Diversion Diagnosis

by Matthew McDaniel

[Author's Note: I am not a mechanic, nor do I pretend to be. In preparing this article, all digital engine data was carefully analyzed by one of the most respected Cirrus mechanics in the world, Jim Barker of Aviation Resources. It is rare that pilots get to see such a detailed postscript of mechanical issues and learn the precise reasons things happened and how and when they did. The judgment calls I made as the Pilot in Command were obviously made without the benefit of such information at the time and, as such, I stand by them.]

IFR operations in small general aviation aircraft, at the height of winter, can make even those native to the upper Midwest shiver. Winds often howl, plunging sub-zero temperatures into bone-numbing wind chill factors. While the snow banks grow, hangar doors develop ice dams, and airport surfaces must be shared with plow trucks and snow blowers to move the tons of accumulation. After 20-plus winters spent flying a variety of aircraft in these conditions, I still relish the interaction with *Old Man Winter* and a trip south during one of the coldest winters in decades is not such a bad assignment either!

Warm Welcome

As I ride in a dilapidated taxicab, staring into the pre-dawn darkness, I see the airport beacon blink, confirming my arrival. I came the night before, via airliner, and took the opportunity to enjoy dinner with family members. After dinner, I was looking at weather forecasts when Jim texted me. "Wanted to see if you are there and if you are still coming, cause it is really cold here – negative four degrees now, and going to be at least negative 15 degrees Fahrenheit." I replied, "Still coming. Cold is fine, and weather is good otherwise." And, so it was, with the aid of my flashlight, that I was pre-flighting at 6:30 a.m.

Ferry flying often puts pilots at an immediate disadvantage. I've never logged an hour in the plane ... never even laid eyes on it before. I didn't know of its mechanical history, how its owners cared for it, or precisely which gremlins dwelled within its structures. I was hoping any gremlins choose to remain dormant that day, but just in case, I took my time, shining my light into air inlets, inspection ports, and fuel tanks, in hopes I would see them before they saw me. Paperwork, manuals, logbooks, oxygen supply and masks: all check. A few minutes later, a mechanic arrived with TKS anti-icing fluid, which he pumped into this 3rd-Generation Cirrus SR22TN's wing-reservoir. With chocks pulled, I climbed in and shattered the silence of the breaking dawn with the bark of 310 hp through dual exhausts. While the engine warmed at idle, I listened to ATIS, retrieved my IFR clearance to the frozen north, and went about programming my route into the Avidyne R9 Flight Management System (FMS).

With the engine warm and run-up complete, four minutes passed as I finished checklists, double checked my inputs into the FMS and my iPad's© ForeFlight© app, and awaited the tower's departure clearance. Had I been staring at the R9's Engine Monitoring page during that time, rather than dancing between the other important tasks, I might have seen it then, but I wasn't ... and I didn't [Figure 1].

North by Northwest

While it is certainly not Wisconsin, it was still a brisk morning and the plane climbed with gusto at over 1,000 feet per minute. On course to the initial waypoint, I was climbing at 140 KIAS. I had a long flight ahead and hoped with good fuel management to complete it non-stop. At 3,000 feet AGL, I leaned the mixture briskly for a fuel-conserving, Lean-of-Peak climb [Figure 2].

Parking the Turbine Inlet Temperature (TIT) gauge at 1,560 degrees, I set the DFC-100 autopilot to climb at 130 KIAS to 12,000 feet. By my planning, that altitude was the sweet spot for balancing true airspeed and headwind component to give me the best groundspeed. The Exhaust Gas Temps (EGTs) and Cylinder Head Temps (CHTs) were stable in their low-normal ranges and I was happy with the steady drone of the engine. Taking advantage of the relative calm, I took and recorded my baseline readings from the pulse-oxymeter, then donned an oxygen cannula at around 8,000 feet. Level at 12,000 feet, I settled in, "cruised out" the engine and looked at the latest information on the snow-producing-system tracking northeasterly across Tennessee and Kentucky. I believed crossing this system would be where I earned my paycheck that day, but I was only half-right [Figure 3].

I checked the engine control friction lock yet again. The manifold pressure, fuel flow, and TIT seemed to "drift" more than I was used to and I found myself fidgeting with the throttle and mixture every five minutes or so to reacquire the exact settings I desired. The friction lock was as tight as it would reasonably go and I resigned myself to tweaking the settings all day. Mischievous little gremlins!

As the Georgia/Tennessee state line slipped beneath me, the snow bands drew closer and I saw both the snow showers below them and the blue skies above. I requested 16,000 feet, to climb above the fray. I enjoyed the view, as ice crystals below me bended beams of morning sunlight into tiny rainbows. My relaxation was short-lived as the ragged cloud tops soon came up to meet me, confirming there was, indeed, trace icing in the cloud tops. I requested flight level 180 (FL180). I should have known that the day's barometric pressure made that an unusable altitude, but my mouth beat my brain to the punch and I asked for it anyway. Fortunately, the airspace was quiet at that hour

and I was allowed to pop up to 17,000 feet, instead, to stay clear on top. I watched the satellite radar on the R9 screens and on my iPad, hoping that the RUC sounding charts I'd pulled up that morning accurately predicted the cloud tops across Kentucky. Steady snow was falling there, with areas of heavy accumulation expected, by Kentucky standards. I slipped off the cannula and donned the full-face oxygen mask, knowing another climb was coming soon. I'd anticipated the need to cruise in the low flight levels, for 30 minutes or so, to stay on top. Again, the controller was happy to give me the odd altitude, in spite of my northwesterly course. I sat at FL190, safely on-top and ice-free. The wind speeds had actually decreased, but my headwind component hadn't really changed since leaving 12,000 feet, thanks to the clockwise swing in wind direction with altitude putting the wind more on the nose. Since I'd picked up a few knots of true airspeed, I was getting a slightly better groundspeed as well, but to keep it, I had to endure the infernal O_2 mask!

Gremlins

Out of curiosity, I checked the latest METAR for my destination of Cumberland, Wis. (UBE), 50 miles south of the Cirrus factory in Duluth, Minn. At negative 22 degrees Fahrenheit, it was only eight degrees warmer on the surface there than my current location at 19,000 feet.

After 18 minutes at FL190, I saw the northern edge of the snow bands, just beyond the Kentucky/Indiana border. The weather was virtually clear sailing across Indiana, Illinois, and Wisconsin. I observed some heavy, but very localized, lake-effect snow burying the Chicago/Gary area [Figure 3], but I'd be well west of that on my route to "Crumby." Quite literally, as I depressed the push-to-talk switch to request lower, and get rid of the mask, the gremlins startled me.

Initially, it was a short-lived, but significant, engine misfire. The aircraft shuddered and then everything was smooth again. The request that had been on the tip of my tongue evaporated as I jabbed the R9's "SYS" button to display the

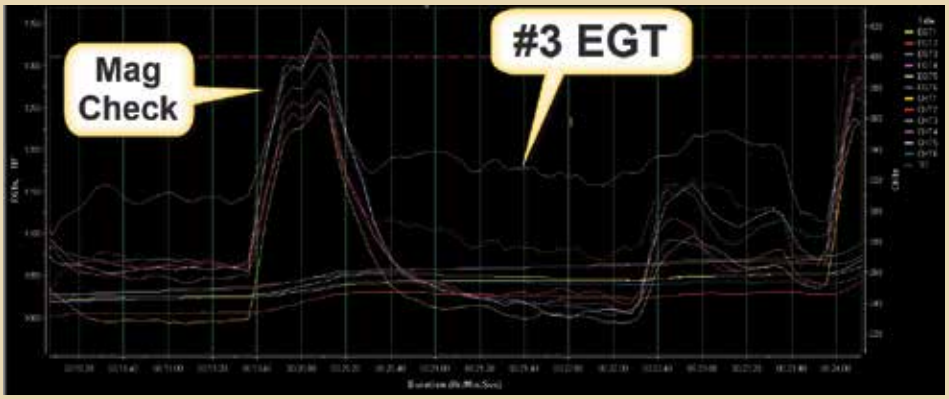

Figure 1: Post-flight analysis of the pre-flight engine run-up. All is normal during startup and taxi. At the 10-minute mark (far left end of graph), the #3 EGT rises about 100 degrees above the rest, but stays relatively cool at only 1,150 degrees. The mag-check is the spike around the 20 minute mark. After which, the #3 EGT (grey) stays warmer than the others. Yet, when the power comes up again (at 00:22:40) to taxi into position on the runway and again at takeoff (00:24:00), the other EGTs close the gap between themselves and #3. It's easy to see and diagnose this via digital engine data, after the fact, but, at the time, not so much. The temperature variation is only about 100 degrees over a four-minute span, and all of it below 1,200 degrees (a temp low enough to not be cause for concern, all by itself). Add to this, a busy time of completing checklists, FMS programming, and ATC communications. The takeoff occurs just before 24 minutes, during which, the #3 EGT is again "running with the pack" and of no cause for concern. The signs were there, but would you have seen them? The #3 cylinder is one of three later determined to have over-tight valve guides, which was the likely cause of the temperature anomalies seen here.

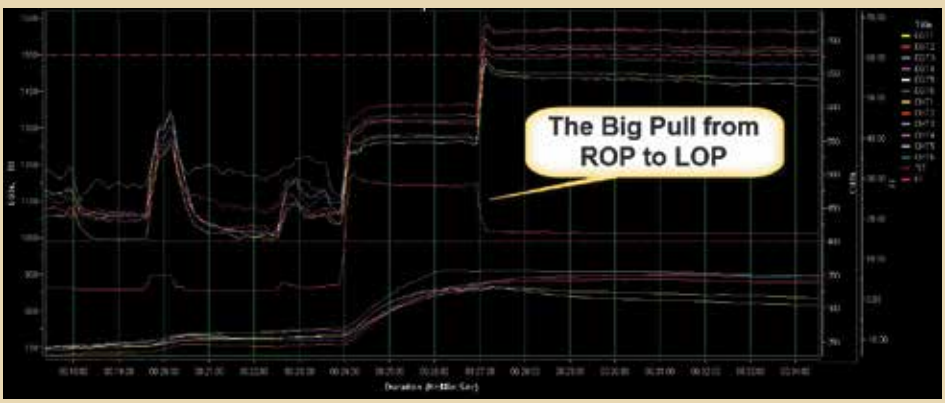

Figure 2: Three minutes after takeoff (at 00:27:00), "The Big Mixture Pull" is performed to achieve the most efficient climb fuel flow to conserve fuel for the long flight ahead. Thereafter, the engine was running well with less than a 50-degree spread across the CHTs and about a 100-degree spread across the EGTs. Fuel flow is stable at 17.5 GPH and the TIT is happy at a relatively cool 1,560 degrees.

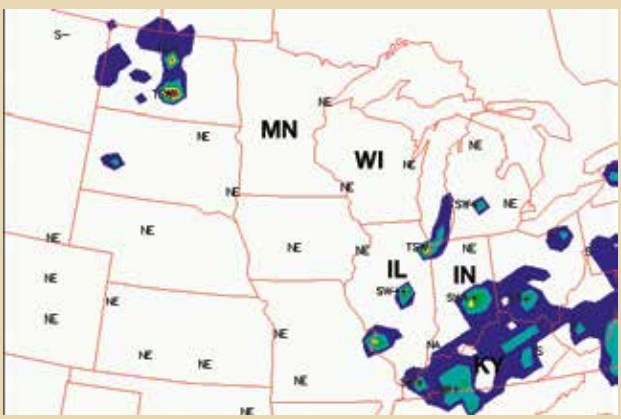

Figure 3: While not a radar plot of the exact time the system was overflown, it is close enough to give an idea of the overall weather situation on the day of the flight and the system needed to be overflown en route to Wisconsin, not long after departure from northern Georgia. While not a factor for this flight, also note the lake-effect snow band at the southern tip of Lake Michigan, which was producing heavy snowfall across the southern Chicago suburbs and northwestern Indiana at the time.

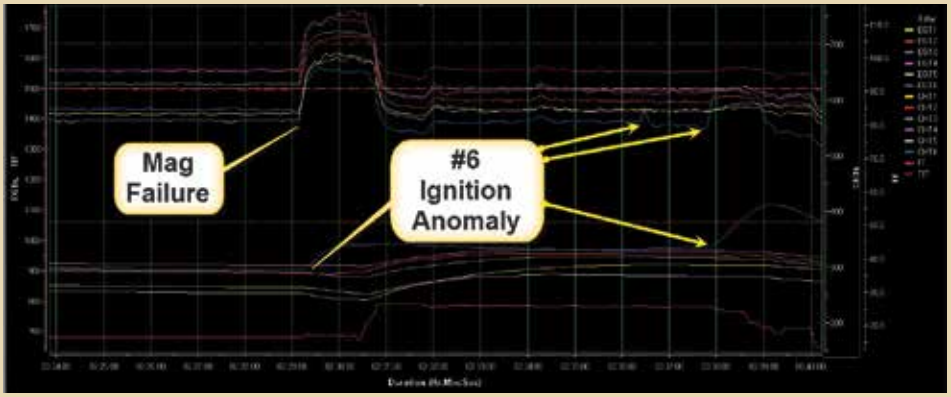

Figure 4: Two hours and 29 minutes into the flight, a magneto failure occurred, causing the initial engine shudder. Within two minutes, engine parameters had re-stabilized and the mixture to a Rich-of-Peak fuel flow was reset, but the effects of running on a single mag are obvious in this engine data. The "failed" mag (which had sheered about 25% of its drive-gear teeth [Photo 1] likely continued to function in a reduced and intermittent capacity, functioning intermittently from close to normal, to not at all, or somewhere in between. This mag malfunction, combined with a malfunctioning #6 spark plug, and at least three cylinders that were found to have overly tight valve guides, likely all contributed to the engine temperature anomalies during the flight. The first ignition anomaly occurred with the mag failure at 2:29, but the worst one (suspected detonation) is at 2:38. This was the point where the engine began to shudder wildly as the #6 EGT and CHT shot towards their limits. None of the subsequent ignition or temperature anomalies were nearly this severe, as they occurred while operating at greatly reduced power settings.

Figure 5: The flight's ground track from soon after reaching initial cruise altitude until landing. The diversion point is pretty obvious! The right turn put most of the 50-knot westerly wind on the tail, helping to expedite the arrival to the most suitable diversionary airport.

full-screen engine monitor. I stared at it for perhaps a minute, while making slight adjustments to the power and mixture. The EGTs had all spiked slightly and briefly, but within a few minutes had all stabilized near their previous settings in response to me returning the mixture to a Rich-of-Peak (ROP) fuel flow. I began to relax and decided that I could tolerate the mask in favor of the extra altitude cushion, as I contemplated the fuel stop that running ROP would now require. Then, the gremlins awakened fully and the engine shook vigorously, like a dog getting rid of water. I scanned the engine monitor with darting eyes and saw the #6 CHT was rapidly rising through 370 degrees. I yanked the throttle back and requested an immediate descent in what I hoped was a semi-calm voice. The #6 CHT's upward trend quickly reversed, but not before it peaked at something over 400 degrees [Figure 4].

My mind was racing and I reached over and cranked the oxygen flow to maximum. I wanted a clear head right now and I think the owner would forgive my over-abundant oxygen usage. What was happening? Several possibilities came to my mind. First was that the magnetos on the turbo-normalized engine were pressurized. If one of them had lost its pressure line, its performance would suffer up in the flight levels. If that was the case, things should improve in the descent, but the engine was still running very

rough. Next, I considered that #6 cylinder was dead or dying – had I allowed one of its spark plugs to foul? I dismissed that, as the cylinder was obviously not dead. It was running hotter than the others, but I'd gotten that under control. Maybe it was an ignition malfunction, causing the cylinder's fuel-air mixture to pre-ignite or detonate, rather than ignite on time and burn smoothly. Maybe I'd lost an entire magneto? The shaking felt like other mag failures I'd experienced, but the #6's volatility didn't add up. I hadn't the fortitude, the time, nor a free hand to devote to testing that theory by turning off either mag to see if the engine would quit entirely when I selected the failed one! Instead, I coordinated with ATC and quickly scanned through the data at the top of the Nearest Airports page. If I couldn't get the airplane running better very soon, I was going to need to pick a good one.

The pitch came up as the autopilot leveled at 16,000 feet and I followed it with a push on the throttle. The engine protested with convulsions and crackles, while #6's temps started climbing again. I slowly retarded the throttle, stopping immediately when the protests fell to a level I found tolerable – about 18 inches of manifold pressure (MAP), and the airspeed correspondingly low. I dismissed the magneto pressure line as the problem. At that altitude, it shouldn't be a factor sufficient to create the chaos. While I still needed thicker air for safer airspeed margins with such reduced power available to me, I also needed to stay high enough to allow for good gliding distances should this partial power failure develop into a complete engine failure. A compromise was necessary. I requested 12,000 feet and commanded the autopilot to take me there at a sedate 500 feet per minute. I reduced power slightly and the engine smoothed out; #6 was not "running with the pack," temperature-wise, but it was stabilized again. I had eight minutes in the descent to evaluate options.

The Cold, Hard Facts

Evansville, Ind. (EVV) was now behind and left of me. It's a Class C

airport that I'm very familiar with. I've taught at several CPPPs held there and I know the area well. I also knew EVV had a fine Cirrus Service Center (CSC). Unfortunately, it was just under that heavy snow band that forced me up to FL190 in the first place. With clear weather ahead, I couldn't be convinced that turning around, into a snow storm, was the right decision, regardless of what the airport had to offer. I stayed on course in my descent, looking at the airports ahead. I hadn't lived down there in over 20 years, but I learned to fly in the area and I'd flown into nearly every airport near me, at some point, in the last 25 years. Most were adequate for a true emergency landing, but none very desirable for services or even attendance at that hour. I also wondered if some of the smaller ones had even been plowed after the previous day's snowfall. Leveling at 12,000 feet, I was high enough to glide to several airports should the engine fall silent and I settled on my plan.

At this altitude, the engine was much happier ... as long as I didn't ask it for more than 20 inches MAP. I began enacting my plan by telling ATC I needed to change my destination. The frequency was quiet and the controller happily cleared me to make a 90-degree right turn, direct to Eagle Creek (EYE). He confirmed my read-back of the new IFR clearance and said, "State the reason for your change." He accepted my single-word reply without question; "Logistics," I said.

When I leveled at 12,000 feet and had the engine running smooth again, I transitioned from crisis mode to alternative mode. My primary goal is always to be safe. I felt like I had the situation under control and could continue safely to an airport within reasonable distance, rather than needing to declare an emergency and land immediately at an airport that might be less than ideal and only complicate my situation. To my left was St. Louis, straight ahead was Champagne, Ill., and to my right, Indianapolis. All were clear, but windy. Indy was closest, but more importantly, it was downwind. At my reduced power and speed, I'd rather have the 50-knot west wind pushing me. I was able to hold only about 120 KIAS, but with the tailwind component, my groundspeed should be above 150 KTS. The Indiana/Illinois border had just slipped beneath me before I made the hard right turn. I crossed it again, northeast-bound this time. I would not press on unless I could stay within gliding distances of suitable airports. Along my course were several airports, all of which I was familiar with. I'd never be more than eight miles or so from at least one of them (an easy glide distance from my altitude), so I shifted my attention to the airports between me and EYE, watching and waiting as one gave way to the next at the top of the Nearest Airports list. I acquired each visually along the way, setting its CTAF into the #2 COMM for good measure. Eighteen minutes to EYE [Figure 5].

Heat Index and Windchill Factor

Eagle Creek Airpark is on Indy's northwest side and hosts a highly reputable former CSC. ATC assigned me 11,000 feet to put me at the proper directional altitude after my course change. I descended slowly, deciding I would not give up another foot of altitude until I was practically on top of EYE. Twelve minutes to go. The full engine monitor

Photo 1: The failed magneto clearly missing about 25% of its drive-gear teeth. Yet, enough teeth remained to allow it to function in a reduced and intermittent capacity (which was probably worse than if it had just totally failed).

had been my primary focus since the first engine shudder. I diverted my gaze, as necessary, to tend to other tasks, always returning quickly to monitor the #6 temperature tapes. At this sedate power setting, its temperature changes were less divergent and all well inside the normal range; the engine was running smoothly. I made a few minor adjustments to the mixture and throttle to satisfy myself that the #6 would not rise up in heated protest. ATC told me to descend to 5,000 feet. My request to make the descent at pilot discretion was granted and I stayed at 11,000 feet. When I reduced the power next, I wanted to be able to glide all the way to landing without having to throttle-up again ... just in case. Eight minutes remaining.

Eagle Creek's weather was severe-clear, but the wind was gusting above 30 knots, giving me a stiff, but manageable, crosswind for Runway 03. Cleared for a visual approach, I reduced the power to idle about 10 miles out and entered a high and steep traffic pattern. Experience has taught me that the high-drag of a wide-chord propeller at idle-power will consume much of the surplus of altitude I'd hoarded. I disposed of the remaining surplus with a forward slip on final approach. At touchdown, finger drifts of snow snaked across the runway and taxiways, as the stiff wind rearranged the previous day's snowfall.

Taxiing in, I noted the outside air temp was negative five degrees Fahrenheit. I didn't bother to find my coat or hat before stepping outside to stretch my stiff legs. A quick post-flight walk-around revealed nothing obvious as I called Indy Approach to close my IFR flightplan. As a native Hoosier, this was an unexpected homecoming, and I stood on the ramp for another moment to contemplate it. COPA

[Postscript: Hindsight may be 20/20, but hindsight aided by digital engine data is more like 20/10! It was satisfying to have answers. Three separate engine issues were noted in post-flight maintenance; a stripped magneto drive gear (see Photo 1), a malfunctioning (#6) sparkplug whose porcelain insulator had separated from the resistor, and three cylinders with improper valve guide tensions. Although it was impossible to say precisely which issues caused which reactions, as all three likely had at least some role in the ignition and temperature issues. What one can say is that any one of them would have been less problematic by itself (and maybe none of them would have manifested at all below the flight level altitudes). In combination, one problem likely helped to cause or exasperate the others, combining them into a bit of a "perfect storm." If I had it to do over, would I do it differently? Probably. While I stand by my judgment calls made in the heat of the moment (resulting in a safe and successful completion of the mission a couple days later), I would be foolish to ignore the lessons learned and not add them into my future crisis-decision-making.]

About the Author: *Matthew McDaniel is a Master & Gold Seal CFII, ATP, MEI, AGI, & IGI and Platinum CSIP. In 24 years of flying, he has logged nearly 14,000 hours total, over 5,000 hours of instruction-given and over 4,000 hours in all models of the Cirrus. As owner of Progressive Aviation Services, LLC* (www.progaviation.com)*, he has specialized in Technically Advanced Aircraft and Glass Cockpit instruction since 2001. Currently, he also flies the Airbus A-320 series for an international airline and holds 6 turbine aircraft type ratings. Matt is one of less than three dozen instructors in the world to have earned the Master CFI designation six consecutive times. He can be reached at* matt@progaviation.com *or (414) 339-4990.*