

Safety

BY DESIGN

Doesn't the government ensure all planes are safe? It turns out some are safer than others. Diamond Aircraft has reason to think its are better.

BY NEIL MACDOUGALL

When Diamond Aircraft compared the safety record of its planes to its competitors' at AirVenture 2002 in Oshkosh, rivals must have choked. Such open talk of comparative safety is considered akin to putting sugar in a competitor's fuel. Marketers have long believed that talk of accident rates discourages potential buyers.

Yet, Peter Maurer, president of Diamond, said, "We think customers are interested in such things. Our statistics will help consumers make a more informed decision. In the auto industry, there's great emphasis on safety. Aviation shouldn't need legislation to improve." Pilots will applaud this attitude, which has been backed up with expensive crash tests and design modifications.

EVERYONE has heard the well-worn cliché, "Driving to and from the airport is the most dangerous part of flying." Some of us even believe that. But in almost 40 years of flying, I've had two instructors, both talented, killed in plane crashes, as well as three friends. By way of contrast, no friends and only one acquaintance has been killed in a car accident.

The Transportation Safety Board of Canada makes the risk even clearer. In 2001, the accident record of private flying (including flying schools and others) was 66 times worse than that of the airlines. During the last 10 years, private fliers have been twice as likely to have an accident as pilots crop spraying, water bombing and doing other demanding activities.

Diamond's initial interest in safety may have come from its association with the motorglider from which the highly successful Katana 2-seater was developed. Flying cross-country is one of the great fascinations of gliding. But anyone trying to fly even 50 km (the world glider distance record is 2,459 km) without an engine risks having to land in an unprepared farm field. Having seen too many power lines and barbed wire fences on final approach, glider

pilots have long been interested in crashworthiness. The Diamond Xtreme motorglider has rollover protection, four-point harnesses, occupants and fuel in a safety cell, anti-submarine seats and protected stainless steel fuel lines.

Today, Diamond has taken this philosophy farther. Its aircraft design aims to minimize the risk of an accident and to reduce the chance of injury to occupants. That is what engineers call both active and passive safety, respectively. In addition, Diamond continually reviews safety data and makes improvements based on field experience.

Keeping pilots from crashing is the first priority. A forgiving design and an ergonomic cockpit are basic design goals. Doesn't every manufacturer have similar objectives, I thought? Don't the U.S. Federal Aviation Regulations (FAR) ensure that a plane is safe to fly?

"Those are minimum standards," Maurer said. "Look at these automobile crash test pictures on the Internet." He pointed to a picture of a Toyota pickup crash. Much of the structure was smashed, but the dummies were safe in their cell. In the picture of the Ford F Series pickup, the cabin was deformed, and the dummies were mangled. "Both vehicles meet the minimum standard. Which one would you rather drive?"

That made me reflect on the differences in accident rates between certified aircraft. According to a 1979 U.S. National Transportation Board study of 17,312 accidents, the fatal accident rate per 100,000 flying hours was 4.73 for the Piper J-3 Cub, 3.28 for the Piper PA-22 Tri-Pacer, 2.94 for the Grumman AA-5, 2.92 for the Piper Comanche, 2.74 for the Piper PA-32 Cherokee Six, 2.55 for the Beech 33, 35, 36; 2.5 for the Beech 23, 2.44 for the Mooney M20, 2.19 for the Cessna 177 Cardinal, 2.02 for the Cessna 182, 1.97 for the Piper PA-28, 1.47 for the Cessna 172 and 1.34 for the Cessna 150.

The NTSB assured me that no more recent study has been done. Would that be because of complaints from manufacturers? Accident rates have decreased since the 1979 study, but the relative ranking of the most common types is unlikely to have changed. The rates of uncommon types (e.g. the Aeronca 11 Sedan with 53 accidents in five years) vary dramatically from year to year.

All the planes studied are certified. Not all are certified to the same standard. Some aircraft in production are certified to the standards of the long-defunct Civil Aeronautics Board. Most pilots weren't born when the CAB was around (pre-1945 to 1965). Its rules (CAR 3) were far less stringent than today's FAR Part 23. As a result, certification costs of a new plane approach the size of government grants to the Maritimes. That's why it is far cheaper to receive an old plane like the Luscombe Silvalire, the Aviat Monocoupe or Waco YMF-5 than to certify a new model to current standards.

RESEARCH, accidents and field studies cause amendments, roughly yearly, to federal regulations. Only newly certified aircraft have to meet the latest standards. Makers of planes previously certified may adopt some or none of the new standards, as they see fit. For example, the Commander 114 was the first new production aircraft to be required to have anti-siphoning gas tank caps. When the amendment came out, Beech, Cessna, Piper and Mooney could (and, I understand, did) ignore the improvement. Indeed, most piston aircraft now built by those companies meet only CAR 3, and maker-selected provisions of FAR 23. However, any completely new design has to comply with every regulation then current.

Car safety activist Ralph Nader might see these actions as a sign of corporate greed, not to mention disinterest in customers' safety. In fact, it's natural for plane makers to evaluate the benefits and costs of each new regulation. They need to keep their costs down or they'll go out of business. Remember the financial problems of Bellanca, Mooney, Piper, Taylorcraft, Aeronca and others? And now Lancair. Besides, some changes that could be made easily while a plane is being designed might add hundreds of dollars to the price of an existing design. Rarely can anyone show that a single change would save the life of one pilot during the time one aircraft model is being manufactured.

It's hard for a pilot to evaluate the utility of most of these changes. Most pilots can live without anti-siphoning gas tank caps. But what about lack of aileron control during a stall? The advantages are obvious. Yet only the latest regulations require ailerons to be effective during straight ahead and turning stalls, both power on and power off. Planes certified previously don't have to comply. The Mooney Ovation 2 is a good example. During tests by the U.S. Air Force Academy, the Ovation failed the stall test because only its rudder was effective during stall and initial recovery.

The average pilot may never benefit from most of these mandated changes. Yet it's likely that each one advances aviation safety in a small way.

Collectively, the improvement may be significant. You could say the same for rear seat belts, anti-lock brake systems, air bags, traction control and recessed door handles in cars. You'd also conclude that car makers have been much more safety conscious than plane makers.

Maurer estimated that improving crashworthiness decreased the DA20-C1's useful load by 50 pounds. Yet without those changes, the plane still would have met certification requirements.

TODAY'S PLANES are better mannered and more forgiving than the Piper J-3s, Ercoupes and Aeronca Champs of old. Pilots persist in describing these types as docile. Yet they're involved in twice as many accidents as more modern types.

Diamond wants to do even better. To reiterate, avoiding an accident is better than reducing its consequences. Each aircraft model is designed for exceptional controllability and manoeuvrability, positive stability and good performance. Hype from any manufacturer's brochure? Yes, but of 14 aircraft in the U.S. Air Force Academy's trainer contest, only seven passed. Two of those were the DA20-C1 and the DA40 Star. Moreover, the DA20-C1 won the contest.

Maurer is convinced that superior performance increases safety. Aeronautical engineer David Thurston, designer of the Colonial Skimmer (forerunner of the Lake LA-4) and the Schweizer Teal, among other types, is of the same opinion. He studied thousands of accident reports. He concluded that many of the 56% to 74% of accidents due to pilot error could be reduced by better takeoff, climb and landing performance. In his 1980 book, *Design for Safety*, he urged designers to adopt these targets and 27 other items, including better crashworthiness, tapered wings to improve roll rate, an inertia switch to cut the electrical system at impact, nose-wheel steering to permit wheel alignment on touchdown, and a configuration that precludes exceeding aft centre of gravity limits. These items would increase both weight and price by only 10%.

His foresighted recommendations caused as much disturbance as the wake of an ultralight. You'd be hard pressed to find many on 1980's aircraft models. Good handling characteristics were another thing he stressed. Diamond's Jeff Owen gave me an impressive demonstration of slow speed, banking, cross-controlled slow flight in the Diamond Star. No matter how sloppy he tried to be, the Star didn't misbehave.

Oddly, some pilots disable designers' safety features. Many aircraft have washed out wing tips, ones with less angle of incidence than the wing roots. As a result, the root stalls first, often providing warning buffet, while the ailerons are still effective. In Alaska, some Piper Super Cub pilots remove the wash out in order to decrease stalling speed by about one mph. No doubt to allow them to land on smaller sand bars!

Both the DA40 Star and the DA20 (no longer called the Katana) have long, narrow wings. Wings with such high aspect ratio (as the design is called) are superior at high-density altitudes. Safety margins are increased during landings and takeoffs, the times of greatest risk. Such wings also have superior ceilings and glide ratios. The 1972 150-hp Cessna 172Ls have a respectable service ceiling of 13,100 feet. But even when carrying two people and luggage on a hot day in the Rockies, I had trouble struggling above 10,500 feet. The Diamond Star's ceiling is 16,400 feet, compared to 14,000 feet for latest Cessna 172S, and 13,800 feet for the Grumman American Tiger. All three have 180-hp engines. On 125 hp, the DA20-C1 has a maximum cruising altitude of 13,120 feet, but no published service ceiling.



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NASA did 33 crash tests of light aircraft from 1974 to 1983, using a gantry built to train astronauts how to land on the moon. Cherokees, Aztecs, Navajos and Cessna 172s slid down a 45-degree cable before being released to strike the ground at 55 to 60 mph. You flinched when the films showed the cockpits disappearing in dust and wreckage. None of the crashes was survivable.

Faced with an engine failure, a pilot in either Diamond plane has a greater choice of fields than someone in a ship with a shorter wing span. And the DA40 can glide 10.3 miles from a height of one mile, compared to about 8.1 in a Cessna 172.

Both Diamond types use a proprietary airfoil, based on a German Wortmann design. This contributes to better takeoff and landing distances, climb rate, low stalling speed and low approach speed. You may not know how important these are until you take off from Jasper, Alberta, on a hot day, and have to follow the river valley to avoid obstacles. A slow approach speed gives more time for decision making and also reduces the energy (to be dissipated in a crash) by the square of the speed. For example, compare two airplanes with stalling speeds of 50 knots and 60 knots. In a crash, the first has 44% less energy to dissipate, a comfort when things go wrong.

Except for a few French and German designs, most modern light planes have large door frames that block the view of conflicting traffic. A good view ahead is no consolation if an oncoming CF-18 Hornet can hide behind the door post until it's too late. The DA20 and DA40 don't have obstructing frames. They give pilots a superlative view from side to side. The rearward view from the DA20 was poor, so a window has been added.

Diamond thinks that cockpit design influences safety too. The air vent was made large enough to keep the pilot fresh so he or she could think clearly, not just be mildly comfortable. Circuit breakers in the DA40 are grouped logically, by family. All controls and instruments are accessible and visible from both seats, with belts fastened. On the DA20-C1, a 3-position fuel pump switch would have been cheapest. A second separate switch was added to minimize the risk of flooding the engine.

THE U.S. FEDERAL Air Regulations require aircraft seats to survive a 26g crash. Actually, passenger seats need only meet 21gs, even though tests have shown that passengers may face higher loads than pilots. Only aircraft with canopies have to pass a 3g rollover test. Again says Maurer, "These are minimum standards. We can do better. There are no requirements to guarantee survival space, as there are with cars. No regulations to prevent the structure from crumpling around you during a crash. [Nor is there a requirement to keep the engine and its mount out of the cockpit.] It's not enough to have a 26g seat. You also need a cell that maintains its strength and stiffness in a crash, with a deformable structure front and back. You need stiffeners around the cockpit opening to take the impact loads.

"Seats have to be designed so that you don't slide under your seat belt in a crash. An anti-submarine seat, with the buttocks lower than the thighs, is effective. You must not have structures in front that can break knee caps or hurt the head.

"The auto industry is far ahead of plane makers in crash protection. In 1967, toggle switches were outlawed. Diamond uses rocker switches to minimize occupant injury, but some plane makers still use switches which protrude.

"Obviously, you don't want fuel leaks after a crash. We have electronic fuel and oil gauges so there are no inflammable liquid lines in the cockpit. Nor do we lead fuel lines down door posts, as do many high-wing aircraft. In the DA40 Star 4-seater, a spar on each side protects the fuel tanks. In the DA20, the fuel is in the same protective cell as the occupants. We avoid single-flare rigid fuel lines, which break easily in a crash. Our TSO-approved braided fuel

lines are flexible to minimize the risk of spillage after a crash. They are also designed so that any leaks flow overboard, and can be seen during the pre-flight. These lines are more expensive, but in almost 1,000,000 flight hours, we've not had a single post-crash fire."

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Full-scale crash tests by a German university have confirmed that the occupants in a Diamond DA40 crash would survive. Lancair tested a full fuselage of the Columbia 300 on a sled. The "occupants" not only survived, but also did not strike the panel or glare shield. The Lancair Columbia 300 and the Cirrus SR20 have energy-absorbing structures and seats and an improved shoulder harness system developed from NASA's Advanced General Aviation Transport Experiment (AGATE). Cirrus and New Piper did not respond to a request for information on their tests, if any. Cessna said all its testing was done in accordance with FAA safety standards.

"DESIGNERS still have to find a way to keep an aircraft from digging in after a crash," according to Dieter Koehler, vice-president engineering of Lancair. "In soft ground, a plane digs in like a lawn dart. Because it's impossible to absorb all the energy in 15 inches or so, the tail wants to slap down. The airplane has to be kept sliding to slowly dissipate the forward motion. Metal aircraft are crushable, while composite types are stronger and provide survival volume. We have a special engine mount and a strong cowl to prevent the aircraft from getting stuck.

"The tail slap phenomenon is most pronounced on a hard surface, which exposes the passenger to higher loads than the pilot. The certification requirements allow lower loads for the back seat passenger. At Lancair, we certified the back seats to the same g-level as the front seats."

A preliminary evaluation can be made of Diamond's total safety concept. Since 1995, the North American fleet of DA20s has accumulated over 900,000 flying hours, with 27 crashes, only two fatal. That amounts to a fatal accident rate of 0.22 per 100,000 hours, twice as good as the Cessna 172 and four times as good as the Piper Archer and Mooney M20J.

Diamond gathered statistics on its own aircraft from its operators and the National Transportation Safety Board. The accident rates for the other four common types, all four-seaters, were from *Flying* magazine's safety reports. Some of these reports used data from only two years of accidents, and are therefore less representative than the NTSB's major study. In addition, the DA20 is used mainly as a trainer, an activity that has a lower accident rate than private flying generally. A comparison with the Piper Tomahawk, Cessna 150 or 152 would be more appropriate. In addition, the general aviation accident rates include fast aircraft like retractables and twins that have more fatal accidents than slower, lighter aircraft like the DA20.