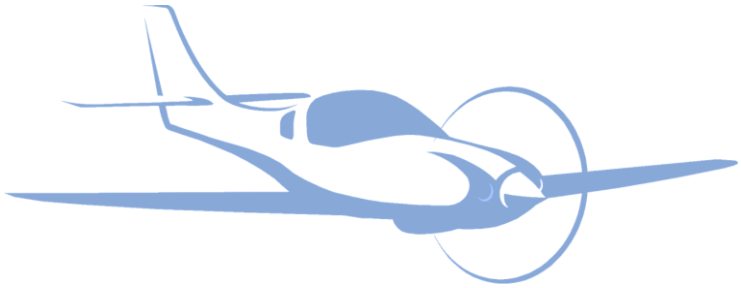
**DRAFT 1**
March 7, 2014



# Lancair Legacy Canopy Safety Issue

**March 7, 2014**

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# Introduction

One of the great joys of aviation is the visual splendor of flight and the Lancair Legacy's large bubble canopy makes that about as good as it can get.

Carl Lewis and His Legacy over Oregon

The Legacy's canopy, though, can create a catastrophic flight hazard if it is not securely latched for flight. The canopy is large and, if not latched down in flight, it will open to varying degrees and alter the air flow over the tail/stabilizers and under some situations create significant pitch attitude stability and control issues.

In the Legacy's flight history to date, there have been seven known flights with the Legacy's canopy unlatched resulting in three fatal crashes, two crash landings with significant aircraft damage and/or pilot injuries, one aborted flight immediately after takeoff with minor damage, and one flight without incident.

The purpose of this report is to collect the known information on this issue, inform the broader Lancair Legacy community of this catastrophic flight hazard, help understand the hazard and its influences, present strategies for effectively controlling the hazard, and help Legacy pilots enjoy a long life flying their amazing airplanes.

# The Evidence

## 26 August 2005 N345MW Hohenhems, Austria

Source: News report and associates of accident pilot (unable to reach pilot for direct information)

Pilot Wolfgang Mascheck just wanted to make a short local flight before the airstrip closed and in his haste he forgot to latch the canopy. The Hohenhems, Austria runway is only 2000 ft long, so there was no room for errors.

After takeoff the canopy popped open, Wolfgang could not see forward, and the aircraft was very difficult to control. It's unknown if he tried to close the canopy. He reduced power and tried to land directly ahead in fields beyond the runway.

The plane lost the wings on the very hard touch down. The fuselage broke behind the seat and ejected Wolfgang out of the plane. It was a muddy soft grass field and the engine was buried in the mud.

Matscheck suffered serious injuries with two broken legs and bones in his face. The airplane was destroyed. Matscheck fully recovered and has not returned to flying.

N345MW Wreckage

## Summer 2006 N495SL Sierra Sky Park, Fresno, California, USA

Source: Pilot Scott Alair (Pvt, ASEL)

**Lancair Mail List Post, 7 Nov 2013:** On a hot summer day in 2006 at Sierra Sky Park airport in Fresno California, I taxied to runway 30 (2473ft. X 50ft) with my canopy open resting on my arm. When I taxied on to the runway I did not push up on the canopy to check that it is latched (I do now). When I rotated at about 80 kts I was startled by the sudden noise and wind of the canopy coming open about 3 inches at the rear edge. I knew I could not stop on the remaining runway, so I continued with a normal takeoff. I left the flaps at 10 degrees, climbed at 120kts to 1,000 ft

AGL and trimmed the plane for level flight (I do not have an autopilot). I then put my hands on the trailing edge of the canopy frame and tried to move it (it had been in a stable open position so far). I could close it about 1 inch and open it about 1 inch farther but that was as far as I could move it. At this point I decided to return to land, I flew a normal pattern, as I flared for landing the canopy opened another 2 inches. Throughout the flight the canopy never oscillated or affected the control of the aircraft.

**Email to Author, March 2014**: I don't have much to add to my existing "story" but I will try to answer any questions best as I can. Keep in mind this happened almost 8 years ago and at the time I considered it a "Non-event" and did not even make a log book entry about it.

I think the most important thing to remember is my mindset at the time my canopy came open on takeoff. Previous to this event I was a pilot and or passenger when a door came open just after liftoff. This happened twice in a Bonanza and once in a Piper Arrow. On all three occasions we were not able to close the door in flight and returned for a normal landing. I believe because of my previous "open door experience", I was able to remain calm when my Legacy canopy opened.

Here's my best guess at the "numbers" for my open canopy flight. I used the power that was required to maintain 120 kts with 10 deg flaps and the gear down. I don't know what it was. I was solo and no baggage and I normally do local flights with half tanks, so the aircraft weight was probably about 2,000 lbs with a C.G. 35% aft of the FWD limit.

Photo of Scott Alair and N495SL

## 13 April 2008 N1177M Lakeland, Florida, USA

Source: NTSB.

According to witnesses, the pilot was observed having difficulty closing the canopy on the airplane prior to takeoff. During the takeoff climb, a witness said he saw the cockpit canopy moving and believed the pilot was pushing it up and down about 6 to 12 inches. Another witness stated that shortly after takeoff, the engine lost power and the airplane continued straight and level. Another witness stated that she saw a plastic bag float down from the sky shortly after the airplane passed over her location. The bag contained several of the airplane's documents inside of it. The airplane then nosed down about 40 degrees and the left wing dropped as the airplane stalled and collided with the ground. A post-crash fire ensued which consumed part of the engine and the majority of the airframe, including the canopy latching system. Examination of the available wreckage did not reveal any evidence of pre-impact failures or malfunctions. The pilot Gerard Schkolnik, (Aeronautical Engineer, Private, ASEL) age 44, was fatally injured.


Photo of N1177M on takeoff before crash, note open canopy

N1177M crash site, wreckage (Photos: The Ledger.com)

## 18 October 2008 N151HT Parawan, Utah, USA

Source: NTSB.

During departure, witnesses in the area reported that the airplane appeared unusually low and then entered a left turn. As the airplane entered the turn, items from the cockpit fell from the airplane. The airplane continued in the left turn until it impacted the ground. Examination of the wreckage revealed no evidence of pre-impact mechanical malfunction. The airplane, by design, does not have a cockpit indication for the security of the canopy. Structural documentation of the canopy latching mechanism did not reveal any damage to the latching mechanism, which is indicative of it not being latched when the airplane impacted the ground. Based on post-mortem toxicology results, the pilot had likely recently used two different prescription painkillers that commonly result in impairment, and that may increase risk of seizure, particularly when used together. Based on his height and weight, poorly controlled blood pressure in spite of the use of at least two different medications to lower it, and the presence on autopsy of right-sided heart enlargement, he likely had obstructive sleep apnea, a condition associated with fatigue and cognitive impairment. His response to a real or perceived emergency may have been impaired by the medications themselves, by a seizure induced by the medications, or by the effects of possible obstructive sleep apnea. The pilot did have a single blocked small coronary artery, but the condition had been present and evaluated just over two years prior to the accident, with evidence of good blood flow in spite of the blockage. It is unlikely that the blockage was related to the accident. The pilot had not indicated high blood pressure, use of medications to treat high blood pressure, or use of prescription painkillers on his most recent application for airman medical certificate just over 16 months prior to the accident. The aircraft was destroyed.

The pilot William Grant Phillips (Physicist, ATP, ASMEL, SES, Balloon, Glider, Helicopter, CFI), age 59, was fatally injured. His wife Janice was seriously injured.

N151HT Photo

## 6 February 2009 N939CB Longmont, Colorado, USA

Source: Pilot David Williams.

**Lancair Mail List Post, 9 February 2009:** After refueling at the Self Service fuel pump at Longmont Airport (KLMO) at around 5:30 pm, I taxied out the to the run-up area for Runway 29 and did the run-up and take off check on N939CB a Lancair Legacy (LEG2). The takeoff proceeded normally until the point of rotation at which time the canopy popped open slightly. As the runway is short (4800') and I was full of fuel, I continued with the takeoff as I felt that try to abort was more dangerous than just going around and landing again. Without event, I climbed to pattern altitude, 1000 AGL, and reduced power to prepare for landing. At that time, the canopy assumed a much more open position and started to oscillate up and down (6" to 12" motion) also causing the aircraft to be very difficult control in pitch (at least 6" stick movements where normal is 1" to 2"). I tried to resume the full power climb attitude again as I thought the change of attitude may have cause this, but this only exaggerated the situation. My concerns were the large oscillations of the canopy, my restricted forward visibility, and the violent pitch changes. I continued with the approach and tried to look out the side opening of the canopy to get myself in a position to land on Runway 29 and avoid any other property damage. I kept the airspeed at around 110 knots with significant power to maintain a much control as possible over the oscillations, but only remember trying to minimize them on final when I impacted the ground.

I believe that when the canopy was sucked up far enough that it blanketed the tail causing the aircraft to pitch nose down, causing the closing of the canopy there in turn causing the elevator to become effective again which then allowed me to regain control and level again, which caused the canopy again to open, etc., etc.

**Email to Author, 5 March 2014:** I think this probably sums it up, other than to say I was full of fuel and no flaps. I know that when I takeoff out of Longmont, I am usually hot as the runway is short and it has flat fields at the end. So the climb would have been at 120+. This means low AOA, which probably kept things under control until I throttled back on downwind slowing, and allowing the AOA to become larger.

**Email to Author, 6 March 2014:** The most memorable part of this incidence, was when I powered back on downwind and the canopy opened enough that I could see the ground between the lower rim of the canopy and the engine cowling, as I pitched down. And until we held your canopy up to that level, I have not till now realized how far it was open. Definitely a problem here.

*From conversation between Dave and the author:*

> *David said on final approach, the canopy opened so far that the airport could be seen between the nose and the forward edge of the open canopy. The view forward was not a sufficient reference to fly from. When looking to the side for reference, the wind blast was so high that it blew his eye glasses off his face. Aircraft landing gear sheared off, skidded through fence posts, significant damage.*

Pilot David Williams, (Electrical engineer, Comm, Inst, ASEL, A&IGI, CFI), had minor injuries.

N939CB After Open Canopy Crash Landing

## 18 September 2013 VH-ALP Geraldton, Australia

Source: Australian Transportation Safety Board (ATSB).

On 18 September 2013, the owner-pilot of Lancair Legacy aircraft, registered VH-ALP, was intending to conduct a private flight from Geraldton to Newman, Western Australia. At 1545 Western Standard Time1 the pilot taxied at Geraldton Airport for runway 32, an 884 m sealed strip.

The pilot began the take-off roll with substantial engine power and the aircraft was observed to accelerate normally to about halfway along the runway. At this point, smoke from the main wheels indicated that the brakes were applied momentarily, and at about the same time the forward-hinged canopy opened about 15 to 30 cm. No change to engine power was evident and the take-off roll continued.

The pilot lifted off with runway to spare and climbed to about 100 to 150 ft above ground level. The pilot banked to the left and during the turn the canopy opened further so that it was at an estimated angle of 30°. Various people on the ground saw the aircraft flying low and fast with the canopy open.

The pilot appeared to be maneuvering for a landing on runway 08 but the aircraft wheels hit a road curb short of the airport perimeter. The aircraft then collided with the perimeter fence and became entangled as it overturned. Shortly after, an intense fire engulfed the aircraft.



VH-ALP Photo and Crash Site

Bystanders tried to extinguish the fire with handheld fire extinguishers and a water truck but were unable to have immediate effect. The pilot, Gerry Gould, age 60, was rescued from the wreckage and treated for, but later succumbed to his injuries.

## N249B Pilot Bill Bradburry

**LML Post 9 Sep 2013:** The Legacy can NOT be flown safely with the canopy unlatched! If you take off with the canopy unlatched, you MAY survive…I did! You MAY not damage the plane…I did! Several others have not survived. It is a harrowing experience! I now check the canopy latch several times before each takeoff!

When the canopy is closed it takes a little extra force to move it up off the canopy seal, then it is easier to raise and you have the gas struts helping you. So at about 60 knots, the canopy will suddenly pop up and go all the way or nearly to the stops. This action blanks off the elevator and you lose pitch control. The canopy then is blown back down and you temporarily regain pitch control before it is sucked back up for another round. By the time it is headed back up the second time, you had better have the power off and using that short instance of pitch control to get the plane either on the ground or close enough for a hard landing. If this happened at 100 feet or so, flowers would be in order.

It is possible that you could unlatch the canopy at cruise speed and it would only open a few inches, but when you tried to land, the lack of prop blast would put you back into this regime. I don't recommend trying any of it. Latch the damn canopy!

**LML Post 20 Sep 2013:** It was a stupid pilot trick that I hope nobody else feels the need to do. The surprise of the canopy popping up at such a critical time can be devastating. My first reaction was to reach up to grab it, but I immediately realized the futility of that and pulled power and grabbed the stick and 'put er down!'.

The damage was a toe in change on the left main and the operating limitations blew out and were never recovered! Luckily I had made a copy of the limitations.

# The Hazard

The collective evidence of accidents, incidents, and pilot reports strongly suggests that if the Lancair Legacy's canopy is unlatched and opens far enough in flight it will create a severe pitch attitude control instability. This instability can lead to loss of aircraft control, inadvertent aerodynamic stall, or insufficient attitude control precision necessary to perform a safe landing of the airplane.

## Hazard Evaluation

The pitch instability is likely the result of separated turbulent airflow downstream of the open canopy affecting the horizontal stabilizer's angle of attack (AOA) and smooth flow of air over a portion of the stabilizer, changing its effective coefficient of lift, and also reducing the effectiveness of the elevator control surface. When the canopy is open less than about 3 inches, the separated disturbed airflow has little noticeable effect on the airplane's pitch stability and control. Beyond about 3 inches of canopy opening, the instability occurs.

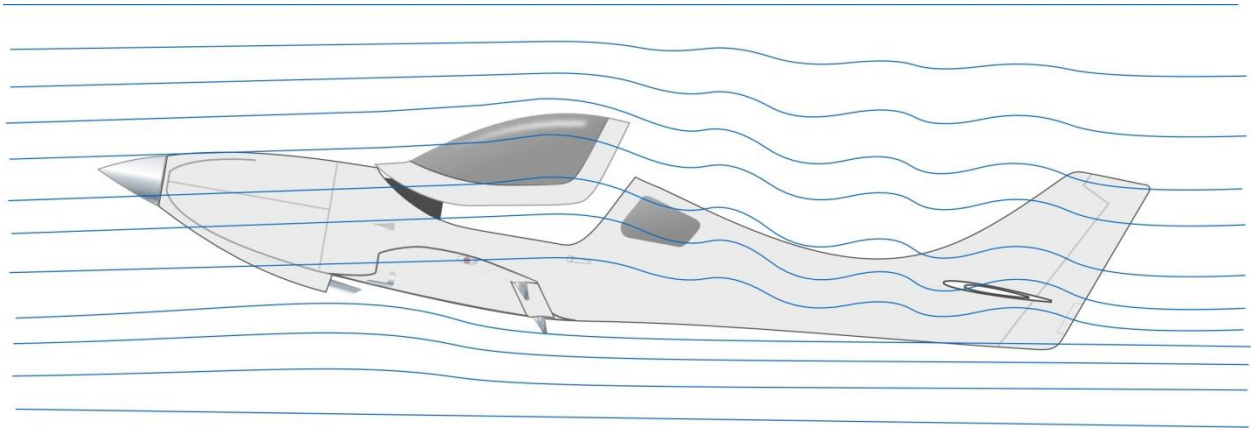
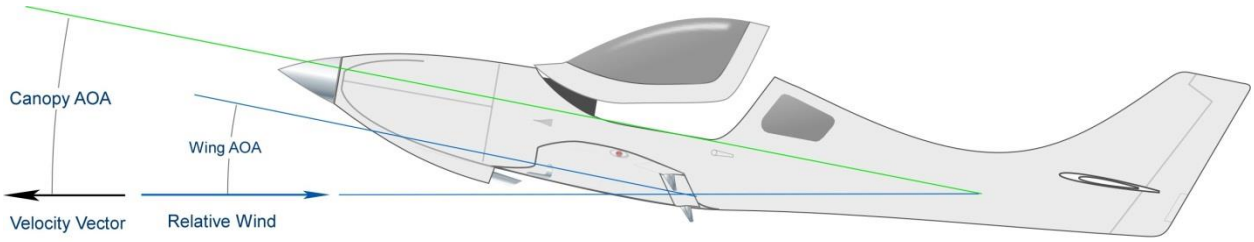
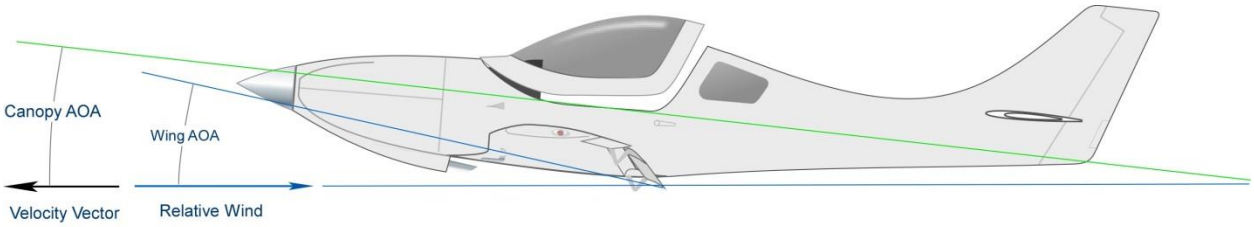


Illustration of disturbed air flow with canopy open

The collective evidence of accidents, incidents, pilot reports, and understanding of aerodynamics suggests that the degree of canopy opening is primarily a function of the relative wind the canopy experiences – mostly the "Canopy's AOA" with the airplane's Side Slip Angle (Beta) playing a role as well. The Canopy's AOA is not to be confused with the airplane's AOA defined as the angle between the wing's average cord line and the relative wind. The canopy will see a lower AOA compared to the wings AOA as the flaps are extended and the wing cord line moves relative to the longitudinal axis of the airplane. See the illustration below.




**Flaps Retracted**




**Flaps Extended**

Illustrations of disturbed flow with canopy open, with and without flaps extended

There has been some speculation that the pitch instability described by surviving pilots was a result of Pilot Induced Oscillations (PIO) because one of the pilots, Scott Alair, did not experience any pitch stability. Also contributing to this speculation, is the fact that the Legacy's ancestor Lancair 360, has a history of numerous canopy open flights without incident. However, even though there is much similarity between the Legacy and 360 as seen from a distance, small differences can create big differences in aerodynamics. For example, the Legacy's cockpit is noticeably larger than the 360 resulting in a larger taper ratio as the fuselage transitions/narrows to the tail.

Regarding the uneventful flight of Scott Alair, it is more likely that Scott's airplane was flown at a lower AOA during its entire flight compared to the other canopy open flights. Scott's airplane was very lightly loaded at only about 2000 lbs gross weight, he kept takeoff flaps down, and maintained about 120 KIAS throughout the flight. David Williams' flight, for example, had just taken on full fuel, flew the approach at around 110 KIAS, and with no flaps – so a higher AOA and Canopy AOA throughout the flight, placing him in the high Canopy AOA region of pitch instability.

These theories as to the aerodynamics behind the open canopy hazard could be verified by wind tunnel testing with a high fidelity scale model of the Lancair Legacy that would allow the canopy to pivot about its hinge line to allow it to seek equilibrium, with low fidelity interior modeling, adjustable flaps and elevator control surfaces. Model scale and wind tunnel selection would need to consider achievable Reynolds Numbers and proper scaling of results where needed. Computation Fluid Dynamics (CFD) analysis could also be useful in confirming the aerodynamics of the hazard. CFD tools, though, have greater uncertainty in predicting the behavior of separated, chaotic airflow, which is key to this hazard. Both of these options would

be expensive and time consuming. Given the available flight history related to this hazard, one can argue there's not enough uncertainty remaining to justify these expenses.

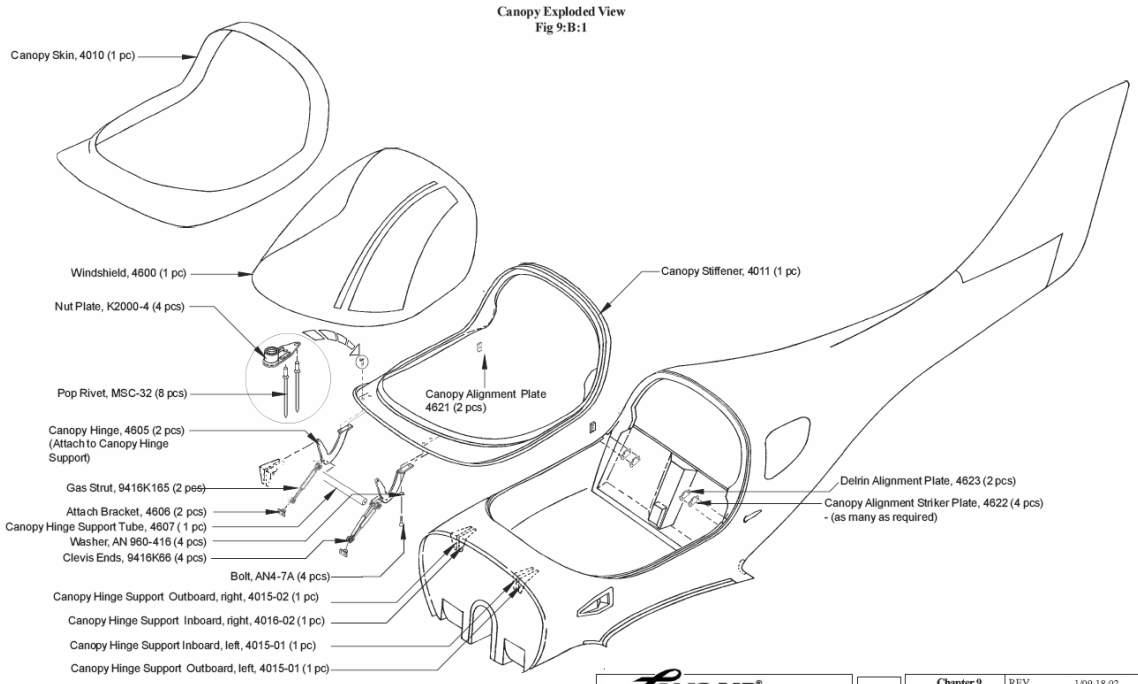
# Background -- Legacy Canopy Design

The Lancair Legacy was not designed for flight with the canopy unlatched/open. The Legacy's canopy is hinged at the front with mechanical latching claws on each side of the aft cockpit opening that engage with latching plates on the aft canopy frame. The latching mechanism is engaged and disengaged by a lever between the pilot seats and an exterior control lever on the left side of the fuselage below the canopy. The canopy sits down in its closed position and is latched by lowering the lever between the seats. The design allows the canopy to rest in its closed position without being latched.


Photo of Rob Logan's Tweedy Bird Legacy with Canopy Open
*(Rob likely has the highest time Legacy flying)*

The following excerpts from the Lancair Legacy canopy construction manual provide detail on the canopy and latching mechanism design.

## B. Canopy Stiffener Alignment



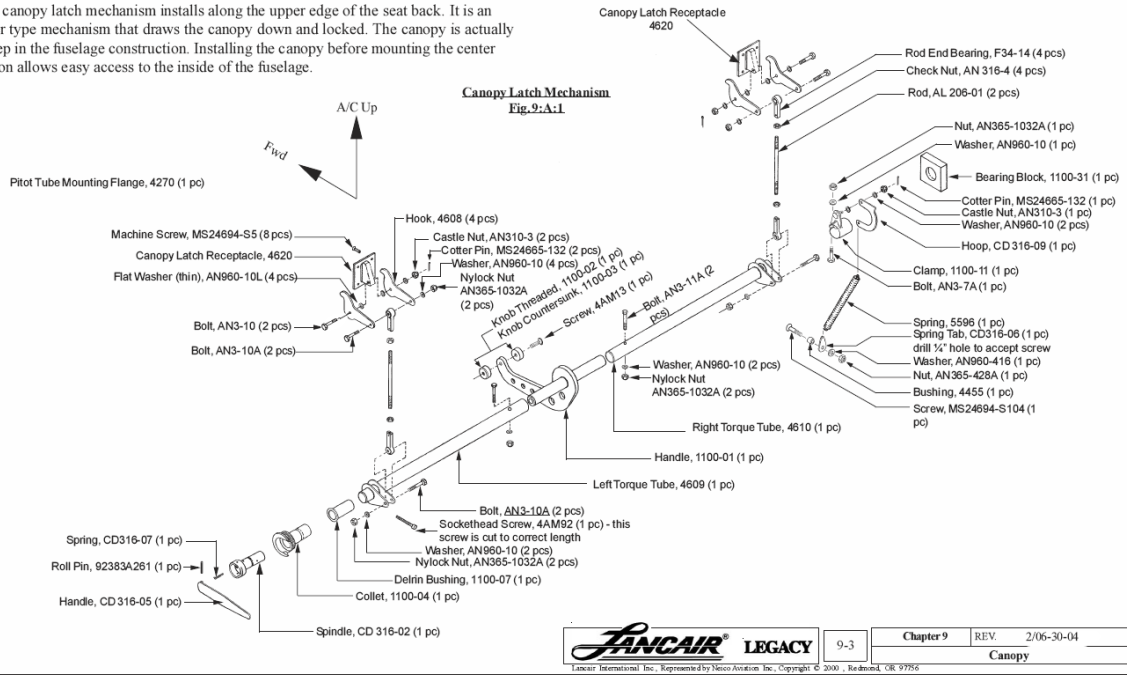




## 3. CONSTRUCTION PROCEDURES

### A. Canopy Latch Mechanism

The canopy latch mechanism installs along the upper edge of the seat back. It is an over-center type mechanism that draws the canopy down and locked. The canopy is actually the first step in the fuselage construction. Installing the canopy before mounting the center wing section allows easy access to the inside of the fuselage.

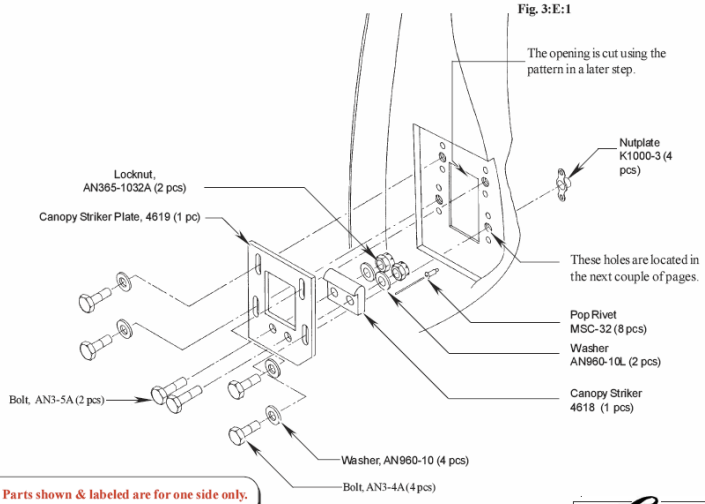


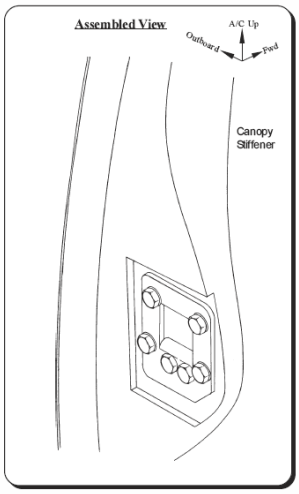
## E. Canopy Stricker Metchanism

In section A you installed the canopy latch mechanism in the fuselage. When closed the canopy hooks move out of their slots and "grab: a catch in the canopy stiffener. The alignment of this catch is obviously critical to properly locking the canopy down. We will refer to this "catch" as the canopy striker mechanism.

We supply two parts used to properly align the canopy striker mechanism. The first is a screw that has a #40 hole drilled through the center. This is used to transfer a reference hole in the canopy stiffener by back drilling through the canopy latch receptacle. The second alignment tool is a drill template. The drill template serves two functions, the first

**Canopy Strikers**
**Fig. 3:E:1**




**Note: Parts shown & labeled are for one side only.**

# The Cause

The canopy open catastrophic flight hazard presents itself when the canopy is not securely latched prior to takeoff and the airplane is flown in a configuration (AOA, flaps, power, airspeed) that results in the canopy opening more than about 3 inches.

# Hazard Controls

The following strategies are options for reducing the risk of exposing the Legacy's open canopy flight hazard.

## Before Takeoff Check List – Canopy Closed & Latched

The first and only intended control of the Legacy's canopy open flight hazard is disciplined use of a pre-takeoff checklist. Human performance history and testing shows the error rate is too high for it to be the only control of a catastrophic hazard. Fred Moreno provided an outstanding discussion of this concept in this LML posting:

> **Pilot Fred Moreno**
>
> **LML Post 3 March 2014:** Quoting fellow pilot, "Not to put too fine a point on it but, including a pre-takeoff checklist item 'canopy latched??' should cure this issue once and for all." [Emphasis added]
>
> Let's put this single pilot check list falsehood [emphasis added] to bed once and for all, and do it based on tests with real world data collected over many years.
>
> Time for some real world data regarding human performance. I learned this from extensive work on production line quality control in high tech manufacturing. If you take a person in a good environment (temperature, lighting, sound) and that person does a task for which they are trained, experienced, and have the right tools such as assembling a complex piece of machinery, on average (40 hour work week, Monday through Friday, all year round), the error rate in a simple task such as installing a screw to a required torque as you do so is....
>
> About 1%. That is, the measured error rate, over time for a trained and experienced person doing a simple task is about 1%.
>
> This has been verified in airline cockpit tests, production lines and many other environments, and seems to be a rough constant for human beings doing repetitive tasks. For some people having a very good day, it may be a fraction of that rate. For others, harried, tired, end of shift, it may be much more. But figure roughly once per hundred small tasks, an error occurs, averaged over a long period under a variety of conditions.

Same applies to a SINGLE pilot running a check list. Some days you will make NO errors on a 20 item check list. Other days, tired, harried, distracted, you will make a mistake. The most common mistake: you miss the checklist item.

Bingo, you are tired, in a long line of traffic waiting to go, hot day, canopy open to stay cool, suddenly you are "cleared for takeoff without delay" and forget the check list item. For most items, no big deal, the airplane flies. For the canopy, maybe, just maybe, missing the item on your Legacy means you die.

This is the reality of human beings and some of our aircraft, so the record clearly shows.

So what to do? On the production line, standard practice for "six sigma" quality (one error per million operations) you do the following, standard operating procedure:

1) Do the task.

2) Go back and check your work referencing the assembly task list.

3) When you pass the assembly to the next guy in line, he/she checks your work, and then proceeds with the next stage of assembly.

4) People rotate positions so you know you will check his work today, but he will check your work tomorrow.

Error rate is then 1% of 1% (the check) of 1% (checking the check) which yields one error per million. Desired result achieved.

Now look at an airliner cockpit.

1) Check list item called out

2) Check list item repeated by 2nd person

3) Check list item accomplished with call out

4) Confirmed by first person calling out who does not move on until the correct challenge and response are obtained.

Error rate: one per million. Or less.

Now look at YOUR cockpit.

1) As you go down you check list, you get to item X, and miss it. Chance of it happening is 1%

2) You proceed to the next item, not knowing you have missed the item.

Overall error rate: 1%. Repeat 20 times for your 20 check list items.

Your error rate, compared to the target rate of one per million, IS AWFUL. Average single pilot alone operating as an individual in his cockpit without internal checking and observer operates at this level.

Not every day. Not every flight. But on average, year in and year out, you will miss a check list item 1% of the time.

And you could die as a result depending on the item missed and its consequences.

NOT GOOD ENOUGH.

So what is needed is a FAIL SAFE method of protecting you from the fact that you are a human being. If you miss a check list item and it could kill you, you need ADDITIONAL LAYERS OF DEFENSE to assure an adequate level of safety.

A virtually perfect defense on a Legacy canopy is a secondary safety latch that automatically prevents the canopy popping up if the main latch is not secured (auto hood safety latch concept). John Smith's analysis showed that conclusively. (Plug for John's work: he has worked safety issues in the off-shore oil and gas industry. Remember Piper Alpha. Much was learned from that and other accidents.)

Otherwise you are working with layers of imperfect defenses: your own secondary check (push canopy up automatically, muscle memory), audible alarm (different sensory input) warning light (easy to miss with sun behind you), big warning message across EFIS display (hard to miss when you look at air speed indicator prior to rotation) or whatever rings your chimes. These provide vast improvements because they catch you when you miss. Most of the time. They add layers of defense, and reduce the probability of a fatal miss from parts per hundred to down to parts per million

Yes, we should all be good boys and girls and always run our check list, every item, ideally with somebody challenging our work. In reality, we are human and the environment (outside and inside your body) sometimes interferes, and you make errors. Guaranteed.

If it means your life, a checklist is NOT good enough if a missed item leads to a condition that is unrecoverable. DO NOT mislead yourself in thinking that it is. History has proven that checklists without discipline and challenge are not good enough. Humans make mistakes.

Fred Moreno

PS

Recommended for retractable landing gear planes:

1) Check three greens when gear extended - don't take your hand off the handle until you see them. That can be a powerful check by itself.

2) Three greens on base.

3) Three greens on final.

Overall error rate: one per million, until you are distracted. So when distracted internal alarm bells should go off. Then you can stay near one per million, not one per hundred.

## Canopy Unlatched/Open Warning System

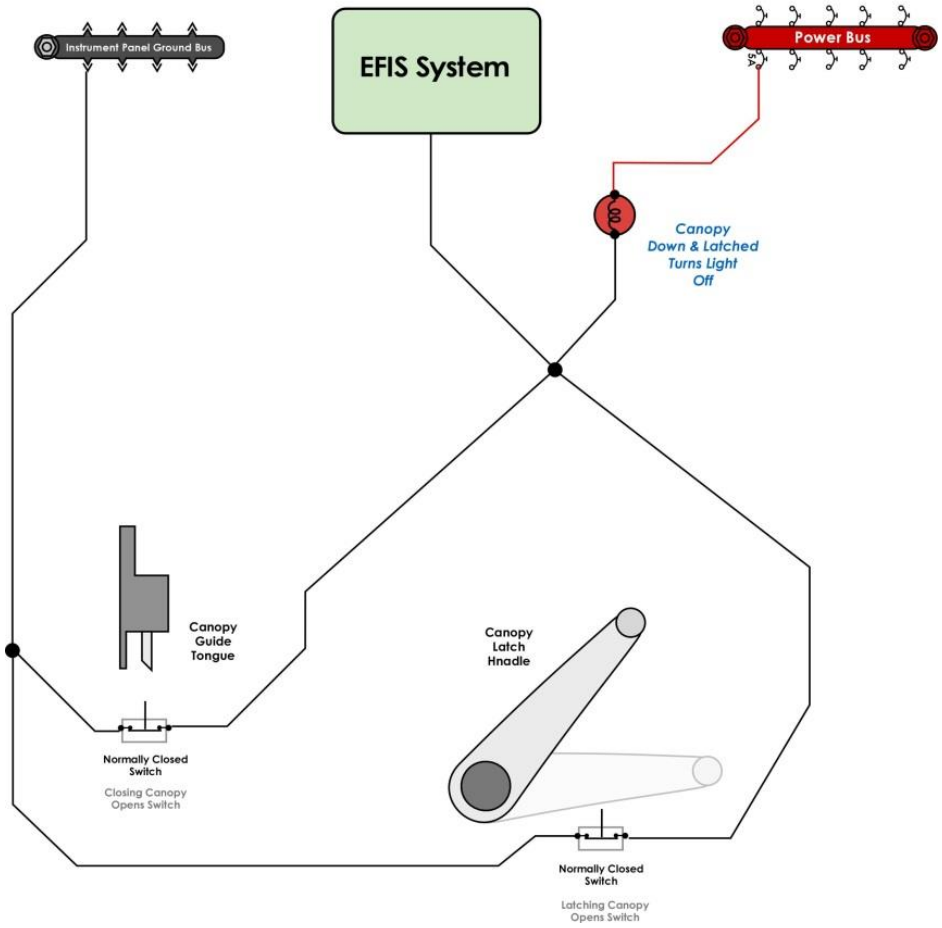
The risk of takeoff without the canopy latched can be reduced with a prominent annunciator on the instrument panel warning the canopy is in an unsafe configuration – not down and latched.

It is not sufficient to measure whether the canopy alone or latching lever alone is in the proper position because both are required to determine the canopy is down and latched. The following wiring schematic shows an example of how to wire micro switches and an annunciator light to provide this warning.

In this example, a micro switch is positioned so that the canopy alignment guide depresses a micro switch and the latching lever depresses a micro switch when it is down. Both the canopy and lever have to be down in order for the warning light to go out. This same signal can be routed to an EFIS system for annunciation.

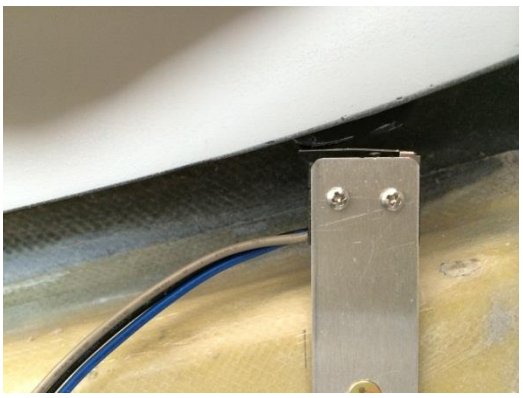

Example Canopy Unsafe Warning Light in Jon Addison's Lancair 360

# Canopy Safety Indicator Circuit

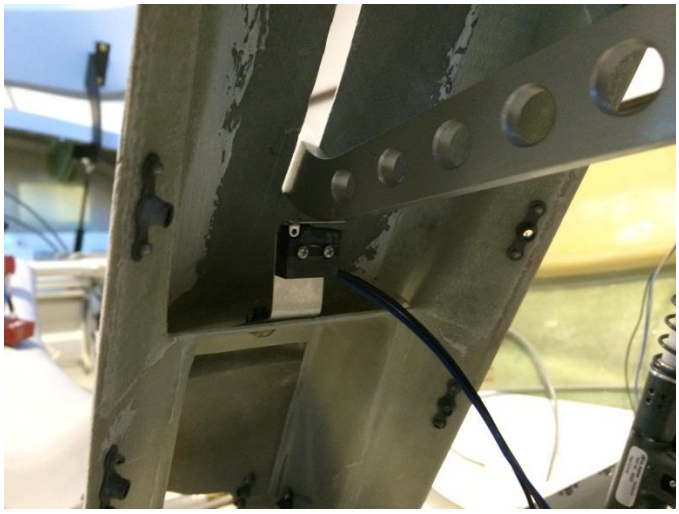



Canopy Safety Wiring Drawing Example

The following photos show examples of micro switch mounting to measure canopy and canopy latch positions. The micro switch is positioned so that the canopy alignment guide depresses the switch. The micro switch mounting shown in these photos are for a Legacy with air ducting below the canopy opening and modifications to the cockpit structure around the canopy latch lever arm. Exact mounting for a stock/unmodified Legacy will be slightly different – but the principle is the same.



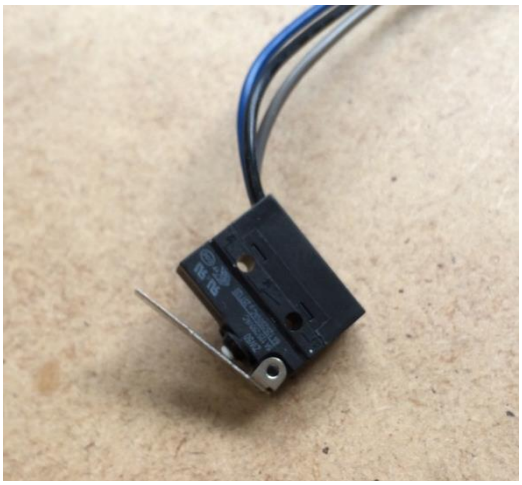
Canopy down micro switch mounting example



Canopy latching lever micro switch mounting example

The micro switches shown can be wired for "Normally Open (NO)" or "Normally Closed (NC)" switching determined by the wires used. The black wire is the Common line, blue is Normally Open and grey is Normally Closed. The Normally Closed switch position means that when the switch lever arm is not pressed, the switched is closed/completes the electrical connection and allows current to flow. In the example shown, the circuit should be connect to the black and grey (NC) wires. With both switches wired through their NC wires, when their lever arms are depressed, the switches will open, cutting of electrical current to the canopy unsafe annunciator light and the EFIS system.

These micro switches are available at Mcmaster.com for $8.11 each:



http://www.mcmaster.com/#8085t15/=qzcvfs

In this example, the micro switches were mounted to 0.032" aluminum strips cut 0.75" wide and three inches long to facilitate their precise positioning and mounting.

The simplest warning system just illuminates a light on the instrument panel. Here's an example of a large annunciator light available at Aircraft Spruce for $15.50:


http://www.aircraftspruce.com/catalog/elpages/legendlights.php?clickkey=4238

Most Electronic Flight Instrumentation Systems (EFIS) support canopy unsafe annunciation. The example below shows how the Garmin G3X system handles the warning.

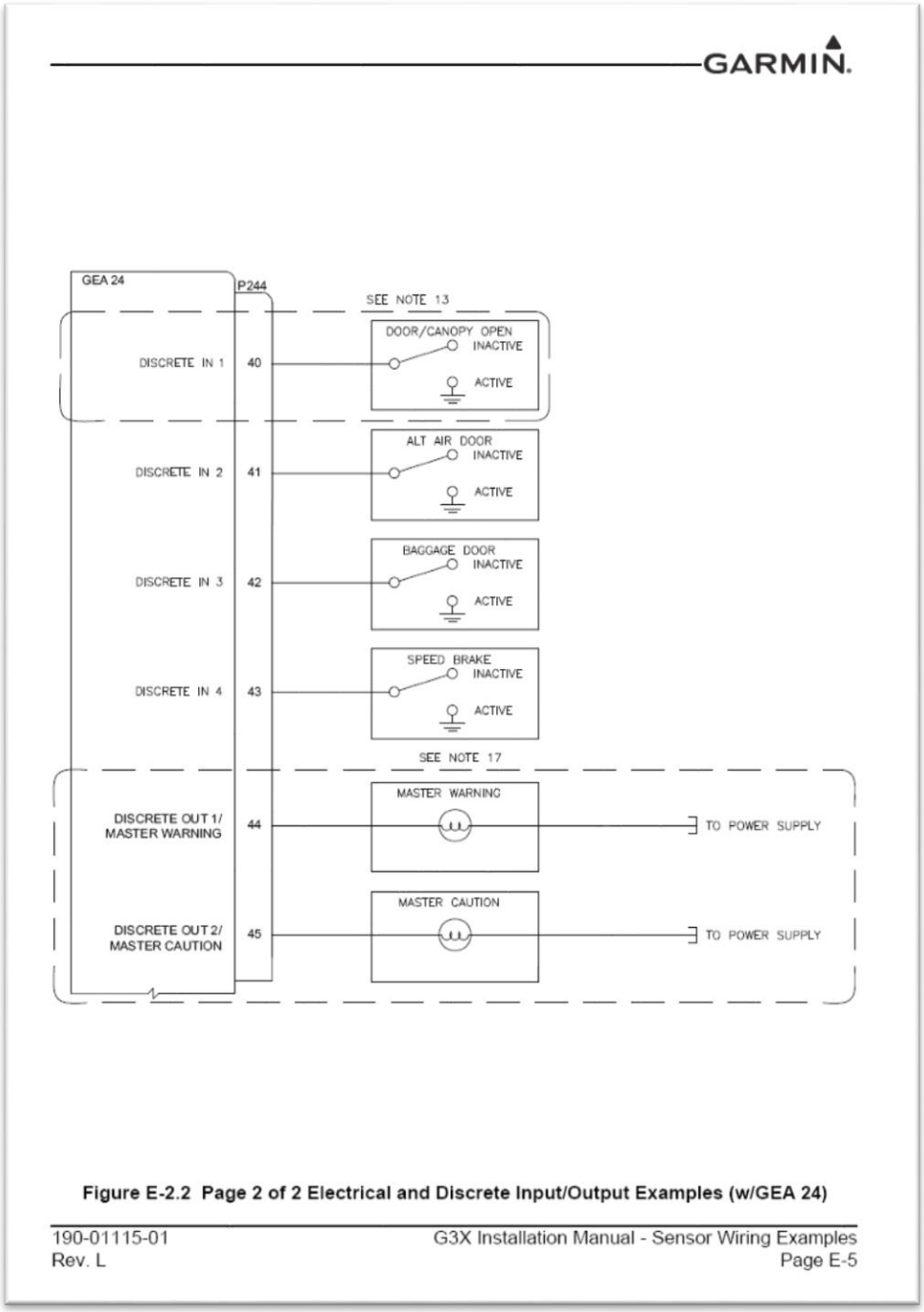
GARMIN.

After a discrete input is configured for either Active Low or Active High, it is assigned to a specific function. The following discrete input functions are supported:

- Canopy Closed - Used with a switch that activates the input when the aircraft canopy is closed and locked. A solid yellow CANOPY OPEN message will appear on the PFD if the Canopy Closed input is not active. If engine power is increased or the aircraft is airborne, the CANOPY OPEN message will flash red and an alert tone will sound.

Garmin G3X Canopy Safety Handling

On the Garmin G3X system, the canopy safety circuit wire connects to the GEA 24 Engine Airframe Unit, Plug 244, Pin 40.




Garmin G3X Canopy Safety Wiring Connection

## Canopy Latching Mechanism Modification

The risk of takeoff without the canopy latched can also be reduced by modifying the canopy latching mechanism so the canopy is not allowed to completely close unless the canopy is latched. The baseline design of the Legacy's canopy latching mechanism allows the canopy to close completely without being latched. Pilots must look between the seats to examine the lever to determine if it is latched and/or push up on the canopy for latching confirmation.

Most Legacy airplanes have enough friction between the canopy and canopy seal to hold it closed until the airplane is rotated for liftoff and the aero forces are strong enough to open it. If there is not runway ahead to safely support an aborted takeoff, pilots continue their takeoff.

The author developed this simple modification of the Legacy's canopy latching system, based on a concept suggestion by Graham Nutt many years ago, with the purpose of starting the canopy open to expose an edge to get fingers under to complete the opening. Likewise, it has the benefit of not allowing the canopy to completely close unless the canopy is latched.

The benefits of this latching modification are that the pilot can clearly see that the canopy is not closed, air flows through the opening as a reminder, and the friction with the canopy seal is so low that the canopy cannot be held down once the takeoff power and/or roll is commenced.

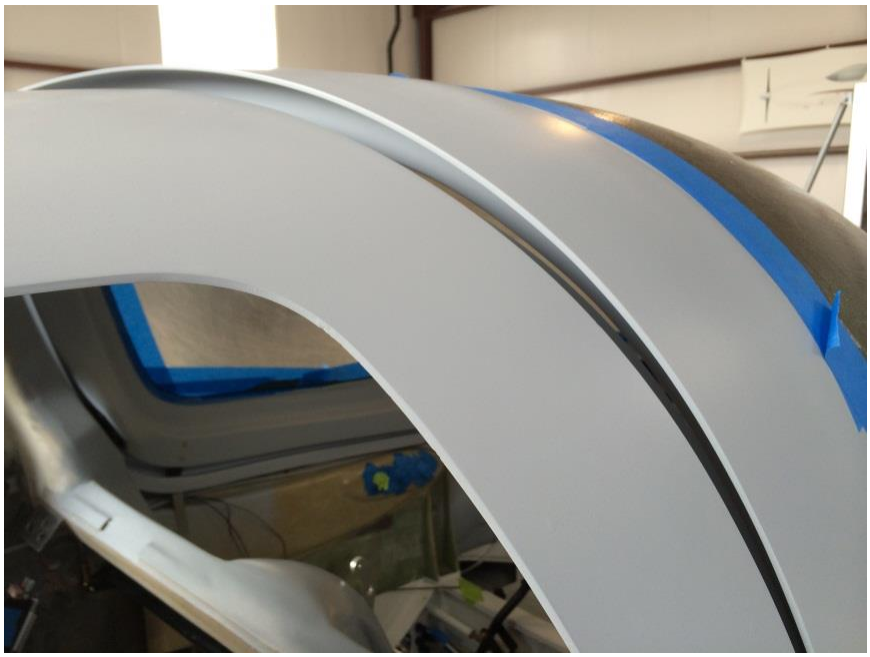


Photo of Canopy Propped Open by Latch Mod

The following are pilot reports of flight experiences related to this canopy latching modification. Doug Brunners' Legacy airplane does not have this modification – but, his friction between the canopy and seal is apparently low enough that on application of takeoff power and at the beginning of takeoff rollout, his canopy will open from the aerodynamic forces. Many Legacy airplanes have too much friction with their canopy seal and if the canopy is not latched, the canopy will not open until rotation for liftoff or later in the takeoff.

**N241DB Pilot Doug Brunner**

**LML Post 5 November 2013:** I have gone down the runway with the canopy unlatched. Before I got to takeoff speed the canopy made the fact that it was open known. We simply slowed down and pulled off the runway, taxied back, closed the canopy and took off. A non-event.

Question:

Doesn't the fact that your canopy is unlatched make itself known either during engine run up and/or during the takeoff roll?

**N927J Pilot Art Jensen**

**LML Post 6 November 2013:** I have had the same thing happen to me. The fact that the canopy seal was on required more pressure to lift the canopy during the takeoff roll. It actually opened as I rotated. I immediately cut power before becoming airborne. Had this happened on a 3000 foot strip I would have probably gone off the end of the runway. I too had a check list, was properly trained etc. yet because of the very thing a pilot cannot afford to be caught, being in a hurry and distractions almost became a statistic. I'd like to think that this could never happen to me again. I actually double check that the canopy is locked before entering the runway now.

**N357V Pilot Paul Miller**

**LML Post 25 Feb 2014:** This mod is excellent (spacer near latch) and easy to implement. My experience has been that at 1800 RPM, the canopy will lift up thereby warning you during mag check. At takeoff power the canopy immediately pops. There is no way to depart with an unlatched canopy with this mod on my Legacy.

**N252JT Pilot Jim Thomas**

**LML Post 10 Feb 2009:** I have the Legacy canopy latch modification that props the canopy open about 1.5" as shown on Don Barne's website. The canopy latch must be locked for the canopy to be fully closed. One time I started my take-off roll with the canopy unlatched and because the canopy was propped open the noise and wind made me immediately aware the canopy was not closed. There was plenty of time to

pull the power and abort the take-off. Now I believe that this mod not only helps ventilate the cabin on the ground, but it may have also saved my life.

The Canopy Latch Mechanism Modification requires the upper lever stop be moved so that the canopy latching claws remain extended 7/16" when the canopy lever is in the fully unlatched position.

Photo of Canopy Latch Claws Modified to Remain Partially Extended
When In Full Canopy Release Position

The canopy latching striker plates require installation of 1" x 2" pieces of 1/8" thick Nylon or ABS. The top AN3 hex head bolts are replaced with MS24694 – S54, (10-32) countersunk screws to secure the new "canopy lift plates".

Photo of Canopy Striker Modified with Lift Plate Installed

Photo Showing Claws and Striker Plate with Canopy Propped Open by Latch Mod

### Secondary Safety Latch

At the time of this writing, a group in Australia headed by John Smith is developing concepts that may provide a secondary means of latching the canopy to provide fault tolerance for the main canopy latching system. This group has presented several options to Lancair Inc. and is awaiting their assessment. No details have been shared with the larger group at this point. A secondary safety latch system, combined with the other controls for this hazard, could reduce the risk of exposure to this catastrophic hazard to near zero. A key challenge to a secondary latching system is ensuring it does not interfere with crash rescue ability to open the canopy from the outside.

## Risk Analysis

John Smith, an expert in safety systems and analysis, has looked at the Legacy's open canopy flight hazard risks and provided this discussion of the subject to the LML community. He is also a principal in the Australian group working on a secondary safety latch. At the time of John's post to the LML, he was unaware of the canopy latching modification so it's impact on the canopy open flight risk is not considered.

> **Pilot John Smith**
>
> **LML Post Excerpt 24 Feb 2014:** As you know, there has been a fair bit of dialogue on the canopy issue on the forum. And a while back, I invited forum members to join in a working group to look at the issue and, in particular, look at a safety latch. The outcome was no takers other than colleagues here in Oz. Whilst a few of us already had dual

micro switch warning systems installed in our Legacy's, but sadly not the Gerladton or Shepparton Legacys, myself and a few colleagues have been feverishly working on a safety latch design to further reduce risk of the canopy open event.

Cutting straight to where I, and no doubt others may have already got to, but quite likely not all…….

IMHO I believe everyone should have / could easily implement following with substantial benefit to pilots and their passengers in the order of 100 times less risk than the historical average risk of a fatal canopy open event:-

- Make sure you have check lists that include the canopy status at run-up, and then again at the holding point / line-up – and use them
- Develop and acknowledge canopy open on ground and in air procedures
  - if on the ground and it opens, whatever – do not proceed to airborne
  - If it opens in the air – above all else, do not attempt to close the canopy, keep the ball centered
- Add a pair of warning switches in series to check for latch position and canopy seat position – wire so fail safe – audible + big visual warning

Next – look at a safety latch, or something similar or identical to Don Barnes' solution – this sort of device offers the potential to reduce the risk to zip – so why not do it?

A bit more detail below…..particularly around the risk assessment. Read on if you're still interested!

As far as a safety latch is concerned, our group here would have between us come up with dozens of different designs, some of which were sufficiently well developed that one could almost start building the CAD drawings / CNC machine inputs files for fabrication of components. The goal was of course to design something that will operate safely and reliably, not hinder egress or external emergency access, and be simple to install both during a build and after build. We short listed a few options, but all required some penetrations in the structure - so I passed these options to Lancair to see if they could provide guidance as to which would be acceptable from a structural point of view – to date no response (I must follow up…). Once we get that guidance, I will most likely build a prototype and install on my Legacy. I fully intend to publish / share whatever we come up with.

Above said, I had forgotten about Don Barnes' solution where I understand the canopy sits up a little bit unless the canopy latch is in the closed position – that may well largely obviate the need for a safety latch, as I'd presume the noise with even with a slightly open canopy (and even with noise cancelling headsets) would be hard to miss – but

may be not 100% fool proof. Anyone know how high the canopy sits up with this mod? 1/2"? 1"?

In order to try and bring a bit of rigour and quantification to the understanding of risk and what measures are useful or not and so forth, I have also done a fair bit of work with event tree analysis to assess how various combinations of check lists, procedures, warning devices and a safety latch effect the risk of a fatal canopy open event. The event tree input assumptions around probabilities of various actions were tuned to match the actual historical risk of a fatal canopy open event. I found it a powerful way to explore what might happen if one does or does not do or have something… Very interesting, and not entirely or always intuitive. There is no doubt that a secondary latch gets straight to a really good outcome – provided such mechanism does not present unintended additional risk or compromise structural integrity. I am happy to share in the detail of this "model" if anyone is interested, but the bottom line messages - and noting the inherent uncertainty around many of the inputs and assumptions - of this work were:-

- At the time I did the work, there had I believe been 3 fatal canopy open events - this equates to a risk factor in the order of 3 x 10-5 (unacceptable cf. a generally understood overall risk target for GA of 10-6)
- This is expressed as risk of a fatal canopy open event per take-off (you can see basis below)
- A dual microswitch warning system (latch position and canopy position) with audible and visual annunciation - in the case of VH-XTZ and VH-ZYA, we have ~3" x 1/2" flashing red warnings in centre of each EFIS screen, combined with the check lists and defined canopy open event flight procedures, get one into the 10-7 event frequency region (again expressed as frequency per take-off) for a canopy related fatal. If it were expressed as a frequency per hour, the number probably wouldn't look different – if avg. flight times were around 1 hour
- So - in theory a Legacy with a decent warning system operated with a decent (and practiced) canopy related check list and acknowledged emergency procedures, may offer the opportunity to reduce the risk by 2 orders of magnitude (100 times less) compared to aircraft without these measures in place
- A big assumption in all this, is that the historical fatal canopy open event aircraft did not have safety switch systems installed – if anyone knows the answer to that question, I'd appreciate it
- A secondary latch (without an alarm) gets one straight into the 10–8 region or better (albeit this is quite sensitive to the secondary latch reliability assumption)

- With a warning system AND a secondary latch, the risk goes to zip

Rolling this up, the picture seems to be:-

- Historical risk of a fatal canopy open event is in the order 10-5
- Add warning devices, check lists for canopy status at run-up and again at holding point => order of 10-7 risk (~ 100 times improvement)
- Add a safety latch alone => order of 10-8 risk (~ 1000 times improvement)
- Add the lot……=> extremely low risk

I'm sure there will be many a clamour about how useful check lists are, or how useful alarms are and how responsive pilots are to alarms… and the work I have done reflects that check lists will not always be done, and that alarms will not always be noticed, and that even if alarms are noticed pilots may not respond or indeed cancel them….. But, in combination – if just some of the measures hit the spot – just one of them alone may well avert a tragedy. Putting it the other way – if none of these things were done – then….?

John Smith

# Recommendations for Inadvertent Flight with Canopy Open

With the measures discussed in this report implemented to mitigate the risk of flight with the Legacy's canopy unlatched, it is very unlikely that flight with the canopy unlatched/open will occur. Should one be faced with this possible harrowing condition, these procedures and flight techniques may help one survive the ordeal.

These suggestions have not been proven by flight testing and are based on reports of Legacy pilots who've flown with their canopy unlatched, reports of fatal canopy open accidents, and knowledge of airplane aerodynamics and associated conjecture. Follow these procedures at your own risk.

The evidence suggests that minimizing the Canopy AOA and keeping the airplane's Beta near zero (side slip ball in the middle) is key to keeping the canopy from opening far enough that pitch instability is induced.

First, do not try to close and latch the canopy in flight – the aerodynamic forces are too great and it will only serve as a distraction from flying the airplane.

## Untested Procedures for Flight with Canopy Open

(Follow these procedures at your own risk)

- If canopy opens on takeoff roll and sufficient runway for stop remaining, abort takeoff
- If canopy opens on takeoff and sufficient runway for stop is not available, continue takeoff, increase speed, add additional flaps if unstable
- Maintain 120 KIAS
- Extend flaps fully
- Do Not Attempt Immediate Landing
    - Climb to >6000 ft AGL to test stability in configuration and at lower airspeed
    - In landing configuration with full flaps, level flight, progressively slow to 100 KIAS. If pitch instability ensues, lower nose, add power, and accelerate back to 120 KIAS.
        - The purpose of this is to find out how much airspeed/AOA margin there is below 120 KIAS for landing. You don't want to learn that it is going to go unstable if you slow to 115 KIAS when you're on final approach at 100 ft AGL.
    - If airplane is stable down to 100 KIAS, still fly approach at 120 KIAS, but you'll know you have good airspeed/AOA margin on your pitch stability
- Return for Landing – Minimize configuration changes, gentle control inputs, bank angles, accelerations, etc.
- Approach speed 120 KIAS until inches above runway

# Conclusions & Recommendations

The Lancair Legacy can become very unstable if flown with the canopy unlatched/open. There is a flight regime with the canopy open less than about 3 inches where the airplane's stability is normal. Beyond about 3 inches of opening a severe pitch instability dynamic occurs.

Legacy flight with an unlatched/open canopy is a catastrophic hazard with a high probability of death or serious injury and aircraft damage.

Use of a Before Takeoff Checklist alone does not provide sufficient control of this hazard given the normal error rates of humans.

Pilots and builders of Lancair Legacy airplanes should install a canopy unsafe warning system and a modification to the latching system that does not allow it to close without being latched. Implementing these three hazard controls – check list, warning system, and latching mod – significantly reduces the risk of exposing this flight hazard.

In case one finds themselves in flight with an unlatched canopy, do not slow down. Low AOA is key to keeping the canopy from opening up wide enough to induce the pitch instability. Maintain 120 KIAS, extend the flaps, get to altitude, test lower speeds at altitude to get confident in your control margins. Fly approach and landing with no configuration changes, minimal bank angles, and don't slow down below 120 KIAS until inches above the runway.