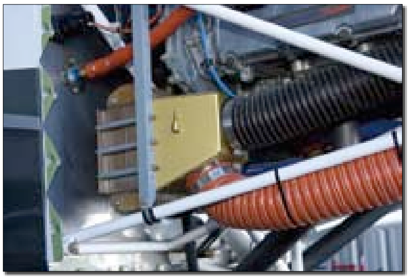
During the summer of 2005 and stretching into the fall and winter, we continued to work on the panel and wiring with a short break to install an Eggenfellner-recommended modification to the cooling system on my yet-to-be-run engine. The original design included two small side-mounted radiators with an oil cooler of approximately the same size mounted below the prop. These were all designed to fit within a minimally modified Van's IO-360 cowling.

The early Eggenfellner H6 adopters discovered that the cooling system that worked so well on the four-cylinder engines was inadequate for the larger engine. Jan responded with a factory recommended upgrade that replaced the front-mounted oil cooler with a third small coolant radiator. This required repositioning the oil cooler to below and to the rear of the engine with a builder-determined location, mounting system and air supply. He also recommended adding additional cooling exit area, preferably in the form of a large cowl flap. Instead, I opted to design a two-cowl flap system, believing that this would be simpler than designing a large central cowl flap around the nosegear.

The first H6 builders to fly with the rear-mounted oil coolers shared their experiences and were struggling to find a way to keep the oil temperatures out of the red. I decided to place my oil cooler on the right side of the engine to make changing the left-sided oil filter easier. I designed a mounting system that positioned the rear of the cooler about 4 inches from the firewall and hoped this would provide adequate airflow. The first version of the oil cooler air supply was installed, and I followed the message boards to see what other builders were doing with their various designs. Having access to this community of shared experience proved immensely valuable in learning what worked and what didn't. Later, I would get to see if my solution worked.

Oh, Those Logistics

Flight Crafters moved about 20 miles north, to a building on the edge of the Zephyrhills Airport, in January of 2006, and we moved the various pieces of the RV-7A and several dozen boxes and storage containers with them. The



Simpson's "homebrew" oil-cooler arrangement uses 3-inch ducts taken off the forward air intake.

The H6 Subaru engine—a sophisticated double-overhead-cam six-cylinder design—is a tight fit in the RV-7 cowling. But it does fit!

project was now approaching its second anniversary, and we were a long way from first flight.

The spring and summer of 2006 saw slow but steady progress. Mounting the MT electric variable-speed prop and prop controller came next, and then it was time to reattach the elevator and rudder after their long, patient wait in storage. In the fall of 2006, Ted Coberly, another member of the Flight Crafters crew, helped install the cowl flap system that I had designed. I was finally becoming aware of weight issues and decided to use small cowling-mounted electric servos to operate the cowl flaps, recognizing that this would result in somewhat severe operating limitations—just another example of the truism that all homebuilders are familiar with: All decisions are trade-offs.

In March of 2007 we cranked up the Subaru engine for the first time and were pleased with how quietly and smoothly it ran. Some hard-starting issues were quickly solved after reviewing the wiring with Jan, and soon we were ready for a formal weight and balance. While not the heaviest RV-7A out there, the combination of a liquid-cooled Subaru engine, a robust, IFR-capable glass panel and lots of little design upgrades

One benefit of using a modified standard RV-7A cowling is that the airplane's sleek lines remain largely undisturbed. That's to say she's still a looker.

A Subie From the Pilot's Seat

Larry Simpson has spent so many hours tinkering, noodling, building and refining his Subaru-powered RV-7A that even he admits to some forest-for-the-trees effect. For some perspective, Larry invited me to spend a couple of days with his airplane to judge its performance and capabilities.

A cowl-on walkaround reveals few of the alterations ahead of the firewall. The unusual cooling inlets—three in the nose, with the central duct closer to the spinner than we're used to seeing on an RV—are tip-offs, as are the Super Trapp mufflers dangling beneath the fuselage. But then your eye is probably taken with the shiny three-blade electric MT propeller. It was Jan Eggenfellner's desire to house the Subaru engines inside stock (or stock-looking) cowls for reasons of aesthetics as well as ease of installation.

Stick your head inside the cockpit, and what stands out beyond the array of electrical switches is the lack of a prop or mixture knob; instead, you get a small panel to control the MT constant-speed prop and a short-throw push-pull throttle.

Wait, Weight

You would think this well-equipped panel would add some weight to the normally svelte RV-7A airframe, and you'd be right. In combination with the Subaru H6 engine and its required cooling gear, Simpson's 7 weighs in at 1290 pounds with an empty arm of 79.38 inches aft of the datum. For comparison, among all the RV-7A owners who have submitted weight-and-balance info to Dan Checkoway's RV site (*www.rvproject.com*), the average 7A weighs 1112 pounds with an arm of 79.85. Several 200-hp 7As are said to weigh around 1140 pounds empty with the heavier angle-valve Lycoming four-banger.

To compensate for the weight of engine package—and, to be fair to the Subaru, the additional systems required aft of the firewall to support this electric-only powerplant—Simpson increased his 7A's maximum gross weight to 1950 pounds, up 150 pounds from Van's recommendations. With full usable fuel, he can carry 420 pounds of people and baggage.

Becoming Familiar

Larry boldly put me in the left seat and let me have at it, relying on his thorough checklists and right-seat encouragement. Getting the Subaru started, even on an unusually cold Tampa morning (temps around 45° F), was almost like starting a car. Turn the electrics on, check that the dual fuel pumps both work, flip on the ignition and crank. On this chilly morning, finding just the right throttle opening to keep the engine running required a bit of trial and error, but later, when warm, the engine started and idled without fuss.

Aside from the growl from the mufflers and a distinctive high-pitched engine note—nothing like the pocketa-pocketa of a big-inch aero engine—getting to the end of the runway is familiar practice. Runup, well there isn't one. Double check that the prop adjusts freely, make sure you have electrical power on both buses and that the alternator is on line, verify that the oil and coolant temps are at 140° F or greater, run a quick check that either fuel pump keeps the engine running—and you're good to go.

Because the prop can be agonizingly slow to respond, you don't just jam the throttle forward for the takeoff. Ease it in, let the prop pitch come in, and down the runway you go. Initial acceleration seemed good, on par with the lighter 180-hp RV-7s I've flown; perhaps the three-blade MT is making up for some of the excess heft. Takeoff and initial climb are with full throttle and 2500 prop rpm, very close to 5000 engine rpm with the 2.02:1 ratio of the Gen 3 PSRU. Rate of climb initially was better than 1000 fpm, but because we were flying out of an airport with overlying airspace, we couldn't maintain full climb performance for long. Later in the flight, the data from the Grand Rapids EFIS showed that our climb up to 7000 feet MSL averaged 700 fpm at 113 knots indicated (KIAS). We continued to 10,000 feet MSL to check cruise performance at best-efficiency altitudes, and the rate for the last 1000 feet of the climb averaged just under 500 fpm at 110 KIAS.

had resulted in an RV that is definitely on the heavy side—the empty weight, with all fluids including unusable fuel, is 1290 pounds.

A few weeks of taxi tests and fine-tuning finally prepared us for the long delayed and surprisingly brief first flight on May 8, 2007. I say surprisingly because that first flight lasted a total of 17 seconds, and the second half of it was unpowered. A basic electrical design flaw that was entirely my responsibility resulted from my miscalculating the power requirements of the Subaru engine computer during sustained full-power operation. A critical circuit breaker popped just as I passed about 80 feet. A long runway and lots of dead-stick practice as a glider pilot made this practically a non-event. It was not until the plane was back in the hangar that the magnitude of this error hit me, and I started the long process of reviewing all of the calculations and decisions I had made while designing and creating the electrical system. It was more than a month before I felt confident making the second flight, which proved relatively uneventful.

The next six months were spent with

Builder Larry Simpson and his wife, Gene, take special care to see that everything under the cowl is "just so."

test flights and data gathering related primarily to engine coolant and oil temperatures. The data-logging capabilities of the Grand Rapids Technologies

Altitude MSL	Outside Air Temp F	Prop RPM	Indicated Airspeed (knots)	True Airspeed	Fuel Flow (gph)	Nautical MPG
2000	68	2500 *	165	173	15.5	11.2
4000	59	1700	127	137	7.0	19.6
4000	59	2000	131	152	9.9	15.4
4000	59	2300	152	164	12.5	13.1
4000	59	2500 *	159	171	14.4	11.9
8000	47	1700	113	130	6.4	20.3
8000	47	2000	129	148	9.0	16.4
8000	47	2300	138	158	11.5	13.7
8000	47	2500	145	166	13.3	12.5
10000	39	1700	109	129	6.1	21.1
10000	39	2000	122	144	8.4	17.1
10000	39	2300	133	157	10.5	15.0
10000	39	2500	138	163	12.1	13.5
* Performance numbers in these configurations are short term; prolonged flight at these power settings will result in oil temperatures at or above the 220° redline.						
Claimed Performance of Stock 200-hp RV-7A						
8000 ft	75% power		177 knots true		10.5 gph	16.9 NMPG
8000 ft	55% power		159 knots true		7.7 gph	20.7 NMPG

Leveled at 10,000 feet MSL with the throttle wide open and the prop set at 2500 rpm, the Subie-powered 7A accelerated up to 163 knots true (KTAS) according to the GRT screens on 12.1 gph fuel burn. At 5000 engine rpm, the Subaru H6 is clearly up on the "high performance" part of its fuel curve, which explains the relatively great fuel flow. Simpson says his installation experiences slightly higher fuel flows than other H6 owners. (A word about our TAS calculations: We ran several three-leg test runs using GPS-derived ground track and speed to determine pitot-static errors. They were commendably small, in most cases 1 to 2 knots.) Further trials are listed in the accompanying table. Some of the performance benchmarks are not achievable in the real world, as, particularly, the low-altitude, high-power settings will result in oil temps at or above the redline. Also, at the higher rpm settings, the engine is smooth and quiet. However, after the change in gearbox ratio to the current 2.02:1, the lower rpm configurations result in an annoying thrum, one that hasn't been eradicated by a careful prop balance.

Coming Home

In most every way, Simpson's RV flies like other 7s. You barely notice the extra weight in maneuvering; the controls are reasonably (but not too) light, wonderfully balanced and full of chatter about what the flight surfaces are doing. Larry likes to demonstrate one of the benefits of the liquid-cooled engine: With a rapid descent at high power right to the airport, followed by a huge throttle pullback, the prop goes fine pitch, the airplane decelerates like you'd just stuck a few 4x8s along the wingspar line, then there you are at approach speed. The electronic temp gauges barely register a change.

Still, you have to accommodate the slow-acting prop. It takes time to move from full-fine pitch at low airspeed to something that provides useful thrust; you don't want to get low and slow, and then have to make a rapid power increase. When faced with the possibility of low-level windshear, it might be best to lock the prop into a midrange fixed pitch (easily done on the control panel) to prevent hunting. For the rest of the flight, from the landing flare onward, the airplane is vintage RV-7A—a good thing all around. *—Marc Cook*

Horizon One EFIS were well-used and proved valuable.

In this period, I was able to test my version of the oil-cooling system. My final variation included ram air provided by a pair of 3-inch SCAT ducts, originating in the floor of the right front radiator air box. I have found that this works adequately under most conditions, but a full-power climb to cruising altitude in Florida, even in the winter, is not an option.

Judging from the message boards traffic, most of the other first-generation H6 builders are either not yet flying or still searching for the optimal solution to cooling issues. The second generation of H6 engines (now called E6) have a new front engine mounting plate, two much larger side coolant radiators, relocation of the oil cooler back up front below the prop and at least two completely new cowl designs. To convert my installation to the new configuration would be a massive undertaking.

About that Gearbox…

During this phase, the Eggenfellner second generation PSRU became an unexpected issue. My Gen 2 gearbox seemed to be running hotter than expected, being within a couple of degrees of the oil temperature and 10° to 15° warmer than the coolant temperature. I was careful to always stay well within Egg-

Sumptuous accommodations for two: The Subaru's low vibration and liquid cooling make for a serene and always-warm ride.

The News From Edgewater

Jan Eggenfellner is an engine man on the move. "My feeling is that we need to leave the past in the past," he says. "The alternative engine movement, not just us but everyone, needs to be viewed from what we do from here on." With that philosophy stated, it should be no surprise that the company's current offerings are just that, current. There are no legacy products in the Eggenfellner line today.

Having learned from field experience, Eggenfellner based his firewall-forward packages on the 3.0-liter and 3.6-liter Subaru six-cylinder engines, and has employed myriad improvements over previous packages.

Start with cooling. The new setup has two larger water coolers, each 33% bigger than before, with a larger oil cooler now residing below the prop spinner. To feed these new coolers comes a new optional cowling with greatly increased inlet area—from distinctive vertical slits on either side of the prop—and a large central cowl flap. "We resisted using a cowl flap," says Eggenfellner, "but it's the best solution. For some reason, the Subaru engine needs a lot more cooling in climb and a lot less in cruise." Eggenfellner says any cooling issues are problems of the past.

"We have changed our attitude. Before, the goal was to produce the cheapest engine package we could, to get people flying inexpensively. Now we treat these conversions like true aircraft engines," he says. To that end, the new 3.0 and 3.6 engines come standard with a special engine-control unit programmed by Eggenfellner. The sophistication and integration of the original Subaru ECU just doesn't work in an airplane; it demands too much of the car be present to work. "We have a neater, lighter wiring loom," says Eggenfellner, "and we have made the sensor pack simpler. We have taken everything we've learned on these engines and applied it to the current product."

The company has also shifted its production methods. Where, before, it would batch-produce engines, now the cores are purchased in much smaller lots, with a goal of producing one complete FWF package a week.

Propellers have caused some delays, too, says Eggenfellner. "We tried some new carbon-fiber blades from Sensenich in a Quinti hub, but found the new airfoil was too hard on the controller. Quinti has begun installing counterweights on the blades, and we're working now on proving that combination." He says the company is looking into alternative props, including the venerable Ivoprop.

The future for Eggenfellner will likely see a move toward the 3.6-liter engine. Right now, the 3.0 is much more widely available, for less money, and that makes it attractive. But the 3.6 benefits from more displacement to offset its lower compression ratio—allowing it to run on regular autogas, not premium—and is, according to Eggenfellner, "absolutely the best engine Subaru has ever built."

Firewall-forward packages start at $23,995 (add $5000 for the 3.6) including ECU, cooling system, engine mount, PSRU, exhaust system (now made from 321 stainless) and fuel pumps. Cowling, propeller and controller are extra.

Contact Eggenfellner Aircraft at 386/566-2616; *www.eggenfelleraircraft.com*.

—M.C.

Twin Grand Rapids Horizon One EFIS displays are the centerpiece of Simpson's high-end panel. The data-logging capabilities of the system have been a huge help in refining the airplane.

enfellner's recommended limitations, but was unable to identify what it was about my particular installation that might have resulted in these higher-than-expected operating temperatures. A third generation (Gen 3) PSRU had been introduced with the second batch of H6 engines, offering a 2.02 engine-to-prop ratio (compared to 1.82 in the Gen 2) and was initially available as a $3000 upgrade to owners of previous generation PSRUs. That upgrade now costs $4500. I did not think that the marginal performance increase justified the significant cost and intended to stick with Gen 2 PSRU.

That attitude changed when, in May 2007, Eggenfellner published a "mandatory" service bulletin insisting that all users upgrade to the Gen 3 gearbox. In part, it said, "...when a product design evolves to a point where it yields a significant improvement in reliability and safety, the decision to phase a product in slowly, versus declaring it a mandatory upgrade is simple. We must always favor safety...." With this move, Eggenfellner grounded all Gen 1 and Gen 2 gearboxes. Being forced to upgrade the PSRU at my expense was a significant and unexpected cost, but there was really no alternative. His grounding effectively shut off support for earlier gearboxes, and there aren't alternatives from other manufacturers that can be reasonably retrofitted. I arranged to fly to Jan's shop in Edgewater, Florida, in December of 2007 and paid for a factory-assisted PSRU upgrade that went smoothly.

A View from the Road Less Taken

During the fall and winter of 2007 I had time to reflect upon the additional risks that builders take when they decide to invest in an alternative powerplant. It's my view that you must be a pretty serious optimist to believe that all of the projected performance claims by a new powerplant package developer will be met and that the development process will be smooth and uninterrupted. Delivery date delays, unexpected post-delivery modifications, extensive testing and development on the builder's part, as well as necessary and expensive upgrades should, based on my experience, realistically be considered the norm rather than the exception.

More than four years after we began this project, N307RV is flying and finally "looks like a real airplane," according to my wife. But the process of completion is still underway and probably won't be finished for a long time.

The Gen 3 PSRU has a subtle harmonic that I have not been able to get rid of, and several other builders have commented on it in the forums. Eggenfellner assures us that with aggressive prop balancing and careful prop-tip tracking this can be cured, but several builders, including myself, have attempted this without success. My oil temps always run a little high, preventing full-power climbouts or full-power cruise below 7000 feet. There are no high-time Gen 3 PSRUs out there, so durability and reliability are as yet unproven.

N307RV is heavier and a bit slower than many RV-7As, but on the upside, I have a smooth engine with no oil leaks that runs on auto gas, saving me $12 to $15 an hour in operating costs. Adapting a first generation auto-engine conversion has been a fascinating, expensive and at times frustrating experience.

It's fair to say that more of the development process took place in my hands than I had ever expected or wanted. So, the big question: Would I do it again? No. Am I satisfied with the finished product today? Yes. But you might want to ask me again in a few years when the longevity of this "firewall-forward" package is proven. ✈

We are not getting drawn into the tip-up versus slider discussions. Not, not, not...

A subtle clue to the RV-7A's powerplant: the Subaru field of stars.

Because the Eggenfellner conversion spins the prop the "right way," it's likely that many homebuilt fans would walk right past Simpson's Seven and never notice the Subaru engine.

The horizontal duct borrows intake air from the copilot-side radiator and takes it back to the oil cooler. Precisely sizing and placing this splitter required many hours of trial-and-error testing.