Aviation Investigation Final Report

Location:	Daytona Beach, Florida	**Accident Number:**	ERA18FA120
Date & Time:	April 4, 2018, 09:53 Local	**Registration:**	N106ER
Aircraft:	Piper PA28R	**Aircraft Damage:**	Destroyed
Defining Event:	Aircraft structural failure	**Injuries:**	2 Fatal
Flight Conducted Under:	Part 91: General aviation - Instructional		

Analysis

An airline transport pilot and a private pilot were performing commercial pilot checkride maneuvers, which included a touch-and-go landing. After the landing and during the climb, the airplane's left wing separated near the wing root and the airplane collided with terrain. The airplane's radar-derived ascent and heading profile following the touch-and-go maneuver was consistent with the airplane maneuvering in a manner that wouldn't reasonably be expected to produce airframe loading that would result in an in-flight structural failure. The airplane was operating under the maximum allowable gross weight and within its center-of-gravity limits at the time of the accident. According to automatic-dependent surveillance broadcast data, the airplane's radar target was last recorded at an altitude of 900 ft mean sea level (msl) and a groundspeed of 80 knots. Witnesses within 1/4 mile of the accident site reported that the airplane climbed "normally" on a westerly heading when they saw the wing separate from the fuselage.

Metallurgical examination of the accident airplane's left-wing main spar lower cap found that it exhibited fracture features consistent with fatigue through more than 90% of the cross-section, reducing its residual strength capabilities almost completely. The examination identified three fatigue cracks in the left-wing main spar lower cap (see figure 1). One fatigue crack initiated near the lower forward corner of the outboard forward wing attachment bolt hole (designated as bolt hole LC-1) and propagated forward to the forward edge of the cap. A second fatigue crack initiated near the lower aft corner of bolt hole LC-1 and propagated aft toward the lower aft wing attachment bolt hole (designated as bolt hole LD-1) and up the cap web almost to the edges. A third fatigue crack initiated near the lower aft corner of bolt hole LD-1 and propagated aft almost to the aft edge of the cap. Fatigue cracks also originated in the forward and aft doublers from both sides of the bolt holes (see figure 2).

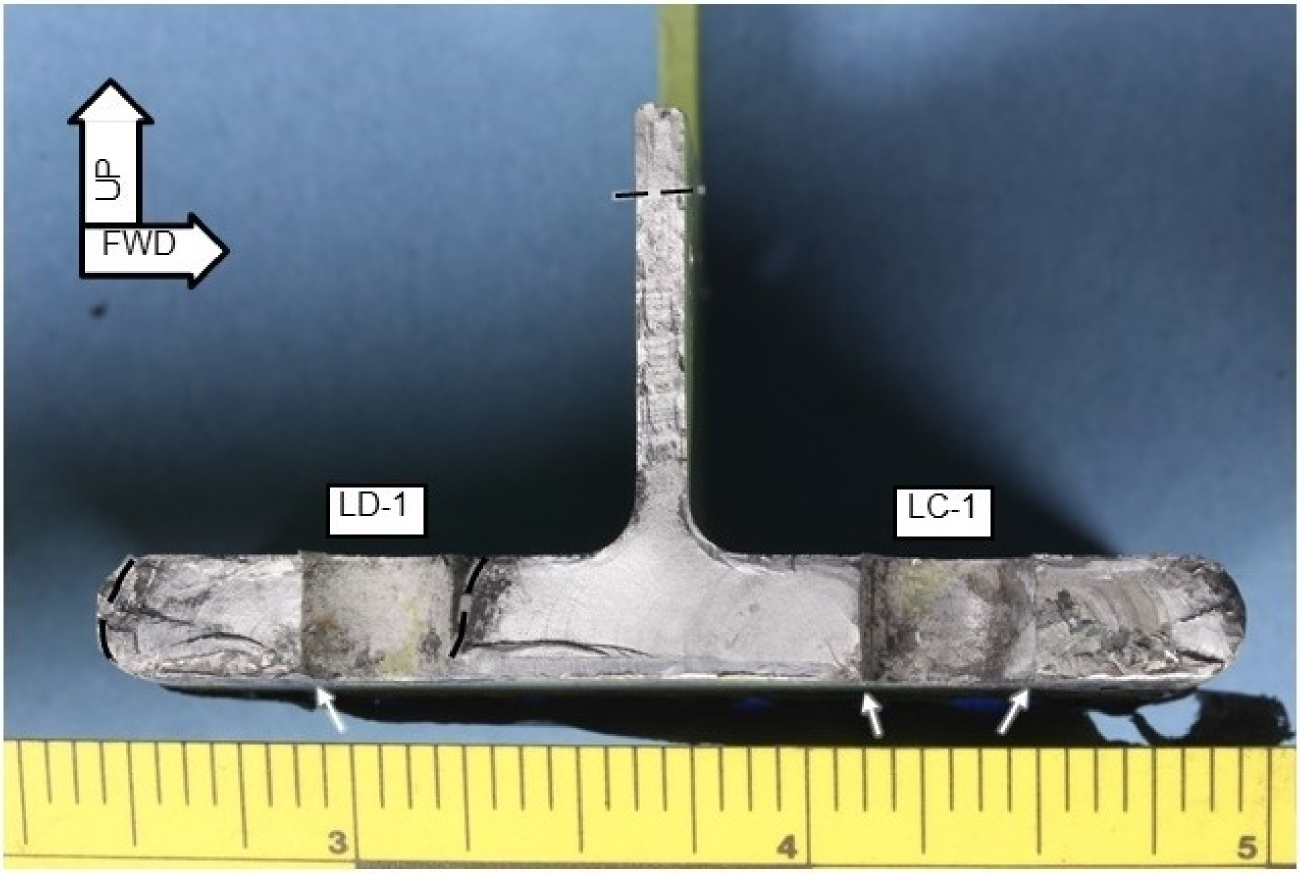


Figure 1. Close view of the fracture surfaces in the left-wing main spar lower cap. Unlabeled arrows indicate fatigue origin areas and dashed lines indicate approximate fatigue boundaries

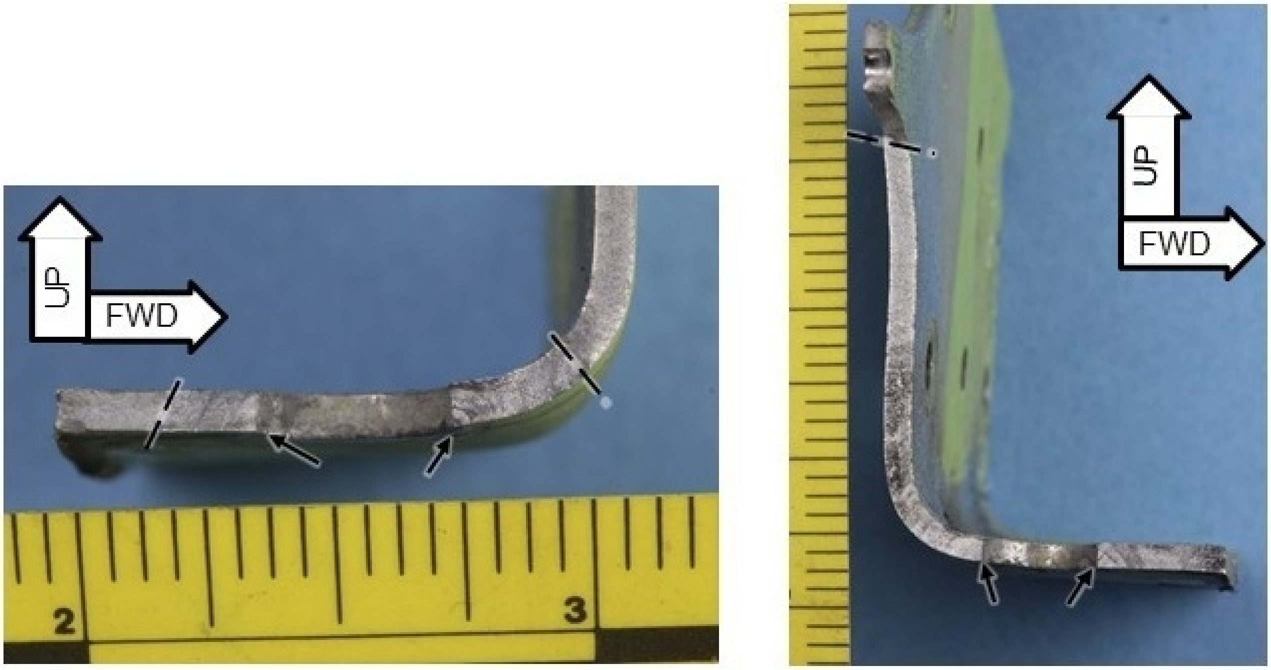


Figure 2. Close views of the fracture surfaces in the aft (left) and forward (right) doublers. Unlabeled arrows indicate fatigue origin areas and dashed lines indicate approximate fatigue boundaries

A small fatigue crack was also identified in the accident airplane's right-wing main spar lower cap; however, that crack had not progressed to the point of failure. Examination of the left-wing main spar of another Piper PA-28R-201 owned and operated by the same operator as the accident airplane; manufactured in the same year with a serial number two previous to the accident airplane; and with similar hours, cycles, and operational exposure found a similar fatigue crack that initiated near the lower forward corner of hole LC-1.

The accident airplane was manufactured about 10 years before the accident and had been used solely for flight instructor and commercial pilot training by the flight school operator. The airplane had accumulated 7,690.6 hours and 33,276 landing cycles before the accident flight, which equates to 4.33 landing cycles per hour of flight time. According to operator personnel, the commercial flight lesson times averaged 1.4 to 1.8 hours; most of that time the airplane was being operated in the airport traffic pattern, performing takeoffs, landings, and power-off 180º maneuvers. While in the airport traffic pattern, the airplane operated between 1,000 ft agl and ground level. On longer flights, necessitating the need to operate in the practice area, maneuvering typically took place between 2,500 and 3,000 ft msl before returning to the airport.

A review of the operator's airframe discrepancy log for the life of the airplane and flight crew safety reporting system for the 24 months preceding the accident found some reported flap extension overspeed, gear extension overspeed, and hard landing events. In each case, the events resulted in airframe examinations during which no defects were noted by maintenance personnel. Interviews with flight instructors did not yield any safety of flight issues or critical airframe or loading exceedances caused by pilot operation that would be expected to precipitate cracking.

The operator's maintenance program alternated between 50-hour and annual inspections that included airframe manufacturer-recommended inspection items. The annual inspection detailed in the airframe manufacturer's maintenance manual includes a specific line item to inspect the wing attachment bolts and brackets that was included in the operator's inspection. There were no specific instructions from the airplane manufacturer or additional steps from the operator for a detailed inspection of the wing main spar lower caps in the area where the fracture occurred. A review of the maintenance logbook for the entire life of the airplane found no indications of airplane damage, major repairs, or significant nonstandard maintenance concerning the wing structure.

About 31 years before this flight training accident, in response to a pipeline patrol accident in which the left wing separated from a PA-28-181 airplane, the airframe manufacturer issued Service Bulletin (SB) 886 recommending a visual and dye penetrant inspection of the wing main spar on certain PA-28, PA-28R, and PA-32 model airplanes. The initial and recurrent inspection intervals recommended by the SB were calculated based on an accounting of the affected airplanes' lifetime usage, which the SB categorized into four usage classes: normal, severe, extreme, and unknown. Based on the SB criteria for the normal usage class, which included normal flight training operations, the accident airplane was not due for an initial inspection for another 23,000 flight hours (the SB recommended an initial inspection of the wing main spar at 30,600 hours).

Considering the absence of anomalies in materials or construction of the examined wing spars from N106ER and N104ER, the disparity between the failure time of the accident wing spar and the inspection threshold time in the SB likely derives from the differences between normal usage (as analyzed after the pipeline patrol accident that prompted the SB) and the actual flight training usage experienced by the accident airplane. The Piper PA-28R-201 and other similar airplanes were type certificated under Part 3 of the Civil Air Regulations, which only required that design details avoid stress concentrations; thus, this airplane model and others similar to it was not subject to the more robust fatigue analysis requirements under Title 14 *Code of Federal Regulations* (*CFR*) Part 23. In 2005, the FAA published Advisory Circular (AC) 23-13A with information and guidance for performing fatigue, fail-safe, and damage tolerance evaluations of metallic airplane structures developed under Part 23 regulations.

AC 23-13A provides flight and ground load information for various types of flight operations. AC 23-13A includes detailed information on the flight gust and maneuver loads, load factors for taxi movements, and landing sink rate data that can be used to determine flight and ground loads for the various types of operations for single-engine airplanes. These flight and ground loads drive the aging and fatigue of metallic airplane structures. The NTSB's investigation referenced this information to evaluate the flight and ground loads that the accident airplane was likely exposed to over its operational life in the flight training environment. This evaluation found that the maneuver loads experienced by the accident airplane were likely similar to the maneuver loads for basic instruction published in AC 23-13A, which are slightly higher than for personal use. The gust loads in the accident airplane flight training environment could also be higher than in the personal use environment (in the personal use environment airplanes are typically operated at higher altitudes, and gust loads are generally more severe and frequent at lower altitudes for any given airspeed). However, the gust loads for basic instruction are presented as identical to personal use in AC 23-13A. Loads associated with taxi movements for the accident airplane were likely similar to those of other operations other than agricultural application as shown in AC 23-13A. Landing impact loads for the accident airplane were likely higher and more frequent than other types of operations. Sink rates for basic instruction use as published in AC 23-13A are higher than that of other uses including the pipeline survey use and normal use analyzed for SB 886, and higher sink rates correspond to higher landing impact loads.

The NTSB concludes that, due to flight training maneuvers, significant operation at low altitudes, and frequent landing cycles, the accident airplane (and its sister airplane in the operator's fleet) likely experienced landing, gust, and maneuver loads that were more severe than expected for training aircraft when SB 886 was developed. Therefore, the low-altitude flight training and frequent landing environment likely resulted in the accident airplane accumulating damaging stress cycles at a faster rate than a personal use airplane.

After the accident, 16 airplanes from 4 flight schools (including ERAU) were examined using eddy-current inspection of the outboard attachment holes. Times in service ranged from 2,777.5 to 10,301.5 hours, and estimated landing cycles ranged from 8,841 to 39,000 cycles. Among the inspected airplanes, a crack was found in one wing of ERAU airplane N104ER, which had a time in service of 7,660.7 hours and 33,288 landing cycles. No additional cracks were detected in the remaining airplanes, including four airplanes with higher estimated landing cycles. However, due to the limited sample size and the expected variability in fatigue crack initiation times, the absence of detected cracks in airplanes with more cycles and/or hours than N106ER and 104ER does not eliminate the risk of fatigue cracking due to loads associated with a more severe training environment.

The location of the fatigue cracking observed on the accident airplane's left-wing main spar lower cap would have prevented visible detection from the interior or exterior of the airplane. Evidence of the presence of a crack would only have been visible after cracking had begun in the doubler and grown past the bolt head to a significant length. The only reliable method to detect the fatigue cracking in the wing main spar, as installed, would have been a nondestructive inspection procedure, such as a high frequency eddy current bolt hole inspection. The FAA issued a notice of proposed rulemaking 8 months after the accident proposing to require such an inspection for all Piper PA-28 series airplanes, except the PA-28-201T and PA-28-236 model airplanes; all Piper PA-28R model airplanes; and all Piper PA-32-260 and PA-32-300 model airplanes. In the NTSB's February 15, 2019, comments to the FAA, we expressed our support of the proposed AD's inspection requirements but urged the FAA to reexamine the proposed AD's applicability to certain airplanes based on airplane usage. As of the date of this report, the FAA has not published an AD for inspection of the accident airplane type and other similar types, especially those operated in the flight training environment.

Probable Cause and Findings

The National Transportation Safety Board determines the probable cause(s) of this accident to be:
Extensive fatigue cracking in the left-wing main spar lower cap and doublers, which resulted in the in-flight separation of the left wing. The fatigue cracks initiated and grew to a critical size due to flight and ground loads associated with flight-training involving flight-training maneuvers, significant operation at low altitudes and frequent landing cycles. Previously established inspection criteria were insufficient to detect the fatigue crack before it grew to a critical size.

Findings

Aircraft	Spar (on wing) - Fatigue/wear/corrosion
Aircraft	Spar (on wing) - Failure
Aircraft	Spar (on wing) - Capability exceeded
Aircraft	Spar (on wing) - Inadequate inspection

Factual Information

History of Flight

Initial climb	Aircraft structural failure (Defining event)
Uncontrolled descent	Aircraft structural failure

On April 4, 2018, about 0953 eastern daylight time, a Piper PA-28R-201, N106ER, collided with terrain following an in-flight separation of the left wing near the wing root during climb after a touch-and-go maneuver at Daytona Beach International Airport (DAB), Daytona Beach, Florida. The airline transport pilot and private pilot were fatally injured, and the airplane was destroyed. The airplane was registered to and operated by Embry-Riddle Aeronautical University (ERAU) under the provisions of Title 14 *Code of Federal Regulations* (*CFR*) Part 91 as an instructional flight. Day visual meteorological conditions prevailed at the time of the accident, and no flight plan was filed for the local flight.

The private pilot was conducting a practical test to obtain a commercial pilot certificate with an airplane single-engine land rating, and the airline transport pilot was acting as a designated pilot examiner (DPE). Radar and voice communication data provided by the Federal Aviation Administration (FAA) and automatic-dependent surveillance broadcast (ADS-B) data provided by the operator revealed that the private pilot began the training flight by departing runway 25L about 0927. The airplane then turned southbound and climbed to about 3,000 ft mean sea level (msl) at a groundspeed of 100 knots. The airplane flew about 14 miles to the south of DAB, and several climbing and descending turns occurred between 1,300 and 3,000 ft. About 0940 the airplane leveled off at an altitude about 2,200 ft and airspeed of 112 knots on an easterly ground track before turning northbound toward DAB.

The airplane tracked parallel to the coastline about 5 miles inland at 2,200 ft and 115 knots before descending gradually to enter the DAB traffic pattern. About 0940, the private pilot contacted the DAB south arrival radar controller and advised he was inbound to DAB for "closed traffic" (that is, he stated his intention to perform successive operations in the airport traffic pattern) and had automatic terminal information service "Yankee." The controller issued a transponder squawk code, which the private pilot acknowledged.

About 1 minute later, the controller informed the pilot that the airplane was in radar contact and assigned the pilot the ROSE 25 arrival. (The ROSE 25 arrival is used by local aircraft inbound to DAB from the south.) At 0945:00, the pilot advised the DAB tower controller that he was on the ROSE 25 arrival. The DAB tower controller instructed the pilot to follow a Cessna Skyhawk and to maintain 1,500 ft, which the pilot acknowledged. About 0947, the tower controller cleared the pilot to descend to the traffic pattern altitude and join the downwind leg while continuing to follow the Cessna.

About 0948, the DAB tower controller cleared the pilot to land on runway 25, which the pilot acknowledged, stating "we're uh cleared for uh closed traffic." The DAB tower controller responded that the pilot was "cleared for the option"—that is, at the pilot's discretion— which the pilot acknowledged. The pilot subsequently performed a touch-and-go maneuver on runway 25.

During the airplane's initial climb after the touch-and-go maneuver, the DAB tower controller advised the pilot at 0951:44 to continue upwind until advised when to turn crosswind. At 0952:28, the controller instructed the pilot to squawk one two zero four, which the pilot read back. At 0952:47, the pilot asked the DAB tower controller, "…can we turn crosswind." The controller replied, ",,,negative, continue upwind," which was not acknowledged. There were no further communications from the accident airplane. According to ADS-B data, the airplane's radar target was lost about 0953; it was last recorded about 2 miles beyond the departure end of runway 25L at an altitude of 900 ft and a groundspeed of 80 knots.

Witnesses within 1/4 mile of the accident site reported the airplane climbed "normally" on a westerly heading when they saw a wing separate from the fuselage. The wing appeared to "float" down and the airplane descended in a steep spiral before it impacted a field.

Flight instructor Information

Certificate:	Airline transport; Flight instructor	**Age:**	61,Male
Airplane Rating(s):	Single-engine land; Multi-engine land	**Seat Occupied:**	Right
Other Aircraft Rating(s):	None	**Restraint Used:**	3-point
Instrument Rating(s):	Airplane	**Second Pilot Present:**	Yes
Instructor Rating(s):	Airplane multi-engine; Airplane single-engine; Instrument airplane	**Toxicology Performed:**	Yes
Medical Certification:	Class 2 With waivers/limitations	**Last FAA Medical Exam:**	April 5, 2017
Occupational Pilot:	Yes	**Last Flight Review or Equivalent:**	
Flight Time:	(Estimated) 27600 hours (Total, all aircraft)		

Pilot Information

Certificate:	Private	**Age:**	25,Male
Airplane Rating(s):	Single-engine land	**Seat Occupied:**	Left
Other Aircraft Rating(s):	None	**Restraint Used:**	3-point
Instrument Rating(s):	Airplane	**Second Pilot Present:**	Yes
Instructor Rating(s):	None	**Toxicology Performed:**	Yes
Medical Certification:	Class 2 Without waivers/limitations	**Last FAA Medical Exam:**	June 17, 2016
Occupational Pilot:	No	**Last Flight Review or Equivalent:**	August 31, 2017
Flight Time:	218.1 hours (Total, all aircraft), 26.7 hours (Total, this make and model), 115 hours (Pilot In Command, all aircraft), 26.5 hours (Last 90 days, all aircraft), 7 hours (Last 30 days, all aircraft), 0 hours (Last 24 hours, all aircraft)		

The pilot, age 25, held a private pilot certificate with ratings for airplane single-engine land and instrument airplane. He was issued an FAA second-class airman medical certificate on June 17, 2016, with no limitations. Review of the pilot's logbook revealed that he had accrued 218.2 total hours of flight experience of which 26 hours were in the accident airplane make and model.

According to FAA records, the DPE, age 61, held an airline transport pilot certificate with ratings for airplane-single engine land and airplane multiengine land. He held a flight instructor certificate with ratings for airplane single-engine, airplane multiengine, and instrument airplane. The DPE was issued an FAA second-class medical certificate on April 5, 2017. He reported 27,600 hours total hours of flight experience of which 400 hours were flown during the 6 months before receiving the medical certificate. The DPE's logbooks were not recovered.

Aircraft and Owner/Operator Information

Aircraft Make:	Piper	**Registration:**	N106ER
Model/Series:	PA28R 201	**Aircraft Category:**	Airplane
Year of Manufacture:	2007	**Amateur Built:**	
Airworthiness Certificate:	Normal	**Serial Number:**	2844137
Landing Gear Type:	Retractable - Tricycle	**Seats:**	4
Date/Type of Last Inspection:	March 21, 2018 Annual	**Certified Max Gross Wt.:**	2750 lbs
Time Since Last Inspection:	28 Hrs	**Engines:**	1 Reciprocating
Airframe Total Time:	7662.3 Hrs as of last inspection	**Engine Manufacturer:**	Lycoming
ELT:	C91 installed, not activated	**Engine Model/Series:**	IO-360-C1C6
Registered Owner:	Embry-Riddle Aeronautical University	**Rated Power:**	200 Horsepower
Operator:	Embry-Riddle Aeronautical University	**Operating Certificate(s) Held:**	Pilot school (141)

The PA-28R-201 airplane, commonly referred to as the "Arrow," has been widely used by flight schools for complex airplane (meaning an airplane that has a retractable landing gear, flaps, and a controllable pitch propeller) flight training. According to FAA airworthiness and operator records, the accident airplane (serial number 2844137) was manufactured on September 17, 2007, and was issued a standard airworthiness certificate in the normal category. It was a single-engine, low-wing, four-place airplane equipped with a 200-horsepower, Lycoming IO-360-C1C6 four-cylinder engine that drove a McCauley two-blade, constant-speed propeller.

ERAU purchased the airplane new (with 5.8 hours accrued) from Piper on September 25, 2007, and subsequently sold it to a leasing company, AVN Air, LLC, on September 28, 2007. ERAU leased the airplane from AVN until September 4, 2015, when it purchased the airplane back from the lessor. The airplane registration number was changed from N712ER to N106ER on July 10, 2014. ERAU was the only operator for the entire operational life of the airplane, which had only been used for flight instructor and commercial pilot training and was never used for initial flight training.

The airframe had accumulated 7,690.6 hours of operation before the accident flight, and 28.3 hours since its most recent annual inspection, which was completed on March 21, 2018. Before the accident flight, the total landing cycles were 33,276 based on ERAU information documented in its education and training administration program.

Maintenance

Examination of the airframe maintenance logbook for the life of the accident airplane found that the airframe was inspected every 50 hours alternating between the ERAU 50-hour and ERAU annual inspection. The accident airplane's most recent inspection was an annual inspection completed on March 22, 2018, at an airframe time of 7,662.3 hours. Between March 28 and April 3, 2018, 12 flight instructors operated the accident airplane, and none reported any anomalies or flight operational safety issues with the airplane. One instructor noted "some side load on one landing" in the discrepancy log. There were no reported hard landings during this period, and all maneuvers were reported as "normal."

The ERAU annual inspection contained all the provisions in the Piper recommended annual inspection with some items added by ERAU. According to chapter 5 of the Piper *Airplane Maintenance Manual* (AMM), the 100-hour inspection was a complete inspection of the airplane and was identical in scope to an annual inspection. The 100-hour inspection was divided into several major groups, including a wing group. Item 13 in the wing group stated, "inspect wing spar to fuselage attachment bolts and brackets" and indicated a recommended interval of 100 hours. According to ERAU, the accomplishment of this item involved removing the small plastic covers over the main spar attach bolts on the lower wing surface to ensure the torque striping on the nuts was not broken. The ERAU inspection would not normally look at the head of the bolts inside the center section even though the airplane interior would be removed from the airplane.

All inspection items for the annual inspection were endorsed by a mechanic and/or inspector, including the wing spar-to-fuselage attachment bolts and brackets. There were no discrepancies pertaining to the wing spars. Examination of an airworthiness directive (AD) compliance list for the airplane revealed that all applicable ADs were in compliance.

The most recent 50-hour inspection occurred on February 27, 2018, at an airframe time of 7,613.4 hours. All the items in the inspection list were endorsed by a mechanic. There were no discrepancies pertaining to the wing spars.

Procedures for a detailed inspection of the wing spars were included in section 57-10-00 of the AMM. The procedures defined airplane usage classes of normal, severe, extreme, and unknown. The normal usage class encompassed most aircraft and included airplanes operated in normal flight training operations, such as the accident airplane. The recommended inspection involved removing the wings from the airplane, visually inspecting the main spar lower caps with a 10-power magnifying glass and performing a dye-penetrant inspection of the spar caps. The special inspections section of the AMM (5-30-00) recommended for airplanes in the normal usage class that the wing spar inspection in 57-10-00 be performed beginning at 30,600 hours, and every 3,000 hours thereafter.

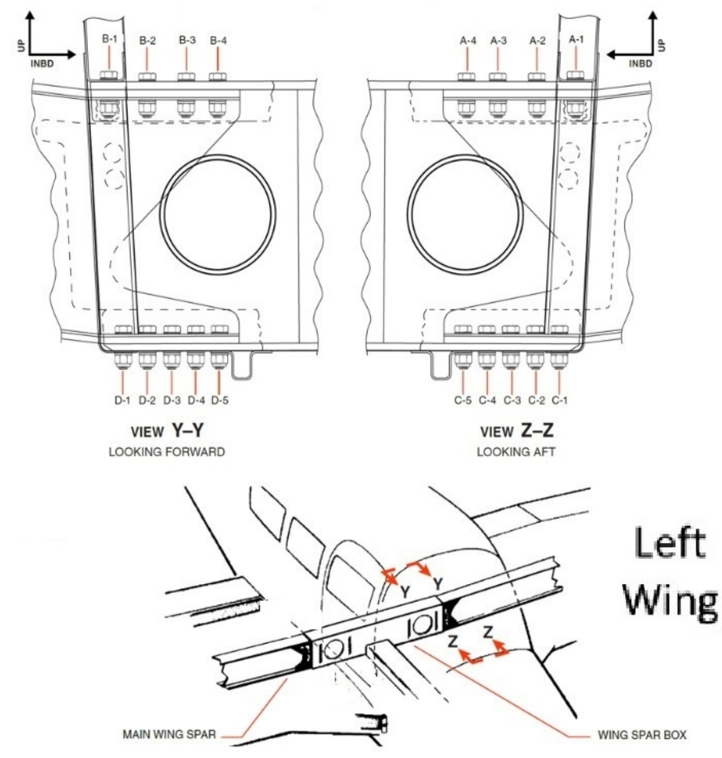
The accident airplane's airframe maintenance logbook indicated four entries for hard landing inspections, dated February 17, August 24, November 11, and November 14, 2011. These four dates corresponded with hard landing entries in the airplane's discrepancy log. The discrepancy log also indicated 14 additional hard landing events including five hard landing events in the 24 months preceding the accident. In each case, maintenance personnel conducted an inspection in accordance with chapter 5-50-00 of the AMM, section 3, which provides instructions for unscheduled maintenance checks.

For reported hard landings, these procedures included inspecting the landing gear, attach points, wheel wells, and fuel tank for damage, as well as internal and external inspections of the wings. These procedures also called for inspecting for popped, cracked, and loose rivets, the wing attach bolts for slippage, damage, and overstress, and the wing skin for wrinkles. Access plates should be removed to inspect for internal damage to ribs, stringers and sparwebs. For each of the hard landing reports, resulting maintenance action determined that no defects were noted with any of the inspection items.

A logbook entry dated July 15, 2014, stated that the airplane was stripped and repainted coincident with the registration change to N106ER. Logbook entries on March 31, 2015, and January 9, February 13, April 25, and July 11, 2017, detailed maintenance to replace rivet nuts, covers, or screws on the lower wing main spar bolt covers. No indications of airplane damage, major repairs, or other significant nonstandard maintenance were noted in the logbook.

Wing Main Spar

Each wing main spar on a Piper-28R-201 airplane is attached to the center wing box with 8 attachment bolts through the main spar upper cap and 10 through the main spar lower cap. As shown in figure 1, the locations on the lower spar cap forward of the spar web are identified as C-1 through C-5, and the locations on the main spar lower cap aft of the spar web are identified as D-1 through D-5 (later in this report, we use L [for the left wing] or R [for the right wing] in addition to the spar cap location identifiers where appropriate [for example, LC-1]). Doublers are riveted to the forward and aft sides of the spar at the attachment location and outboard beyond the bend in the spar that forms the wing dihedral. Flanges for the doublers extend over the main spar upper and lower caps at the forward side of the spar and over the lower cap at the aft side of the spar.



Courtesy of Piper Aircraft, Inc. Arrow Wing Installation Drawings

Figure 1. Diagram showing forward and aft side of wing main spars and associated attachment bolt designator map

Weight and Balance

The airplane was weighed after manufacture and had not been weighed since. The most recent calculated weight and balance report for the airplane listed an empty weight of 1,842.14 lb with a CG position at 86.28 inches. Airplane weight and balance computations and some performance data for the accident flight were recovered at the scene. The airplane's maximum gross takeoff weight (GTW) was indicated as 2,750 lb; the GTW, including occupants, baggage, and fuel, was indicated as 2,524.71 lb, which was 225.29 lb under maximum GTW and the CG was within limits at 86.94 inches.

Previous In-flight Wing Separations on Piper PA-28 Series Airplanes

On March 30, 1987, about 1257 central standard time, a Piper PA-28-181, N8191V, was destroyed when it collided with the ground following an in-flight left-wing separation while in low-level cruise flight near Marlin, Texas (NTSB case number FTW87FA088). The airplane was performing a pipeline patrol flight when the accident occurred. The investigation found fatigue cracking in the left-wing main spar lower cap near attachment bolt hole LC-1. The fatigue cracking initiated on the lower surface of the main spar lower cap and intersected the outboard edge of attachment bolt hole LC-1. The fatigue cracking had progressed from the hole forward through the forward flange and aft about halfway through the main spar lower cap.

On April 10, 1987, the NTSB issued Urgent Safety Recommendations A-87-40 through -42 to the FAA as a result of our preliminary evaluations from the investigation. The recommendations asked for an AD to immediately inspect the main spar lower caps on certain PA-28-series airplanes (A-87-40), a recurrent inspection interval (A-87-41), and a study to determine other Piper airplanes with a similar spar design (A-87-42). The recommendations were respectively classified Closed—Acceptable Action, Closed—Unacceptable Action, and Closed—Acceptable Alternate Action between November 1988 and October 1989. See FAA Actions in Response to Wing Separations in the Additional Information section for more information.

On August 24, 1993, at 2234 eastern daylight time, a Piper PA-28-181, N2093A, was destroyed when it collided with a vehicle and a tree following an in-flight right-wing separation while circling at low level near Provincetown, Massachusetts (NTSB case number NYC93FA140). The airplane was maneuvering in clouds after the non-instrument-rated pilot entered instrument meteorological conditions after takeoff. The investigation found fatigue cracking in the right-wing main spar lower cap near attachment bolt hole RC-1. The fatigue cracking initiated on the lower surface of the main spar lower cap slightly aft and outboard of the edge of hole RC-1 but did not intersect the hole. Several other cracks were noted in the lower surface of the spar cap parallel to the fatigue zone near both attachment bolt holes RC-1 and RD-1. The investigation also found that the nuts used on the wing attachment bolts were incorrect.

Meteorological Information and Flight Plan

Conditions at Accident Site:	Visual (VMC)	**Condition of Light:**	Day
Observation Facility, Elevation:	DAB,34 ft msl	**Distance from Accident Site:**	1 Nautical Miles
Observation Time:	09:53 Local	**Direction from Accident Site:**	
Lowest Cloud Condition:	Few / 25000 ft AGL	**Visibility**	10 miles
Lowest Ceiling:	None	**Visibility (RVR):**	
Wind Speed/Gusts:	7 knots / None	**Turbulence Type Forecast/Actual:**	/
Wind Direction:	260°	**Turbulence Severity Forecast/Actual:**	/
Altimeter Setting:	30.03 inches Hg	**Temperature/Dew Point:**	24°C / 19°C
Precipitation and Obscuration:	No Obscuration; No Precipitation		
Departure Point:	Daytona Beach, FL (DAB)	**Type of Flight Plan Filed:**	None
Destination:	Daytona Beach, FL (DAB)	**Type of Clearance:**	None
Departure Time:	09:27 Local	**Type of Airspace:**	Class C

About 0953, reported weather at DAB indicated wind from 260° at 7 knots, 10 statute miles (sm) visibility, and few clouds at 25,000 ft. The temperature was 24°C, the dew point was 19°C, and the altimeter setting was 30.03 inches of mercury. There were no current turbulence or in-flight weather advisories for the area.

Airport Information

Airport:	DAYTONA BEACH INTL DAB	**Runway Surface Type:**	Asphalt
Airport Elevation:	34 ft msl	**Runway Surface Condition:**	Dry
Runway Used:	25L	**IFR Approach:**	None
Runway Length/Width:	3195 ft / 100 ft	**VFR Approach/Landing:**	Touch and go

DAB is 3 miles southwest of Daytona Beach, Florida at 4.1 ft elevation. The airport has three intersecting runways: two parallel runways oriented east/west (7L/25R and 7R/25L), and one oriented north/south (16/34), which was not in use at the time of the accident. Runway 25L is 3,195 ft long,100 ft wide, and constructed of asphalt. Landing traffic for runway 25L operates in a left traffic pattern.

Wreckage and Impact Information

Crew Injuries:	2 Fatal	**Aircraft Damage:**	Destroyed
Passenger Injuries:		**Aircraft Fire:**	None
Ground Injuries:	N/A	**Aircraft Explosion:**	None
Total Injuries:	2 Fatal	**Latitude, Longitude:**	29.158611,-81.084999

The debris path was about 570 ft long and began about 2 sm southwest of the departure end of runway 25L. The first items discovered along the debris path were a rubber wing root seal and fractured window plexiglass; the left wing was discovered 270 ft farther southwest adjacent to a road and tree line. About 200 ft from the wing on a magnetic heading of about 230°, the main wreckage rested in an adjacent field on the opposite side of the road (see figure 2).

Figure 2. Photograph (looking toward the southwest) showing the separated left wing in foreground and main wreckage in background

The forward portion of the fuselage, including the engine, exhibited significant impact-related damage. A strong odor of fuel was present at the site, and a 30-ft-long swath of grass surrounding the wreckage was brown and discolored, which was consistent with the breached right fuel tank and subsequent spillage. The right wing remained attached to the fuselage. The right-wing leading-edge surface was crushed aft uniformly along the span of the wing, and a corresponding impression of the right-wing leading edge was observed in the ground. The flap and aileron of the right wing remained attached. The right landing gear was in the down and locked position.

The vertical stabilizer, rudder, horizontal stabilator, and trim tab control surfaces remained attached. Rudder control continuity was confirmed from the rudder to the rudder pedals. Elevator control cable continuity was established from the control column to the elevator control surface. Aileron control continuity was confirmed from the right aileron to the control column. Continuity of the left aileron control cables was traced from the control column through fracture features, which were consistent with tensile overload separation, to the aileron.

The left wing separated from the fuselage near the wing root and exhibited mid-span buckling of the surface skin. The left-wing flap and aileron remained connected and moved freely with little resistance. The left-wing fuel tank remained intact and contained about 15 gallons of fuel. The left main landing gear was in the down and locked position.

On-scene visual examination of the left-wing main spar found indications of a significant fatigue crack. Further analysis at the NTSB's Materials Laboratory found that more than 90% of the main spar lower cap and portions of the forward and aft spar web doublers exhibited fracture features consistent with metal fatigue (see figure 3). The remainder of the main spar lower cap, spar web doublers, and upper spar cap displayed fracture features consistent with overstress fracture. The fatigue features originated at or near the outboard forward wing main spar attachment bolt holes LC-1 and LD-1.

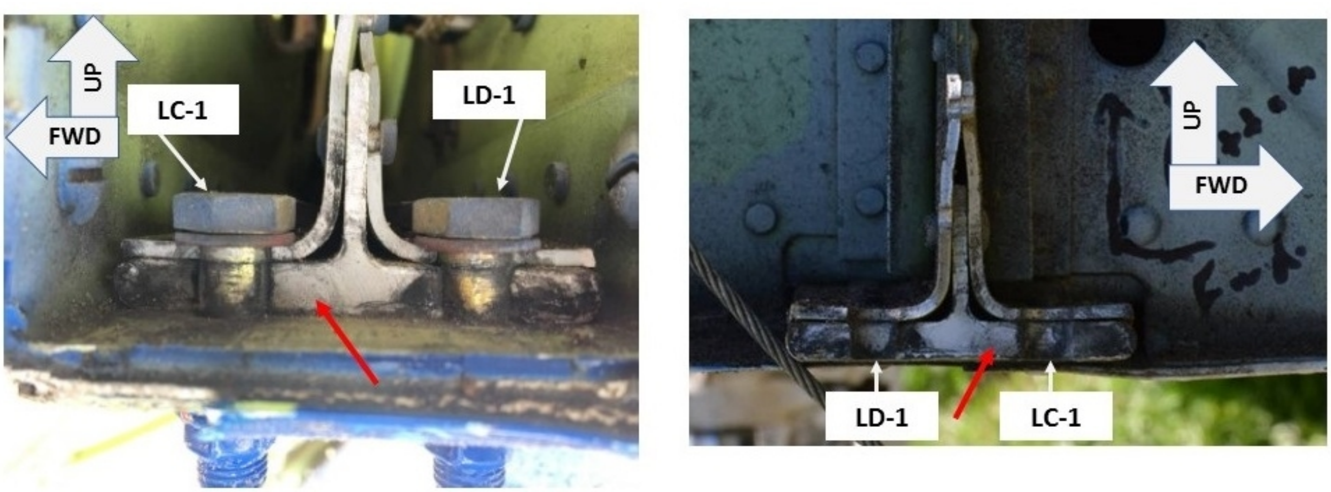


Figure 3. Left-wing main spar lower cap inboard side of the fracture (left frame) and outboard side of the fracture (right frame) with red arrows highlighting areas visually inspected on scene that showed fatigue regions

Medical and Pathological Information

The Office of the Medical Examiner, Daytona Beach, Florida, performed autopsies of the pilot and DPE and determined the cause of death for both to be multiple blunt force injuries.

The FAA Forensic Sciences Laboratory performed toxicological testing on the pilot and DPE; the tests yielded negative results for the presence of drugs and alcohol.

Tests and Research

N106ER Wing Main Spar Examinations

The left-wing main spar lower cap (shown in figure 4) had a fracture that intersected holes for attachment bolts LC-1 and LD-1. Portions of the fracture surface had relatively smooth features in a transverse plane, which is consistent with fatigue fracture. Crack arrest lines were visible on the fracture surfaces of the main spar lower cap and on the forward and aft doublers, also consistent with fatigue fracture. The upper spar cap displayed rough matte gray features consistent with ductile overstress fracture. Deformation associated with the fracture in the upper spar cap was observed, consistent with an upward bending load.

In the doublers, fatigue origins were noted on the lower sides of the doublers both forward and aft of the attachment holes. The fatigue region in the forward doubler was larger than in the aft doubler, extending to the forward edge of the doubler and upward about 1.25 inches from the aft side of the hole. In the aft doubler, the fatigue regions extended from each side of the hole to where they were about 0.88 inch apart.

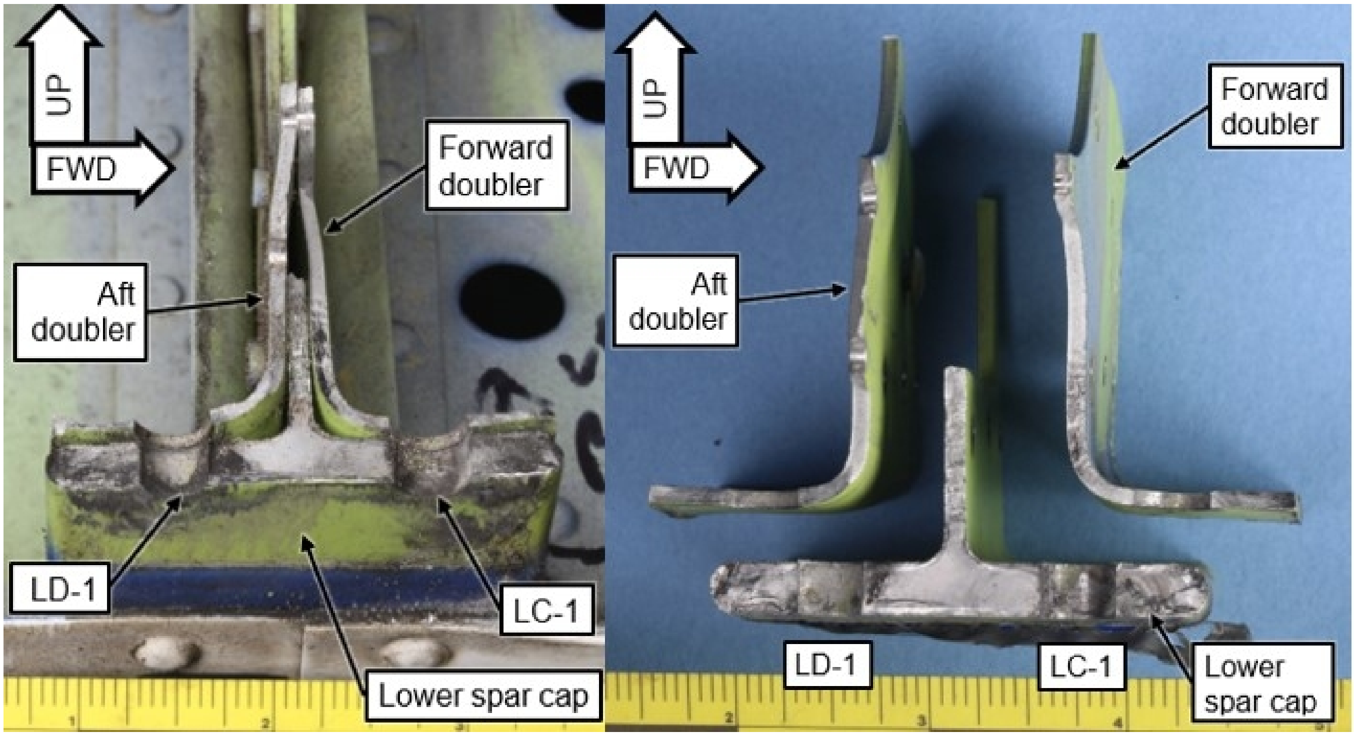


Figure 4. Photographs showing pieces of the accident left-wing main spar lower cap and doublers before (left) and after (right) sectioning and rivet removal to facilitate examination.

The left-wing main spar lower cap was examined using a scanning electron microscope (SEM). SEM images of the origin areas at the forward and aft sides of attachment bolt hole LC-1 are shown in figure 5. Arrows indicate local directions of fatigue crack propagation based on available fracture features in the images. Fracture features appeared to emanate from origins at the lower surface of the spar cap adjacent to attachment bolt hole LC-1.

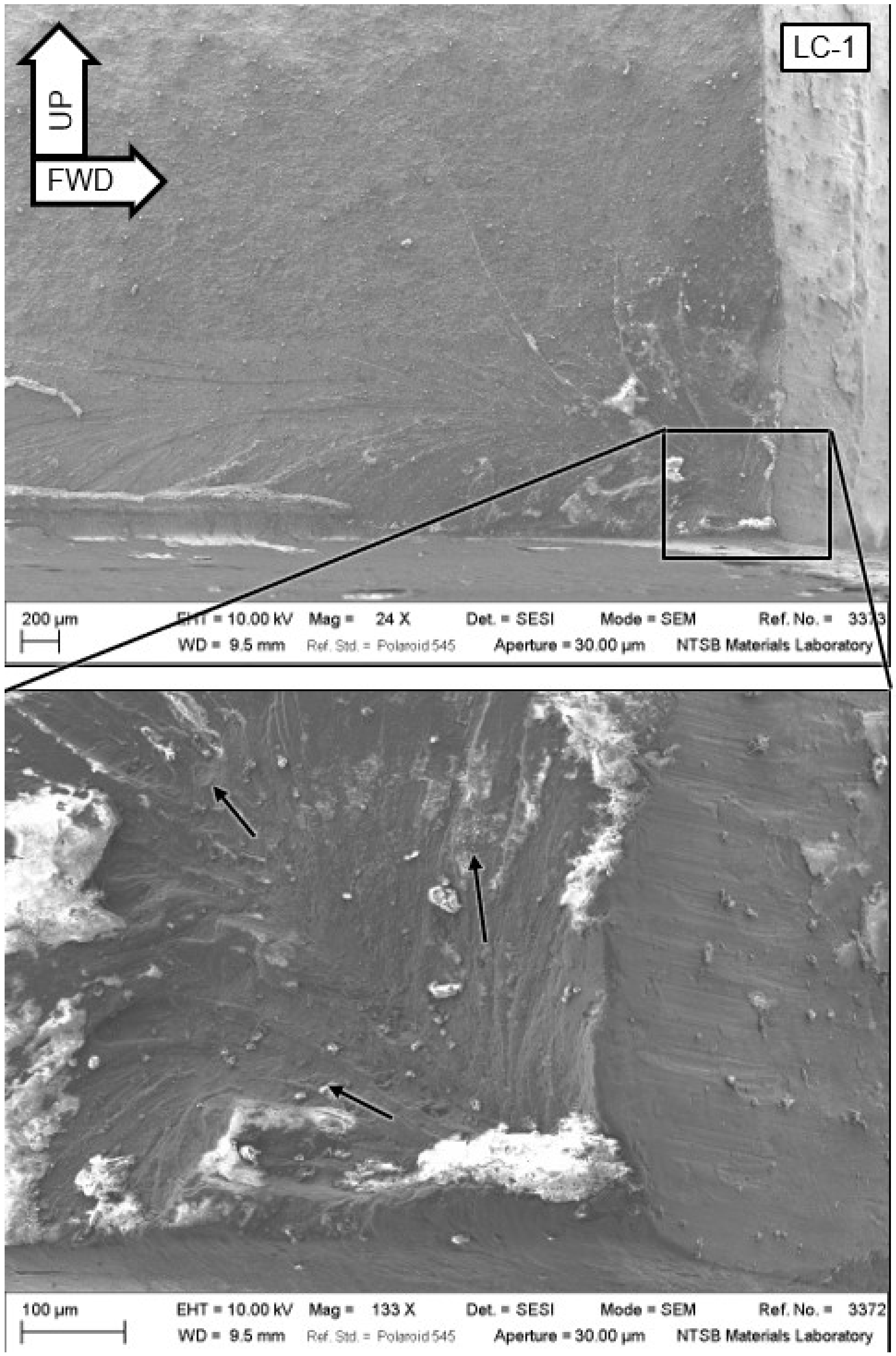


Figure 5. SEM images of fracture features at the aft side of hole LC-1 with a view of the origin area shown at higher magnification (lower image). Unlabeled arrows indicate local directions of fatigue crack propagation

Hardness and conductivity measurements of pieces of the left-wing main spar lower cap were consistent with the specified material. Measured thickness was within the allowable thickness range specified in the engineering drawing. Tensile tests and chemical analysis also showed that mechanical properties and chemistry conformed to specified material requirements.

The right-wing main spar was partially fractured through the outboard attachment bolt holes, and the outboard end of the piece was deflected forward. The right-wing main spar lower cap piece was further examined using an SEM, and the results showed that a portion of the main spar lower cap fracture surface had striations consistent with a fatigue region on the lower aft side of hole RC-1. Fatigue features emanated from an origin area located at the hole surface, extending up to 0.047 inch aft of the hole and 0.038 inch upward from the lower surface of the spar cap.

The overstress fracture at the forward side of hole RC-1 was located outboard of the transverse plane intersecting the hole center. A crack was observed at the forward edge of hole RC-1 where it intersected the lower surface. Smooth fracture features with curving crack arrest lines were observed consistent with fatigue fracture. Ratchet marks were also observed, consistent with multiple fatigue origins.

Postaccident Inspection of Sister Airplane N104ER

Immediately following the accident, ERAU conducted a visual inspection of the wing main spar caps of another PA-28R-201 in its fleet, N104ER, manufactured in 2007 with a serial number (S/N 2844135) two less than the accident airplane. No visual indications of cracking were noted. In addition, two hard landing inspections were recorded in the aircraft logbooks with no discrepancies noted. On April 9, 2018, N104ER, which had accrued 7,660.7 hours time-in-service (29.9 hours less than the accident airplane) and 33,288 landings (12 more than the accident airplane) was subjected to nondestructive inspection by a local FAA-approved repair station.

Specifically, the repair station performed a high frequency eddy current (HFEC) bolt hole inspection of N104ER's left and right lower outboard wing attachment bolt holes (holes C-1 and D-1) with the wings installed, and there were no abnormal findings. The wings were then removed and a follow-up inspection was conducted by the NTSB structures group, an American Society for Nondestructive Testing level III nondestructive testing engineer, and a level II certified ultrasonic testing inspector. Using an HFEC surface probe, this inspection revealed a crack indication on the forward side of attachment bolt hole LC-1. No cracks were discovered on the remaining bolt holes or spar caps.

The NTSB structures group proposed that the wings be reinstalled on N104ER by the same personnel and inspectors to help Piper and FAA evaluate an HFEC inspection procedure developed by Piper that would use a bolt hole probe instead of the surface probe used in the previous examination. The inspection confirmed the crack indication in attachment bolt hole LC-1. The inboard portion of the left-wing main spar was cut from the wing of N104ER and sent to the NTSB Materials Laboratory for additional examination. As shown in figure 6, a crack feature was visible under optical magnification (the bracket in figure 6 indicates the location of a crack feature extending from the forward side of attachment bolt hole LC-1). No crack features were detected under optical magnification at the aft side of attachment bolt hole LC-1.

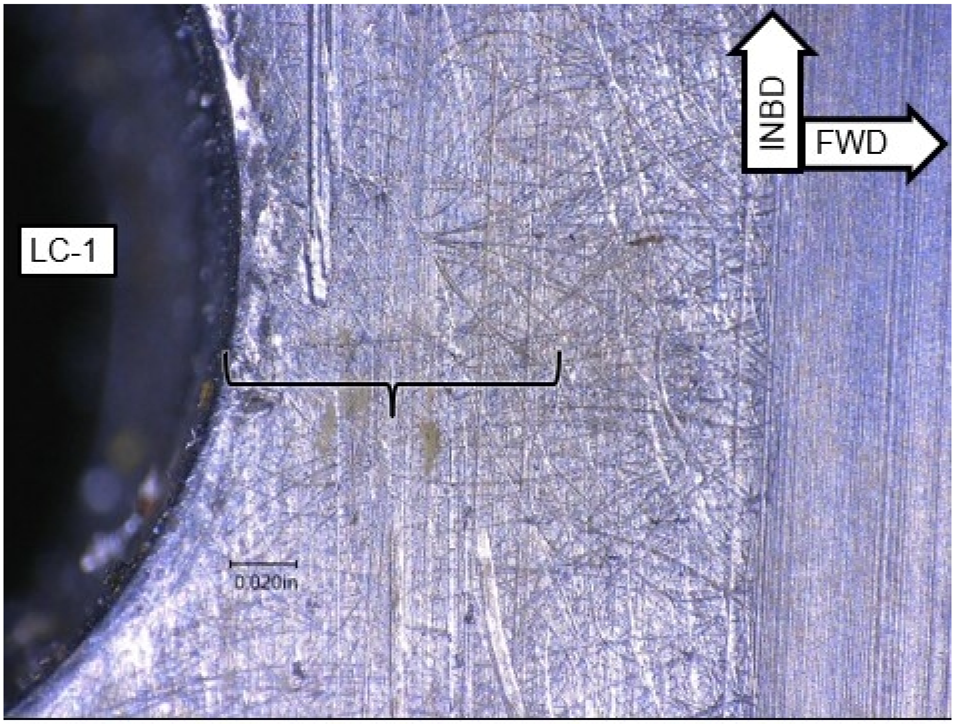


Figure 6. Magnified image showing a faintly visible crack feature extending from the forward side of attachment bolt hole LC-1

SEM examination of a sectioned piece of the fractured left-wing main spar from N104ER found the crack fracture surface had relatively smooth features with curving crack arrest lines, which are features consistent with fatigue. The fatigue region extended up to 0.126 inch forward from the hole surface and up to 0.115 inch upward from the lower surface. Where the fatigue region intersected the lower surface, the length from the hole surface to the fatigue boundary was 0.119 inch. A closer view of the fatigue origin area showed ratchet marks indicating multiple fatigue origins in the area located within the corner radius between the bore of attachment bolt hole LC-1 and main spar lower surface.

Another ERAU Piper PA-28R-201 airplane, N102ER (S/N 2844081, manufactured in March 2012 and with 5,864.6 hours [1,826 less than the accident airplane] and 15,808 cycles [17,468 less than the accident airplane]), was inspected. The right and left lower outboard wing attachment bolts (C-1 and D-1) were removed for inspection by HFEC surface probe, and no indications of cracking were found. The maintenance records weren't examined for N102ER.

Piper Aircraft, Inc., personnel, observed by the NTSB structures group, performed HFEC inspections on the remaining five ERAU PA-28R-201 airplanes (N108ER, N110ER, N115ER, N116ER and N117ER) using a bolt hole probe instead of a surface probe (the maintenance records for these airplanes weren't examined). These inspections revealed no cracking on any of the remaining fleet airplanes (for more information, see the NTSB Structures Group Chairman's Factual Report in the public docket for this investigation).

Inspections of Piper PA-28R-201 Airplanes at Other Training Facilities

The flight training facilities in the following table submitted various numbers of Piper PA-28R-201 airplanes to HFEC bolt hole probe inspection by Piper in conjunction with the NTSB structures group. Brief descriptions of the airplanes' operational lives and inspection findings are also provided (for more information about these airplanes and the inspections, see the NTSB Structures Group Chairman's Factual Report in the docket for this accident investigation).

Training Facility	Location	Number of Aircraft Inspected	Aircraft Background	Inspection Findings
Florida Institute of Technology (FIT)	Melbourne, FL	2	Operated by FIT since manufacture; used only for flight instructor and commercial pilot training	No evidence of cracking
Flight Safety International (FSI)	Vero Beach, FL	5	Purchased from private operators; used by FSI for flight instructor and commercial pilot training.	No evidence of cracking
Texas State Technical College (TSTC)	Waco, TX	2	Used by TSTC for flight instructor and commercial pilot training. Maintenance records for both airplanes documented hard landings.	No evidence of cracking

Evaluation of Exposure to Severe Weather

While investigating additional potential sources of the damage observed on the accident airplane, the structures group considered the possible impact of severe weather. Since 2007, the ERAU campus in Daytona Beach, Florida, has been impacted by two hurricanes: Hurricane Matthew in October 2016 and Hurricane Irma in September 2017. In October 2016, the ERAU fleet was moved to Auburn University Regional Airport (AUO) in Auburn, Alabama, in accordance with ERAU's Emergency Response Plan, which indicates that ERAU aircraft that can fly will be evacuated to a safe location before storm arrival. In September 2017, part of the ERAU fleet was moved to AUO while the Piper PA-28R-201 airplanes, including N106ER and N104ER, were moved to Birmingham-Shuttlesworth International Airport, Birmingham, Alabama. None of the Piper-28-201 airplanes were damaged during Hurricane Irma because the storm tracked closer to Auburn and spared Birmingham (two of the Cessna airplanes at AUO were damaged).

Inspection of New Wing Main Spar Pieces

Piper Aircraft provided pieces from three different lots of recently purchased main spar extrusions for examination. Hardness and conductivity measurements were made on the lower caps of each new spar piece, and results were consistent with expected values for the specified material. The grain structure was comparable to the microstructure from the accident airplane's main spar lower cap.

US Air Force (USAF) Examination

Due to their technical expertise in aging aircraft and metal fatigue, members of the USAF A-10 Aircraft Structural Integrity Program (ASIP) were invited to participate in the NTSB's investigation as part of the structures group. The USAF participants were asked to perform an independent analysis of the accident airplane failure using the methods they have perfected for use on the A-10 airplane.

The USAF first examined the historical usage of N106ER (the accident airplane) and N104ER (its sister airplane) to develop a load spectrum based on the information contained in a report prepared by the Lockheed Georgia Company for Piper as part of the 1987 wing-separation accident investigation. A preliminary crack growth analysis was then performed to validate the assumptions, load spectrum, and stress levels. A finite element model of the main spar lower cap was created and validated for use in obtaining the internal stresses in the lower cap. The USAF then used the Broad Application for Modeling Fracture (BAMF) to join the preliminary crack growth analysis and finite element model and provide a 3-D structural representation of the main spar lower cap. The BAMF analysis was run several times to examine the effect of initial flaw size and the fastener fit on the fatigue crack growth in the lower cap. The model results were then compared to the evidence from N106ER and N104ER.

Combining the average flight time between landings for both N106ER and N104ER (14.2 minutes for the life of the airplanes) with the normal climb and descent rates for the PA-28R- 201 showed that both airplanes spent most of their lives operating below 2,500 ft agl in normal operation; therefore, since peak gust velocities are inversely proportional to altitude, these airplanes remained in a more severe gust environment for their operational life than a personal use airplane. The BAMF analysis assumed a severe gust environment similar to the pipeline patrol gust environment detailed in the Lockheed report, but maneuvering loads for the flight training mission were less severe. A full load spectrum was developed and included taxi, gust, maneuver (severity reduced from pipeline patrol in the Lockheed report), and landing loads.

The accident airplane had three separate fatigue cracks in the left wing main spar lower cap that all initiated at or near the lower corner of a fastener hole. The NTSB was unable to determine which crack initiated first. The results of the USAF analyses, which were performed with varying initial flaw sizes at each location and with an open or filled hole configuration, showed that the initial flaw size has a significant effect on the fatigue life, the crack growth rate increases significantly once the crack size reaches about 0.050 inch, and the filled hole provides a life improvement on the order of 1.5.

The USAF also examined the damage tolerance of the lower cap. There is an unknown portion of the spar cap's fatigue life before fatigue crack initiation and propagation to a detectable size. Detectable size limits differed depending on the type of nondestructive inspection using HFEC: manual right-angle probe, a manual bolt hole probe, or a semi-automated bolt hole probe. The USAF has not accepted the use of manual HFEC bolt hole inspection because the method reduces the probability of detection due to its reduced sensitivity and human factor variables.

The data indicate that the detectable crack size for an HFEC inspection with a semi-automated bolt hole probe is 0.050 inch and if using a manual probe, the assumed detectable crack size would be 0.250 inch. Using the crack growth data and the detectable crack size for a manual probe showed that a significant portion of the fatigue life is gone before the crack becomes detectable. The USAF estimated that the sister airplane's wing, with a fatigue crack measured at 0.18 inch, was less than 2,000 hours from failure.

Organizational and Management Information

ERAU Commercial Flight Program

ERAU operated as a 14 *CFR* Part 141 flight school. Unlike pilot training conducted under 14 *CFR* Part 61, Part 141 flight schools are required to use a structured training program and syllabus. For this accident investigation, the review of ERAU commercial flight program objectives was limited to commercial pilot flight operations pertinent to airplane single-engine land (ASEL) training.

According to the ERAU commercial pilot ASEL flight training course syllabus, the flight training course outline was for private pilots with airplane single-engine land and instrument airplane ratings seeking to attain an FAA commercial pilot certificate with a rating for airplane single-engine land. The syllabus contained 38 commercial lessons consisting of 9 oral lessons, 5 flight-training device lessons, 15 non-complex flight lessons (conducted in a Cessna 172), and 9 lessons in the complex category using a PA-28R-201 airplane. The suggested lesson time for the complex flight training was 14.7 hours.

ERAU Flight Instructor Interviews

Three front-line commercial instructors were interviewed at the ERAU Daytona Beach campus regarding flight operations and their experience in the PA-28R-201 and its usage. The instructors were independently questioned and each relayed corroborating statements.

According to the instructors, the PA-28R-201 was used for complex operations only and accounted for about one-third of the commercial flight training.

Typically, each flight lesson was about 1.5 to 1.8 hours; of that, 1.2 hours were spent in the airport traffic pattern, and between five and eight takeoffs and landings were conducted per flight. Of those, over half were simulated emergency approach and landings, also known as "power-off 180s." As described, the maneuver involved reducing the engine power to idle to simulate a loss of engine power while in the airport traffic pattern on downwind. The student attempted to land on a specific point of the runway using normal stabilized maneuvers and control input. The instructors stated the landings were "firm" and that this maneuver was "where most pilots get behind the airplane."

When questioned about emergency descents, all the instructors stated that the maximum G- load was no higher than perceived 1.5 Gs, with the objective to descend the airplane as rapidly as possible while maintaining operational limitations. The instructors described the maneuver as moderate and stated that they had never experienced excessive G loads or airframe limitations during the maneuver. They stated that most airspeed exceedances occurred during flap extension and for landing gear operation and that most occurred during gusty conditions though typically only by a "couple of knots" over a short duration.

Six additional flight instructors were interviewed later, and, according to them, the PA-28R- 201 was used only for commercial or flight instructor training. The block time was scheduled for 2.3 hours but the average flight time per flight is between 1.5 to 2.0 hours. They operate between 2,500 to 3,000 ft msl for maneuvers in the practice area. If they were conducting emergency descents, they may climb up to 5,000 ft msl briefly, however, they spent most of their time between the surface and pattern altitude (about 1,000 feet agl) practicing takeoff and landings.

ERAU Maintenance

ERAU's maintenance facility operated under 14 *CFR* Part 145 as a certified repair station, and its maintenance program was certified by the FAA. All ERAU airplanes, including engines, systems, and appliances, were maintained in a continuous state of airworthiness by a program of preventive and corrective maintenance. The ERAU maintenance and quality department was responsible for the airworthiness, maintenance, servicing, alteration, and inspection of ERAU airplanes, as well as the maintenance or alterations performed on ERAU aircraft by other organizations.

ERAU Safety Reporting

The ERAU Aviation Safety Department has an established system in place for flight crews and maintenance personnel to voluntarily identify and report safety and operational concerns. The collected information was reviewed and analyzed to facilitate early detection and improved awareness of operational deficiencies and adverse trends.

There were two primary methods to report safety issues: an aviation safety action program (ASAP) for employees to voluntarily identify and reduce possible flight safety concerns and a flight operations general safety reporting system for employees to voluntarily identify safety and operational deficiencies within their respective departments.

A review of limited and redacted PA-28R-201 ASAP data covering the 24 calendar months preceding the accident found one tailstrike event involving the accident airplane, but no damage occurred. The rest of the data showed nothing across the entire fleet of PA-28R-201s that appeared to be a safety of flight issue or reported damage or issues with the wing(s) or wing main spar as the result of an in-flight airframe exceedance, high G-load, or hard landing event.

A review of PA-28R-201 general safety reporting system data from April 1, 2016, to just before the accident found no known flight operation events that indicated damage to the wing main spar of the accident airplane. According to the ERAU flight crew safety reporting system, all of the hard landing events reported in the 24 months before the accident resulted in "no defects noted" and were captured in the maintenance discrepancy log. There were no additional reported events across the fleet that indicated a safety of flight issue or damage or issues with the wing(s) or wing main spar as the result of an exceedance, high G-load, or hard landing event.

Additional Information

Fatigue Certification Requirements and Guidance

The Piper PA-28R-201 was type certificated under Part 3 of the Civil Air Regulations (CAR), according to Type Certificate Data Sheet 2A13. The only fatigue requirements in CAR 3 effective for the airplane were that the design details should avoid stress concentrations.

In contrast to the relative lack of fatigue requirements when the Piper PA-28R-201 was type-certificated, guidance in Advisory Circular (AC) 23-13A (released on September 29, 2005) provides an acceptable means of compliance with the Part 23 regulations for fatigue, fail-safe, and damage-tolerance evaluations of metallic airplane structure. The AC contains approved gust and maneuver loads for the various types of operations of single-engine airplanes; see the NTSB Structures Group Chairman Report for more information.

FAA Actions in Response to Wing Separations

In response to Urgent Safety Recommendation A-87-40, the FAA issued emergency AD 87-08-08 in April 1987, to require the inspection of the wing main spar lower caps on all PA-28, PA-32-260, and PA-32-300 model airplanes. The AD required removal of the wings, a visual inspection with a 10-power magnifying glass, and dye penetrant inspection of the main spar lower caps "from the wing skin line, outboard of the outboard row of wing attach bolt holes to an area midway between the second and third row of bolt holes from the outboard row" for both wings. The AD required the replacement of any wing spars found to be cracked, as well as the visual inspection of the upper wing skins for cracks.

In August 1987, the FAA issued revised AD 87-08-08R1, which removed Piper PA-28-201T airplanes from the group of affected airplanes because they had a different spar design. In September 1987, the FAA issued revised AD 87-08-08R2, which suspended the effectivity of the AD while the issue was reevaluated and additional data were examined. In May 1989, the FAA issued revised AD 87-08-08R3, which rescinded the original AD and revisions R1 and R2.

In the discussion published for the rescission, the FAA reported that its inspection results from about 560 airplanes showed only two Piper PA-32-300 airplanes with spar cracks. The cracks were discovered in airplanes that were operated overweight, in "severe" environments, and had documented damage and repairs. Based on its examination of fatigue test data from Piper and a fracture mechanics analysis, the

FAA concluded that the cracks found on the two airplanes were isolated occurrences and not likely to exist or develop in other PA-28 and PA-32 series airplanes operated in a normal usage class environment.

The FAA maintained in the rescission that instructions provided in FAA-approved Piper Service Bulletin (SB) 886, which was published in conjunction with AD 87-08-08, would address the inspection of the wing spars for those PA-28 and PA-32 series airplanes that were operated in a severe usage class environment. Based on additional fatigue analysis work done by Piper and Lockheed after the 1987 accident, SB 886 contained instructions for determining the usage class of affected airplanes and inspecting the wing spars at prescribed times.

In response to the preliminary findings from the NTSB's investigation of the April 4, 2018, accident, the FAA issued a notice of proposed rulemaking (NPRM) for a new AD applicable to most Piper PA-28, all PA-28R, and most PA-32 series airplanes. The proposed AD would require calculating the factored service life for the wing main spar, eddy current inspection of the main spar lower outboard attachment bolt holes for cracks at a specified time, and replacing any cracked wing main spars. In the NTSB's comments submitted to the FAA on February 15, 2019, we expressed our support of the proposed AD's inspection requirements for all PA-28R and most PA-32 airplanes but noted that the risks associated with disturbing the joint to complete the required inspection may outweigh the risk of fatigue cracking in all affected PA-28 series airplanes other than the PA-28-235 and urged the FAA to reexamine the proposed AD's applicability.

Airframe Manufacturer's Information

Maintenance information for the PA-28R-201 in chapter 4 of the AMM specifies that "No limitations, related to fatigue life of the airplane and its components, have been established for the PA-28R-201 Arrow airplane" and there are no mandatory structural inspection intervals.

Piper published Service Letter (SL) 997 in May 1987 to supplement AD 87-08-08. The SL provided instructions for the removal and reinstallation of the wings on all PA-28, PA-28R, and PA-32 series airplanes. Warnings were included in the SL to use extreme care when removing and reinstalling the wing attachment hardware to preclude damaging the holes.

Piper published SB 886 in June 1988 after the original issuance of AD 87-08-08 and the subsequent revisions of the AD to provide instructions for inspecting the wing main spar on certain PA-28, PA-28R, and PA-32 model airplanes. Piper considered the FAA-approved SB instructions mandatory. The SB divided the airplanes into two groups and defined four usage classes, A through D (see figure 7) based on an accounting of the lifetime usage to determine the inspection compliance times. The SB provided instructions for calculating a factored service life for airplanes that had a mixture of Class A and B usage. The SB also provided a table to specify the initial inspection time and recurring inspection interval once the airplane group and usage class were determined.

A. Normal Usage, Class 'A'.

This class applies to all aircraft which do not and have not engaged in operations considered as "Severe", "Extreme", or "Unknown" in the Usage Class described below.

Most aircraft affected by this Service Bulletin will fall into this "Normal Usage Class". Normal flight training operations fall into this class as well. However, if there is any doubt as to the aircraft's operating history, it is recommended that the initial inspection be conducted in accordance with the UNKNOWN USAGE CLASS 'D' Compliance Time.

B. Severe Usage, Class 'B'.

This class applies to aircraft which have engaged in severe usage, involving contour or terrain following operations, (such as power/pipeline patrol, fish/game spotting, aerial application, aerial advertising, police patrol, livestock management or other activities) where a significant part of the total flight time has been spent below one-thousand (1000) feet AGL, altitude.

NOTE: Aircraft with part of total time in service in SEVERE USAGE CLASS 'B' operations and part in NORMAL USAGE CLASS 'A', may adjust compliance times by a "Factored Service Hours" calculation. See Instruction 2A to calculate "Factored Service Hours".

C. Extreme Usage, Class 'C'.

This class applies to aircraft which have been damaged due to operations from extremely rough runways, flight in extreme damaging turbulence or other accident/incident which required major repair or replacement of wing(s), landing gear or engine mount.

D. Unknown Usage, Class 'D'.

This class applies to aircraft and/or wings of unknown or undetermined operational or maintenance history.

Figure 7. Excerpt of Service Bulletin 886 from 1988 showing usage categories

Class A airplanes had an initial inspection time of 30,600 hours or 62,900 hours depending on the group. Class B or mixed Class A and B airplanes had an initial inspection time of 1,800 factored hours or 3,700 factored hours depending on the group. Class C and D airplanes had an initial inspection time within 50 hours' time-in-service from the issuance of the SB. In August 1999, Piper published SB-978A, which was identical to SB 886 but added additional PA-28 and PA-28R series airplanes that were not manufactured at the time SB 886 was published.

Many of the Piper PA-28 series airplanes have the same or very similar spar configuration as the PA-

28R-201 accident airplane at the wing attach location. The spar configuration for the following airplanes is identical to the accident airplane:

- · PA-28-140/-150/-151/-160/-161/-180/-181/-235;
- · PA-28R-180/-200/-201T;
- · PA-28RT-201/-201T; and
- · PA-32-260/-300 airplanes

The spar configuration on the remaining unlisted PA-28, PA-32, PA-34, and PA-44 series airplanes, while similar, uses additional structural elements and/or different fasteners that differentiate the spar configuration.

In late 2018, the Piper Aircraft engineering group performed analysis work to assess the risk of wing-spar fatigue within the PA-28 airplane fleet using FAA data published in AC-23-13A. This proprietary analysis determined that an airplane in the flight training environment has higher loads than personal use that increase the risk of fatigue at the wing main spar lower outboard attachment bolt hole.

Piper's comparison of each of the airplane models above with an identical spar configuration to the accident airplane showed that PA-28R-180/-200/-201T, the PA-28RT-201/-201T, and PA-32-260/-300 airplanes have similar loads and fatigue lives to the PA-28R-201 and warrant further consideration for applicability under the proposed AD, especially if operated in the training environment. Piper's analysis for all PA-28 (fixed landing gear) airplanes, except for PA-28-235/-236 airplanes, showed that the loads were less and the resulting fatigue lives were higher than the PA-28R-201. Piper's analysis for PA-28-235/-236 airplanes indicated that the fatigue lives when operated in the training environment are similar to the PA-28R-201. However, Piper maintains that these airplanes are unlikely to be operated in this environment due to their higher operational costs.

Administrative Information

Investigator In Charge (IIC):	Mccarter, Lawrence
Additional Participating Persons:	Matthew Rigsby; FAA AVP; Fort Worth, TX Damian Galbraith; Piper; Vero Beach, FL Thomas Bruno; ERAU; Daytona, FL Jacob Warner; USAF; Hill AFB, UT Mark Thomsen; USAF; Hill AFB, UT Michael Gordon; Piper; Vero Beach, FL William McCulley; FAA ACO; College Park, GA
Original Publish Date:	September 3, 2019
Last Revision Date:	
Investigation Class:	Class 3
Note:	The NTSB traveled to the scene of this accident.
Investigation Docket:	https://data.ntsb.gov/Docket?ProjectID=96975