Aviation Investigation Final Report

Location:	Firebaugh, California	**Accident Number:**	WPR17LA104
Date & Time:	May 15, 2017, 16:44 Local	**Registration:**	N846PM
Aircraft:	EVOLUTION AIR LLC LANCAIR EVOLUTION	**Aircraft Damage:**	Substantial
Defining Event:	Miscellaneous/other	**Injuries:**	3 Minor, 2 None
Flight Conducted Under:	Part 91: General aviation - Personal		

Analysis

The pilot reported that, while in cruise flight at 25,000 ft, the airplane's windshield shattered, immediately followed by a rapid decompression of the cabin. The pilot shut down the engine, entered an emergency descent, and navigated to a nearby airport. During the approach for landing, the pilot received an anomalous landing gear indication and chose to perform a gear-up landing. The airplane touched down with an 8-knot tailwind and slid along the runway until it impacted a fence, continued across a road, and came to rest in dirt. Both wings were substantially damaged.

Postaccident testing showed that the relay modules responsible for opening and closing circuits to the left main landing gear were dislodged when the windshield shattered, resulting in the anomalous gear indication. The landing gear system functioned normally once the modules were reinstalled.

A portion of the windshield that remained attached to the frame exhibited a fracture consistent with pure tension loading, likely from internal pressurization. Due to the curvature at that location, the fracture area was likely one of high stress on the windshield. Examination of the windshield fragments and frame did not show any evidence of impact from a foreign object, but showed significant structural flexing of the fuselage due to delaminated wet-layup plies during construction, as evidenced by extensive cracking at the aft engine cowling. However, the absence of an airplane structural analysis from the manufacturer precluded further review of the structural flexing of the fuselage. A material and bond evaluation showed that the windshield frame material did not exceed its glass transition temperature, indicating that the acrylic windshield was likely intact at the time of the failure; however, further analysis of the bond between the windshield and window frame could not be performed, as the manufacturer did not provide bond strength design values for either section.

Several other factors in the construction of the windshield may have contributed to increased stresses at the location of a key fracture, which may have caused cracks to initiate and grow. In particular, parallel grinding marks around the edges of the windshield were inconsistent with the use of a dual-action

grinder with 40-grit sandpaper as prescribed by the windshield installation instructions. These grinding marks may have introduced stress concentrations at the edge of the windshield and may have contributed to one of the primary windshield fractures. The overall appearance and mechanical behavior of the adhesive during the examination suggests that the bond strength between the windshield and frame was relatively low. Thus, the presence of disbonded areas may have affected the stress state on the windshield and contributed to increased stress at the primary fracture area. Finally, the overall composite layup varied from the specified layup schedule for the fuselage skin at two locations on the windshield frame. Alterations in the material used in the fuselage skin can change the elastic response to a given load. The change in the layup schedule and elastic response may have increased the stress at the location of the primary fracture area.

Probable Cause and Findings

The National Transportation Safety Board determines the probable cause(s) of this accident to be:

A failure in the windshield, frame, or windshield-to-frame bond, which resulted in a rapid decompression during cruise flight.

Findings

Aircraft	Flight compartment windows - Fatigue/wear/corrosion
Aircraft	Flight compartment windows - Failure

Factual Information

History of Flight

Enroute-cruise	Miscellaneous/other (Defining event)
Enroute-cruise	Emergency descent initiated
Landing	Landing gear not configured
Landing	Collision with terr/obj (non-CFIT)

HISTORY OF FLIGHT

On May 15, 2017, about 1644 Pacific daylight time, an experimental, amateur-built Lancair Evolution, N846PM, was substantially damaged when it was involved in an accident near Firebaugh, California. The front seat passenger and one rear seat passenger received minor injuries; the private pilot and two other passengers were uninjured. The airplane was operated as a Title 14 *Code of Federal Regulations* Part 91 personal flight.

The pilot reported that he and four family members departed on a cross-country flight to return to their home airport. While cruising at an altitude of 25,000 feet, the windshield suddenly "exploded." The airplane's cabin experienced an instant decompression, and the pilot activated the oxygen system and donned his oxygen mask. During the subsequent steep descent, the pilot located and navigated to a nearby airport. After he turned to the final leg of the airport traffic pattern, the pilot extended the landing gear but did not receive confirmation that the left main landing gear was extended and locked via the landing gear position indicator lights. After recycling the landing gear and receiving the same indication, the pilot decided to land with the landing gear retracted. He stated that, although the airplane made contact with the runway at high speed, the touchdown was smooth and level. The airplane overran the runway, impacted a fence, and continued across a road before it came to rest in a field, sustaining substantial damage to both wings.

The airplane came to rest in a field about 900 ft beyond the departure end of runway 12. All major components of the airplane were accounted for at the accident site. Most of the windshield was broken, with the exception of a few fragments that remained attached to the fuselage frame. Each of the engine's four propeller blades was bent aft. The airplane did not display any evidence of a bird strike.

During postaccident testing, all three-landing gear deployed normally using the landing gear bypass valve; however, the landing gear status display showed unsafe indications for the main landing gear. Postaccident photographs of the accident site showed that both the left main landing gear down and up position relay modules had been dislodged from their terminals in the avionics bay, located below the windshield on top of the instrument panel. Once the left main landing gear modules were installed in the terminal bay, the left main landing gear down indications worked normally and indicated down with the landing gear down and locked.

Windshield Examination

The windshield was cast acrylic and the frame was a carbon fiber reinforced polymer (CFRP) with layers of carbon-fiber fabric and epoxy. Most of the windshield was fragmented and departed the airframe in-flight, but portions remained encased in the window frame. (See figure 1) Three pieces along the lower edge of the windshield were easily removed from the window frame. Large portions of the windshield extended beyond the edge of the integral window frame from about the 4 to 6 o'clock and about 6 to 8 o'clock positions. Additional sections of the windshield remained attached to the windshield frame but did not extend beyond the edge of the window frame cutout in the fuselage. The window frame had visible signs of damage to the composite airframe structure at the 2, 6, and 10 o'clock positions.

Figure 1. Forward Face of Windshield

The entire windshield frame was removed, including all of the composite structure to which the windshield was bonded. The composite airframe window frame structure, windshield pieces, and a small section forward of the frame were sent to Wichita State University's National Institute of Aviation Research (NIAR).

NIAR Examination & Limitations

The NTSB and NIAR made multiple requests to Lancair International, Inc. the manufacturer of this experimental amateur built airplane, for engineering data related to the windshield, frame and paste adhesive. The manufacturer failed to provide the engineering and test data required to complete NIAR's analysis, thus their report was inconclusive. The section below contains a summary of NIAR's examination.

A total of 12 windshield artifacts were submitted to the NIAR lab for examination. Visual examination of the two large intact sections of the windshield showed gaps, indicating that the remaining portions were not fully bonded into place. Once the fracture surfaces were documented, the samples were subjected to failure analysis, material and bond evaluation, and paint evaluation.

Due to the limited technical information provided to the NTSB and NIAR, NIAR was unable to continue its analysis of the windshield, frame, and paste adhesive. Specifically, a review of the structural design of the fuselage/windshield design could not be performed as no structural analysis was provided by the manufacturer. Further, a review of the bond strength design values for the bond between the windshield (acrylic) and the window frame could not be conducted due to the absence of bond strength test data for the window to windshield bond from the manufacturer. Finally, the paint scheme restrictions presented in the build manual could not be evaluated due to an absence of the manufacturer's analysis and reasons for these restrictions.

Extensive cracking was found directly in front of the windshield, consistent with delaminated wet-layup plies that were applied to the fuselage after the two fuselage halves were joined together. (See figure 2) These findings indicated significant structural flexing in the fuselage.

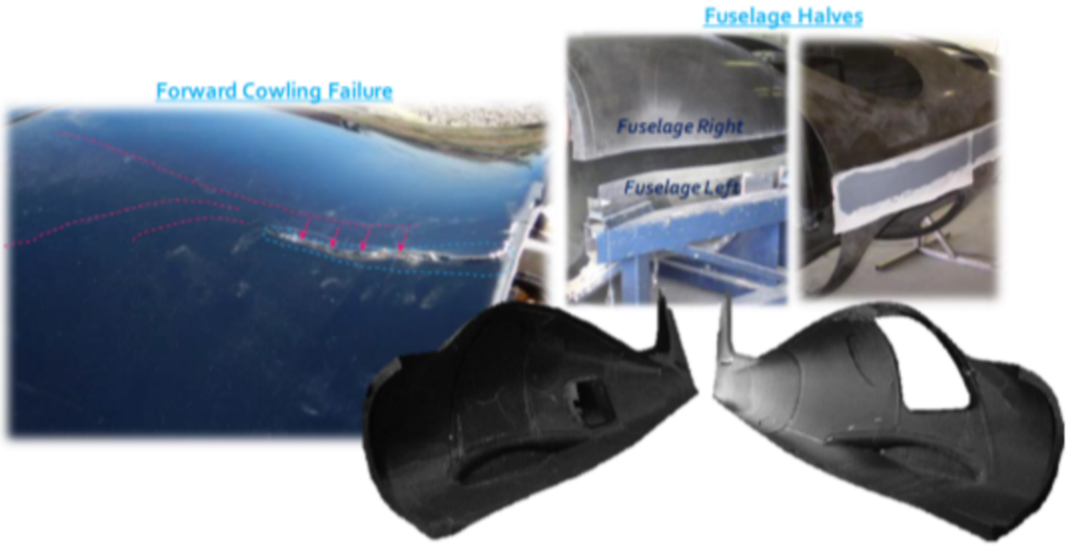

Figure 2: Excerpt of Forward Cowling Failure and Fuselage Halves from NIAR Report

Material and Bond Evaluation

According to NIAR, airframe temperatures can reach high levels when the airplane is parked and exposed to solar radiation and adverse ambient conditions.

Glass transition temperature (Tg) is the temperature range where the polymer substrate changes from a rigid glassy material to a soft material and is usually measured in terms of the stiffness or modulus. Thermal analysis was used to evaluate the Tg of the composite windshield frame, acrylic windshield, and paste adhesive used for bonding the windshield to the frame. Testing showed that the average low Tg was 192°F for the paste adhesive, the lowest Tg for the evaluated materials.

At the time of the windshield failure, the outside air temperature (OAT) was recorded as -34°C (-29°F), which had been constant for the previous 6 minutes. For the 15 minutes before that, the OAT was -18°C (0°F). Thus, the windshield frame material was not beyond the Tg at the time of the failure.

Paint Evaluation

Solar reflectivity or reflectance is the ability of a material to reflect solar energy from its surface. Six samples of the airframe were extracted to evaluate the total solar reflectance (TSR) and emittance value, or effectiveness at emitting thermal energy, associated with the aircraft coating used. The TSR values captured for these samples were consistent with a low amount of reflectance and higher heat retention for aircraft coating applications. Airframes with coatings that promote absorption of solar energy (such as dark colors), can reach temperatures outside of the intended operational temperature. In this particular case, the potential risk for the airframe to reach high temperatures was a concern due to the paint color and region of the airplane's home airport in Arizona.

Lancair did not provide the engineering and test data required to complete NIAR's analysis, thus, the results of the analysis and evaluation of the material was inconclusive. Specifically, a review of the structural design of the fuselage/windshield design could not be performed as no structural analysis was provided by the manufacturer. A review of the bond strength design values for the bond between the windshield (acrylic) and the window frame could not be conducted due to the absence of bond strength test data for the window to windshield bond from the manufacturer. Finally, the paint scheme restrictions presented in the build manual could not be evaluated due to an absence of the manufacturer's analysis and reasons for these restrictions.

NTSB Materials Laboratory Examination

The windshield was forwarded by NIAR to the NTSB Materials Laboratory for further examination.

According to the window installation instructions, the exterior surface of the windshield is bonded with Hysol EA 9360 paste epoxy, and the interior surface of the windshield is bonded in place with Rhino 1307-LV resin plus hardener. The windshield remnants and bond surfaces were examined visually, and the directions of fracture propagation were determined.

The windshield remnant at the left side of the frame included a longitudinal fracture (fracture A), and a crack in the lower left side of the windshield was adjacent to the frame (fracture B). Three other adjacent fractures were secondary.

The forward lower end of fracture A was flat and perpendicular to the interior and exterior surfaces across the thickness of the windshield and along the length of the fracture consistent with fracture under mostly tension loading.

Ratchet marks were observed from the interior surface at the origin area of fracture B, indicating a fracture initiation on multiple slightly offset planes from the interior surface. The overall subsequent progression of the fracture from the interior to exterior along the length of the crack was consistent with higher tension stress at the interior surface, indicative of a combination of tension and bending loads during fracture.

The forward end of fracture B intersected with the forward edge of the windshield near the start of fracture A; however, the relationship between fracture B and fracture A could not be determined due to a lack of available evidence.

According to the windshield installation process specified by the kit manufacturer, the edges of the windshield within the frame are roughened by hand with 80-grit sandpaper near the edge of the windshield. A dual action (DA) sander with 40-grit sandpaper is used to roughen the interior and exterior surfaces that are then bonded to the frame and to create a round edge to the outer edge of the windshield.

An examination of the windshield edge near fracture B showed gouges inconsistent with a rounded edge from a DA sander with 40-grit sandpaper. Further, the Hysol adhesive near the forward ends of fractures A and B showed impressions of parallel, curving grinding marks about 2 inches of the forward end of fracture B, also inconsistent with a DA sander with 40-grit sandpaper.

According to the airplane construction drawings, the fuselage skin was a sandwich panel construction with exterior and interior carbon fiber reinforced polymer separated by a honeycomb core. The observed layup differed from the expected layup schedule. Further, the interior skin included 2 more layers than the total number listed in the layup schedule for that location, and the exterior skin included 4 more layers than expected. In another section of the windshield frame, the interior skin layers matched the expected layup for that location, but the exterior skin varied from the expected layup orientations and included 4 additional fabric layers.

Pilot Information

Certificate:	Private	**Age:**	39,Male
Airplane Rating(s):	Single-engine land; Single-engine sea	**Seat Occupied:**	Left
Other Aircraft Rating(s):	None	**Restraint Used:**	3-point
Instrument Rating(s):	Airplane	**Second Pilot Present:**	No
Instructor Rating(s):	None	**Toxicology Performed:**	No
Medical Certification:	Class 3 With waivers/limitations	**Last FAA Medical Exam:**	February 23, 2017
Occupational Pilot:	No	**Last Flight Review or Equivalent:**	March 11, 2017
Flight Time:	1133 hours (Total, all aircraft), 110 hours (Total, this make and model), 1120 hours (Pilot In Command, all aircraft), 34 hours (Last 90 days, all aircraft), 10 hours (Last 30 days, all aircraft), 3.7 hours (Last 24 hours, all aircraft)		

Aircraft and Owner/Operator Information

Aircraft Make:	EVOLUTION AIR LLC	**Registration:**	N846PM
Model/Series:	LANCAIR EVOLUTION NO SERIES	**Aircraft Category:**	Airplane
Year of Manufacture:	2016	**Amateur Built:**	Yes
Airworthiness Certificate:	Normal; Experimental (Special)	**Serial Number:**	EVO-0065
Landing Gear Type:	Retractable - Tricycle	**Seats:**	5
Date/Type of Last Inspection:	May 1, 2017 Condition	**Certified Max Gross Wt.:**	4550 lbs
Time Since Last Inspection:	13 Hrs	**Engines:**	1 Turbo prop
Airframe Total Time:	187.8 Hrs at time of accident	**Engine Manufacturer:**	Pratt and Whitney
ELT:	Installed	**Engine Model/Series:**	PT6A125-A
Registered Owner:	On file	**Rated Power:**	750 Horsepower
Operator:	On file	**Operating Certificate(s) Held:**	None

Meteorological Information and Flight Plan

Conditions at Accident Site:	Visual (VMC)	**Condition of Light:**	Day
Observation Facility, Elevation:	MAE,255 ft msl	**Distance from Accident Site:**	18 Nautical Miles
Observation Time:	16:53 Local	**Direction from Accident Site:**	45°
Lowest Cloud Condition:		**Visibility**	10 miles
Lowest Ceiling:	Overcast / 9000 ft AGL	**Visibility (RVR):**	
Wind Speed/Gusts:	8 knots / None	**Turbulence Type Forecast/Actual:**	/ None
Wind Direction:	340°	**Turbulence Severity Forecast/Actual:**	/ N/A
Altimeter Setting:	29.84 inches Hg	**Temperature/Dew Point:**	23°C / 4°C
Precipitation and Obscuration:	No Obscuration; No Precipitation		
Departure Point:	LIVERMORE, CA (LVK)	**Type of Flight Plan Filed:**	IFR
Destination:	MARANA, AZ (AVQ)	**Type of Clearance:**	IFR
Departure Time:	16:06 Local	**Type of Airspace:**	Class A;Class E;Class G

Airport Information

Airport:	FIREBAUGH F34	**Runway Surface Type:**	Asphalt
Airport Elevation:	157 ft msl	**Runway Surface Condition:**	Dry
Runway Used:	12	**IFR Approach:**	None
Runway Length/Width:	3102 ft / 60 ft	**VFR Approach/Landing:**	Forced landing;Straight-in

Wreckage and Impact Information

Crew Injuries:	1 None	**Aircraft Damage:**	Substantial
Passenger Injuries:	3 Minor, 1 None	**Aircraft Fire:**	None
Ground Injuries:	N/A	**Aircraft Explosion:**	None
Total Injuries:	3 Minor, 2 None	**Latitude, Longitude:**	36.853054,-120.45527

Administrative Information

Investigator In Charge (IIC):	Stein, Stephen
Additional Participating Persons:	Michael Coberly; Federal Aviation Administration; Fresno, CA Robert Wolstenholme; Evolution Aircraft LLC; Redmond, OR
Original Publish Date:	May 5, 2021
Last Revision Date:	
Investigation Class:	Class 3
Note:	The NTSB did not travel to the scene of this accident.
Investigation Docket:	https://data.ntsb.gov/Docket?ProjectID=95177