NATIONAL TRANSPORTATION SAFETY BOARD
Office of Aviation Safety
Washington, D.C. 20594
July 8, 2018

Group Chairman's Factual Report

STRUCTURES

WPR17LA104

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A. Structures Group

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B. Summary

On May 15, 2017, about 1644 Pacific daylight time, an experimental amateur built Lancair International, Lancair Evolution, N846PM, was substantially damaged during a forced landing attempt at Firebaugh Airport (F34), Firebaugh, California. The private pilot and two rear seat passengers did not sustain any injuries. A front seat passenger and rear seat passenger received minor injuries. The airplane was owned and operated by a private individual and operated by the pilot under the provisions of Title 14 Code of Federal Regulations Part 91. Visual meteorological conditions prevailed, and an instrument flight rules flight plan was filed for the cross-country flight that departed Livermore Municipal Airport (LVK), Livermore, California at approximately 1606. The flight was destined for Marana Regional Airport (AVQ), Marana, Arizona.

The pilot reported that he and four family members were en route to their home airport following a recent stay in Northern California. The departure, climb out, and most of the cruise flight was smooth and uneventful; however, further into the flight, at an altitude of 25,000 feet, the windshield “exploded” instantaneously without any pre-indication.

C. Details of the Investigation

1.0 Airplane Description

Registration Number:	N846PM
Airplane Serial Number:	EVO-0065
Airplane Manufacturer:	Evolution Air LLC
Model:	Lancair Evolution
Engine Manufacturer:	Pratt & Whitney
Model:	PT6A 125A
Airplane Year:	2016
Airworthiness Certificate:	Experimental
Approved Operations:	Normal
Aircraft Type:	Fixed Wing Single-Engine
Engine Type:	Turbo Prop
Airplane Category:	Experimental
Number of Engines:	1
Max. T/O Weight:	4,550 pounds
Total Time:	Unknown hours
Total Cycles:	Unknown
Type Certificate	N/A

2.0 Investigation

The windshield fractured into numerous pieces. Portions of the windshield that were common to the airframe remained encased in the window frame which is common to the airframe fuselage structure. Three pieces of the windshield along the lower edge of the windshield were easily removed from the window frame common to the airframe. Large portions of the windshield extending beyond the edge of the integral window frame from about the 4 to 6 o'clock and about 6 to 8 o'clock positions remained attached to the airframe. Additional sections of the windshield remained attached to the windshield frame common to the airframe but did not extend beyond the edge of the window frame cutout in the fuselage. The window frame common to the airplane fuselage at the 2, 6 and 10 o'clock positions had visible signs of damage to the composite airframe structure. (Figure 1)

Figure 1 – Windshield prior to removal.

The entire windshield frame common to the fuselage was removed including all the composite structure that the windshield is bonded to was removed for further investigation and associated windshield plexi-glass. The composite airframe window frame structure, windshield pieces and a small section forward were sent to Wichita State Universities National Institute of Aviation Research. The material characteristics of the composite fuselage structure, the adhesive used to bond the windshield to the composite airframe structure and the windshield will be documented, examined and destructively tested to determine the structural integrity of the individual components and the assembly.

The overall approach to the investigation consisted of four key phases. Results and findings are summarized in the following sections for each phase. These consisted of:

- Phase 1 – Receiving Inspection
- Phase 2 – Failure analysis
- Phase 3 – Material & Bond Evaluation
- Phase 4 – Aircraft Paint Evaluation

A limited amount of technical information was provided by the manufacturer to support the investigation. The required information necessary to support future work in determining a probable cause is provided in Section 2.

2.1 Phase 1 – Receiving Inspection

In-flight data from the flight data recorder (FDR) included the characteristics of the flight profile leading up to the in-flight failure of the windshield. This was reviewed to fully understand the flight characteristics leading up to the windshield failure. FDR data indicated a rapid change in the flight characteristics as the aircraft reached an altitude of 25,998 ft (time stamp of 16:31:02). At this time, the aircraft began to descend and an increase in airspeed was witnessed. Leading up to this apparent time of failure, altitude was steadily increasing, although the rate of climb was reduced significantly as the aircraft approached 25,700 ft (Figure 2).

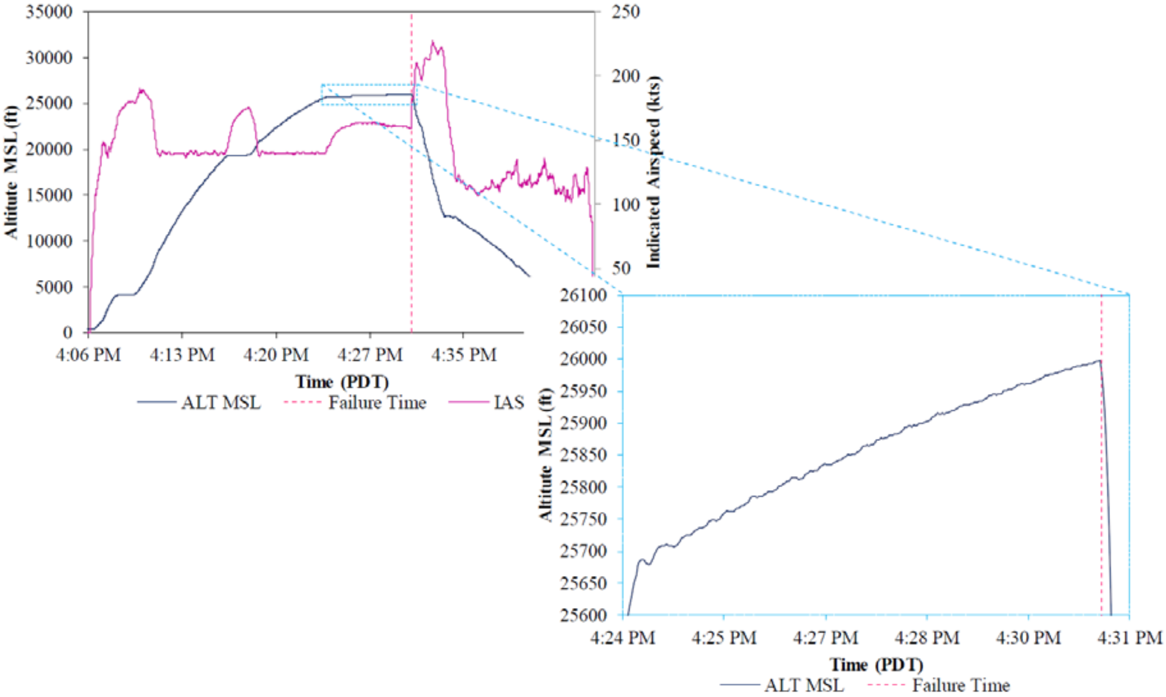


Figure 2 – Altitude (MSL) vs. Time

At the apparent time of the windshield failure, the outside air temperature was recorded as approximately -30°F (-34°C). The airframe was exposed to this constant temperature for approximately 6 minutes leading up to the apparent time of failure (Figure 3). At the apparent time of failure, outside air temperature data was lost for approximately 5 seconds.

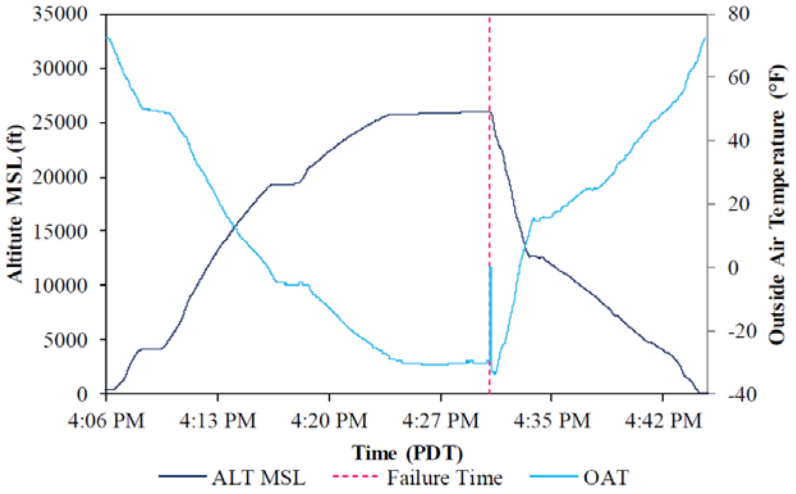


Figure 3 - Altitude (MSL)/Outside Air Temperature vs. Time

Initial examination of the windshield revealed most of the windshield was missing. A total of 12 windshield artifacts were recovered from the event. This included artifacts that were fully separated from the aircraft windshield frame and some artifacts that were easily removed from inside the windshield frame (debonded). Large sections of the windshield that remained in the frame as shown in Figure 3.

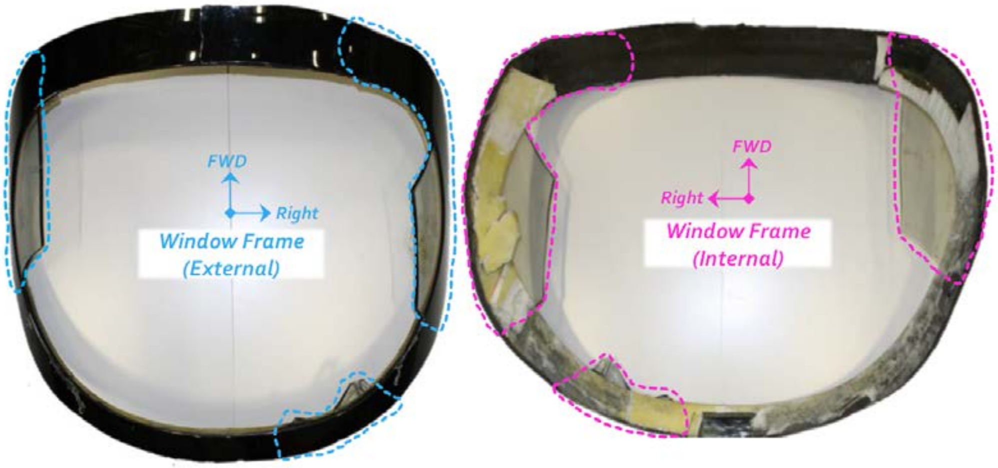


Figure 4 - Windshield Frame Receiving Inspection

The two large sections of windshield shown in Figure 4 were firmly intact with the windshield frame and could not be removed. Although this was the case, gaps witnessed from a visual inspection between the windshield and the frame indicated the remaining portions are not fully bonded in place. The remaining large intact sections of the windshield were documented using a 3-D scanner so that their specific size and location were understood (Figure 5). Furthermore, the location for each windshield artifact was determined, and the fracture surfaces were documented. This created the opportunity to compare the fracture pattern with stress analysis to supplement proposed failure scenarios.

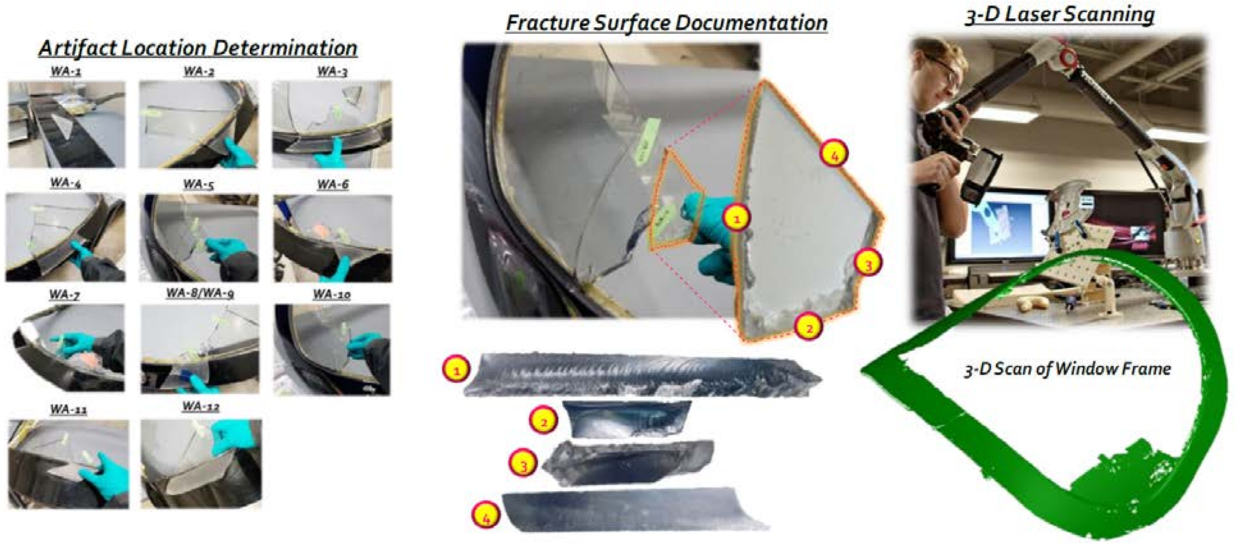


Figure 5 - Documentation of Windshield Frame & Artifacts

2.2 Phase 2 – Failure Analysis

A total of 10 out of the 12 windshield artifacts recovered contained a region that was previously bonded to the windshield frame prior the failure event. All the recovered artifacts showed no visible presence of adhesive on the windshield bond surfaces consistent with an adhesive failure between the windshield and the windshield frame (Figure 6).

Figure 6 - Windshield Artifacts

Paint cracking was observed both forward and aft of the windshield frame (Figure 7 & Figure 8). The paint cracking observed forward of the windshield frame extended from the windshield frame to the firewall. This occurred near the center of the fuselage where the left and right fuselage halves are joined. A section cut revealed the paint cracking occurred over the sharp transition near the edge of the ramped sandwich construction (circled in Figure 7). A failure through the thickness of the windshield frame was observed at point A as shown in Figure 7.

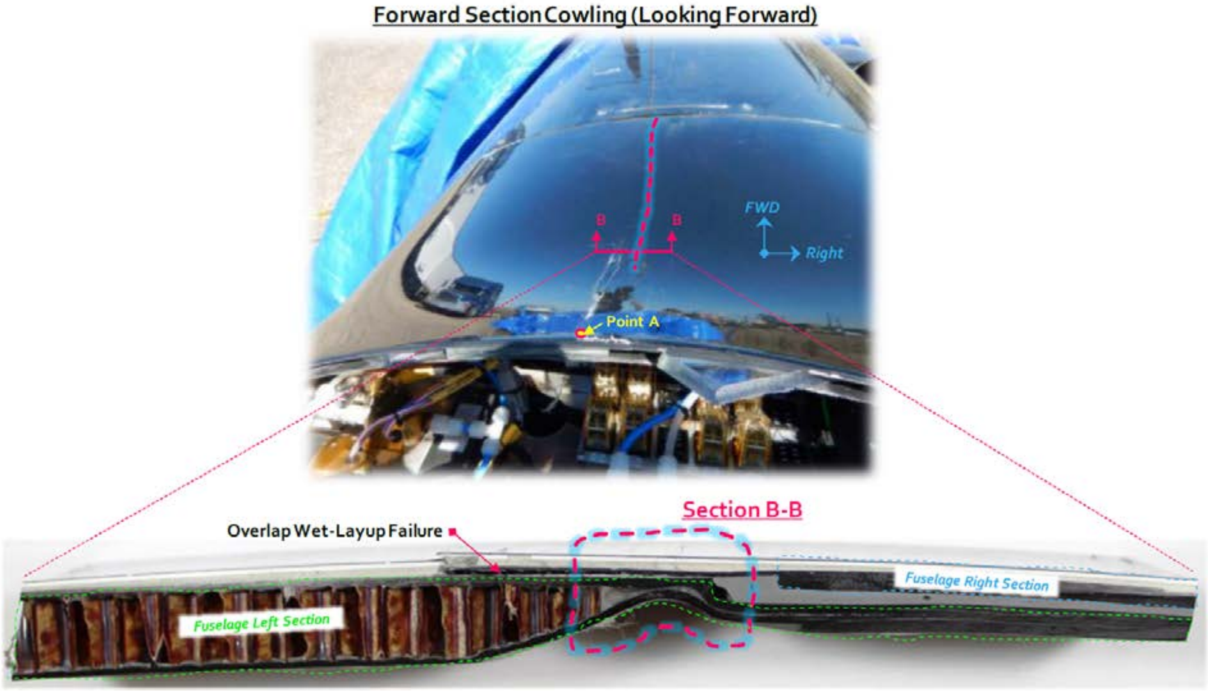

Forward Section Cowling (Looking Forward)

Figure 7 - Forward cowling paint cracking

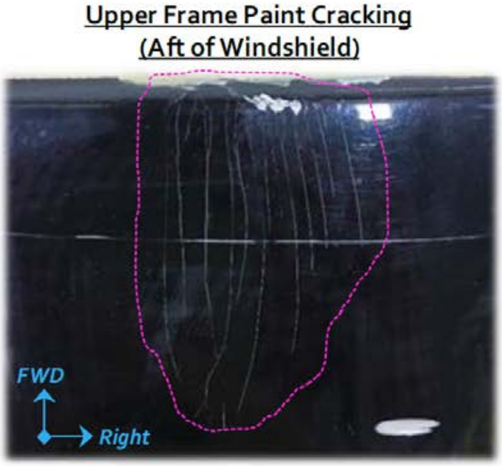

Upper Frame Paint Cracking
(Aft of Windshield)

Figure 8 - Windshield frame aft of windshield

To the left there was paint cracking that extended to the firewall, the extensive cracking directly in front of the windshield was coincident with the delamination of the wet-layup plies that were applied to the fuselage after the two fuselage halves are joined together. The application of these plies in the manufacturing process is shown in Figure 9. These findings are consistent with significant structural flexing of the fuselage.

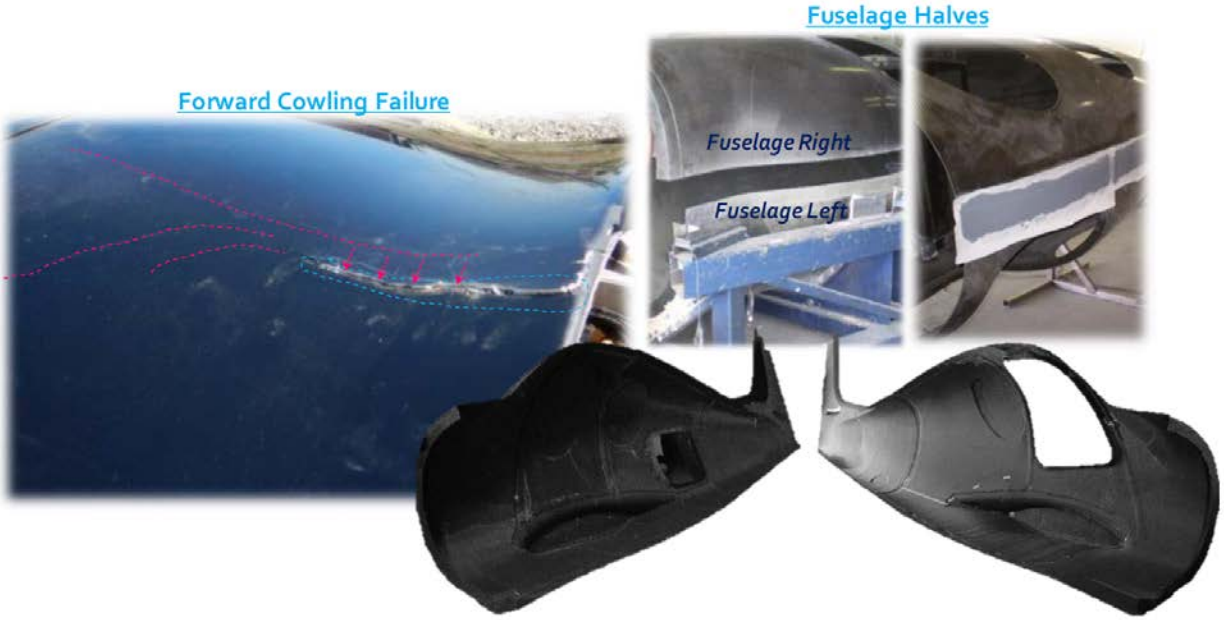


Figure 9 - Overlap failure characteristics

2.3 Phase 3 – Material Bond Evaluation

Aircraft airframe temperatures can reach high levels while parked on the ground when exposed to solar radiation and adverse ambient conditions. This largely depends on the ambient environment (temperature, solar radiation, and wind velocity) and the airframe construction (type of material, material thickness and geometry, and coating) [1]. Airframes with coatings that promote the absorption of solar energy (dark colors), can reach temperatures outside of the intended operational temperature. Therefore, the glass transition temperatures were evaluated for all materials near the failure region.

Thermal analysis was done to evaluate the glass transition temperature (Tg) of the composite windshield frame, acrylic windshield, and paste adhesive used for bonding the windshield to the frame. Tg values were acquired to determine if any of the constituent materials could have been subjected to temperatures above the Tg in operation. When extracting windshield frame samples for testing, the bond surfaces were evaluated prior to the removal of the adhesive for testing. Bond thickness variation was noticed on multiple samples, like the variation witnessed in the bond procure documentation photos (Figure 10). Adhesive surfaces were also noted to be very smooth.

Dynamic Mechanical Analysis (DMA) test results for the windshield frame and windshield material were compared to the Differential Scanning Calorimetry (DSC) test results for the paste adhesive in Figure 11. DSC testing was used to determine the Tg of the paste adhesive as limited material was available. The average lowest Tg of 192°F was witnessed for the paste adhesive. As expected, this was the lowest Tg within the evaluated materials.

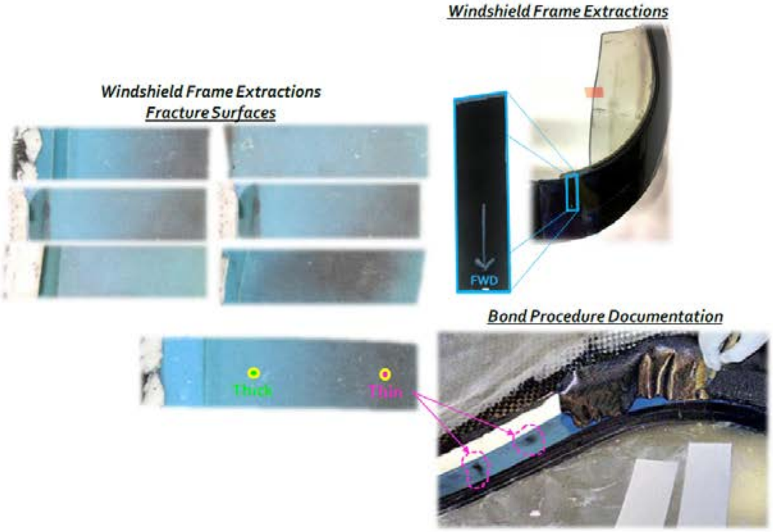


Figure 10 - Windshield frame bondline thickness variation

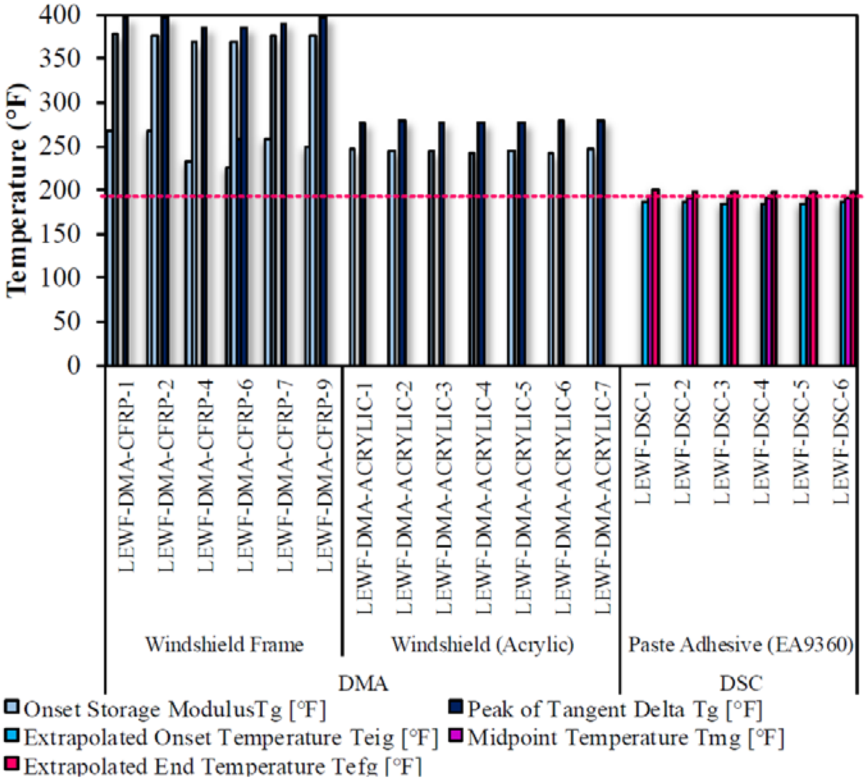


Figure 11 - Tg comparison

At the apparent time of the windshield failure, the outside air temperature was recorded as approximately -30°F (-34°C), which had been constant for up to 6 minutes before the failure and the outside air temperature had been under 0°F (≈-18°C) for approximately 15 minutes prior to the failure. Considering only the outside air temperature, this indicates the windshield frame material was not beyond the Tg at the time of failure due to the extended period the airframe was subjected to low temperatures [2].

2.4 Phase 4 – Paint Evaluation

Airframes with coatings that promote the absorption of solar energy (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 of the majority of the airframe and the region of the home airport and indicated in Figure 12.

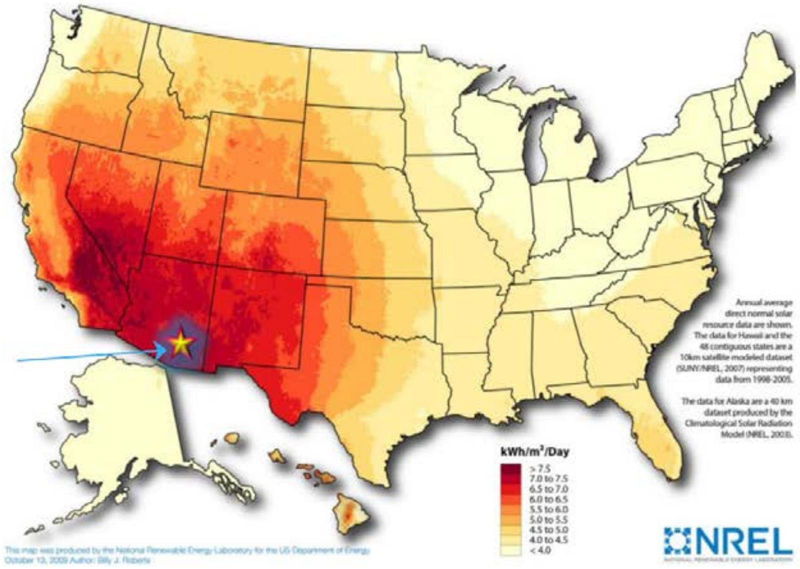
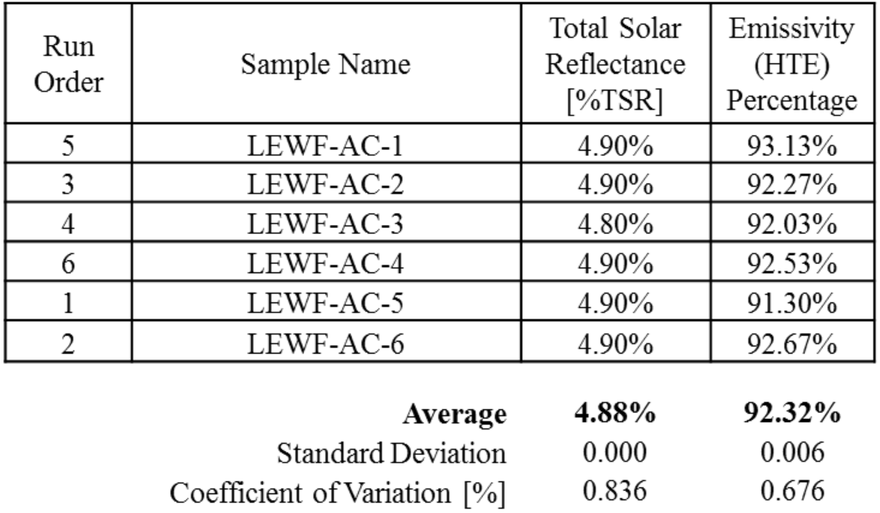


Figure 12 - Solar Resource Distribution for United States [3]

At discrete locations around the window frame, 6 small composite coupons (≈ 1.5-inches x 1.5- inches in length and width) were extracted for evaluating the total solar reflectance (TSR – ASTM C1549 [4]) and emittance (ASTM E408 [5]) values associated with the aircraft coating used. TSR (Ultraviolet-Visual-Near Infrared) and emissivity values are shown in Table 1. The TSR values recorded for these samples suggests a low amount of reflectance for aircraft coating applications.

Table 1 - %TSR and Emissivity Results



Run Order	Sample Name	Total Solar Reflectance [%TSR]	Emissivity (HTE) Percentage
5	LEWF-AC-1	4.90%	93.13%
3	LEWF-AC-2	4.90%	92.27%
4	LEWF-AC-3	4.80%	92.03%
6	LEWF-AC-4	4.90%	92.53%
1	LEWF-AC-5	4.90%	91.30%
2	LEWF-AC-6	4.90%	92.67%

Average	**4.88%**	**92.32%**
Standard Deviation	0.000	0.006
Coefficient of Variation [%]	0.836	0.676

Average thicknesses for the paint, primer, and surfacing materials are provide in Figure 13. Averages were derived over a series of 6 extractions at varying locations around the window frame. A high overall thickness was observed.

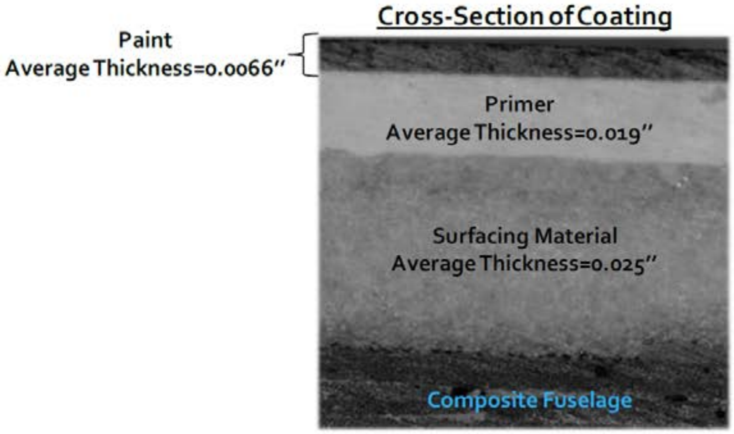


Figure 13 - Coating thickness

References

1. Miller, S. L., Waltner, J., Mazmudar, T., Merchant, M., Tomblin, J., "Thermod Composite Airframe Temperature Prediction Tool Evaluation, Validation, and Enhancement with Initial Steady-State Temperature Data," FAA report DOT/FAA/AR-04/30, September 2004.
2. Miller, S. L., "Impact of Aircraft Operation on Composite Airframe Temperatures," AGATE report AGATE-WP3.3-033051-112, October 2001.
3. Roberts, B., "U.S. State Solar Resource Maps". National Renewable Energy Laboratory, October 13, 2009

4. ASTM Standard C1549, 2016, “Standard Test Method for Determination of Solar Reflectance Near Ambient Temperature Using a Portable Solar Reflectometer,” ASTM International, West Conshohocken, PA, DOI: 10.1520/C1549-16.
5. ASTM Standard E408, 2013, “Standard Test Method for Total Normal Emittance of Surfaces Using Inspection-Meter Techniques,” ASTM International, West Conshohocken, PA, DOI: 10.1520/E0408.

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