Aviation Investigation Final Report

Location:	Palm Springs, California	**Incident Number:**	WPR15IA046
Date & Time:	November 23, 2014, 11:04 Local	**Registration:**	C-GJOL
Aircraft:	Embraer EMB-505	**Aircraft Damage:**	Minor
Defining Event:	Sys/Comp malf/fail (non-power)	**Injuries:**	5 None
Flight Conducted Under:	Part 91: General aviation - Personal		

Analysis

The airline transport pilot was preparing to take off for a personal cross-country flight. He reported that the preflight preparations were normal, including the removal of the rudder gust lock pin. He stated that the taxi out for takeoff was normal but that he "detected an abnormal 'feel' to the rudders." He added that all of the turns to the runway were right turns and that he "easily executed" the turns. Following rotation on takeoff, the pilot noticed a significant right yaw and roll, which he initially countered with left aileron. As the airplane continued to climb, the airplane's flight was uncoordinated, and the pilot had to continuously apply left rudder to counter the right yaw; he also attempted to apply left yaw trim, but neither action resolved the issue. At this time, the pilot advised air traffic control (ATC) that he needed to return to the departure airport, and ATC cleared the pilot for a visual approach. The pilot landed the airplane; only minor damage to the left wing tip was incurred as the pilot tried to unsuccessfully correct (with the right rudder and aileron) a drift to the right after landing.

The initial examination of the airplane revealed that the rudder gust lock had failed in the locked position. Upon further examination, it was determined that the gust lock actuator had likely begun to retract as commanded by the pilot when he removed the rudder gust lock pin during the preflight/startup checks. However, the solenoid located within the gust lock actuator failed, which resulted in the pin no longer being held in the retracted position. Once the pin released from its retracted position, it engaged the ball nut, which then stopped the rotation of the actuator shaft. The failure occurred at a time when the gust lock bellcrank had not fully disengaged from the rudder quadrant, which likely resulted in the rudder being locked throughout the taxi, takeoff, climb, descent, approach and landing, and landing roll segments of the flight.

Although it is possible that a momentary power interruption could have caused the solenoid pin to release, which would have then resulted in the pin moving to the extended position and interfering with the ball nut, no conclusive evidence was found during the investigation that supported this possibility. The reason for the failure of the gust lock actuator solenoid could not be determined.

Probable Cause and Findings

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

The failure of the gust lock actuator solenoid for reasons that could not be determined because postaccident examination of the rudder gust lock system revealed no mechanical malfunctions or failures that would have precluded normal operation.

Findings

Not determined	(general) - Unknown/Not determined
Aircraft	Gust lock or damper - Failure

Factual Information

History of Flight

Initial climb	Sys/Comp malf/fail (non-power) (Defining event)
Landing-landing roll	Collision with terr/obj (non-CFIT)

On November 23, 2014, about 1104 Pacific standard time, an Embraer EMB-505 airplane, C-GJOL, experienced an uncommanded severe yaw to the right immediately after takeoff from the Palm Springs International Airport (PSP), Palm Springs, California. Neither the airline transport pilot or the 4 passengers on board were injured. The airplane, which was owned by a private individual, was operated by Hawkeye Aviation Holdings Ltd, Kelowna, British Columbia. Visual meteorological conditions prevailed for the planned cross-country flight, which was being operated in accordance with 14 Code of Federal Regulations Part 91. The left wing received minor damage during the landing. An instrument flight rules flight plan was in effect at the time of the event, with Springbank, British Columbia, the reported destination.

In a statement provided to the National Transportation Safety Board investigator-in-charge, the pilot reported that prior to takeoff the preflight preparations were normal, including the removal of the control lock pin. The pilot stated that the initial taxi out was normal, although he "detected an abnormal 'feel' to the rudders." All turns to runway 13L were right turns, which the pilot described as "easily executed." The pilot opined that the initial takeoff acceleration was normal, but at some point he drifted slightly right of centerline. Upon rotation the pilot noticed a significant yaw tendency to the right, accompanied by a significant roll to the right. The pilot stated that both tendencies were easily counteracted by application of left aileron, after which he flew the departure procedure to the best of his ability. The pilot reported that due to the surrounding terrain, he elected to climb to a safe altitude in order to deal with the problem. At this time the airplane was uncoordinated, with the electronic slip indicator displaced significantly to the left. The pilot stated that he was continuously applying left rudder in an attempt to correct the yaw [to the right], ran the yaw trim to the left, but it did help in resolving the situation.

The pilot reported that he climbed to about 11,000 feet, and at some point received fuel imbalance warning due to the uncoordinated flight. After advising air traffic control that he had a control issue, he was cleared for a visual approach to runway 31L at PSP. The pilot subsequently asked the passenger who was occupying the right front pilot seat, a private pilot, to assume the pressure on the left rudder so he could rest his leg prior to the landing. The pilot stated during final approach, he took control of the rudder and performed the landing.

The pilot opined that the touchdown was normal; however, after touchdown the aircraft began to drift right of the center line, as there was a left to right crosswind at the time of the landing. The pilot stated that trying to correct the drift with rudder was to no avail, he used aileron and power to the best of his ability. In the process the right wing lifted and the left wing tip contacted the runway, which resulted in minor damage. The pilot added that he was able to bring the airplane under control, exited onto the taxiway, and taxied to the local fixed based operator and shut down.

An examination of the airplane shortly after the incident revealed that the airplane's gust lock actuator had failed in the locked position. Under the supervision of a Federal Aviation Administration aviation safety inspector, the component was removed from the airplane and taken into possession of the NTSB IIC.

Pilot Information

Certificate:	Airline transport	**Age:**	60,Male
Airplane Rating(s):	Single-engine land; Multi-engine land	**Seat Occupied:**	Left
Other Aircraft Rating(s):	None	**Restraint Used:**	4-point
Instrument Rating(s):	Airplane	**Second Pilot Present:**	No
Instructor Rating(s):	None	**Toxicology Performed:**	No
Medical Certification:	Class 1 With waivers/limitations	**Last FAA Medical Exam:**	August 5, 2014
Occupational Pilot:	Yes	**Last Flight Review or Equivalent:**	April 26, 2014
Flight Time:	13185 hours (Total, all aircraft), 368 hours (Total, this make and model), 11748 hours (Pilot In Command, all aircraft), 147 hours (Last 90 days, all aircraft), 35 hours (Last 30 days, all aircraft), 0.2 hours (Last 24 hours, all aircraft)		

The pilot, age 60, possessed a current Canadian issued airline transport pilot certificate, with airplane single-engine land, multiengine land, and instrument airplane ratings. The pilot also possessed a Canadian designated E55P type rating, which is the Canadian designator for the EMB-505 airplane. Additionally, the pilot's most recent flight review was completed on April 26, 2014, and his most recent first-class airman medical examination was performed on August 5, 2014.

The pilot reported a total flying time of 13,185 hours, with 4,178 hours in multiengine airplanes, and 368 hours in the EMB 505 make and model. The pilot also reported a total number of hours flown in the last 90 days and 30 days to be 147 and 35 hours respectively, with 21 hours in make and model.

Aircraft and Owner/Operator Information

Aircraft Make:	Embraer	**Registration:**	C-GJOL
Model/Series:	EMB-505	**Aircraft Category:**	Airplane
Year of Manufacture:	2012	**Amateur Built:**	
Airworthiness Certificate:	Commuter	**Serial Number:**	50500089
Landing Gear Type:	Retractable - Tricycle	**Seats:**	9
Date/Type of Last Inspection:	October 31, 2014 Continuous airworthiness	**Certified Max Gross Wt.:**	17968 lbs
Time Since Last Inspection:	141 Hrs	**Engines:**	2 Turbo fan
Airframe Total Time:	730 Hrs at time of accident	**Engine Manufacturer:**	Pratt & Whitney
ELT:	C126 installed, not activated	**Engine Model/Series:**	535E
Registered Owner:	On file	**Rated Power:**	3360 Lbs thrust
Operator:	On file	**Operating Certificate(s) Held:**	None

The airplane involved in the incident was an Embrarer EMB-505, Canadian registration C-GJOL, serial number 5050009, manufactured in 2013. The airplane is a twin-engine cantilever monoplane with a low-positioned, swept wing. It is equipped with two rear positioned Pratt and Whitney Canada 535E turbofan engines, one on each side of the fuselage. The airplane can accommodate 2 crewmembers and 7 passengers; if operated single-pilot, it can accommodate an additional passenger. The airplane is equipped with an airstair door on the left forward side of the fuselage, single-point refueling, and a private lavatory.

The EMB-505 was equipped with an Umbra Group gust lock actuator, serial number 00075. The actuator was designed specifically to prevent rudder surface movement due to ground gusts.

According to documentation provided by the manufacturer, Umbra Cusinetti, the actuator, S/N 00075, was delivered by Umbra to Embraer on February 28, 2011. It subsequently failed during tests on aircraft S/N 00052, at the Embraer assembly line on May 19, 2011. The non-conformity report by Embraer stated, "Rudder gust lock actuator inoperative". The actuator was then returned to Umbra by Embraer on July 15, 2011. Umbra replaced both microswitches and returned the actuator to Embraer on November 28, 2011. Embraer then installed the actuator on the incident airplane, C-GJOL.

Rudder Gust Lock Actuator

General Description

The EMB-505 flight controls have a control lock system installed which is designed to prevent damage to the control column and flight control systems caused by wind gusts. There are two parts of the control lock system, namely the elevator and aileron control lock and the rudder control lock.

The aileron, rudder and elevator control systems are locked by means of the installation of the gust lock safety pin in the pilot control yoke assembly. The rudder gust lock actuator is installed in the aircraft's

rear fuselage, at frame 46. The function of the rudder gust lock is to prevent rudder surface movement due to ground gusts by locking the rudder control system at the rear fuselage torque tube.

In order to preclude in-flight uncommanded locking, the system has the following interlocks:
• TLA (Thrust Lever Angle)
• WOW (Weight-on-Wheels)

No maintenance is required over the rudder gust lock actuators life.

Components

The gust lock system comprises the following elements:
• Aileron/rudder/elevator gust lock cockpit assembly
• Gust lock safety pin
• Rudder gust lock mechanism
• Gust lock quadrant

The rudder gust lock mechanism has the following elements:
• Gust lock actuator
• Command spring
• Bellcrank
• Control box with connector

The bellcrank, pivoted by the action of the actuator, locks one of the grooves on the gust lock quadrant, which is connected to the rudder rear torque tube, thereby preventing the movement of the rudder surface in case of wind gust.

Operation

The aileron control system and the elevator control system are mechanically locked by means of the installation of the gust lock pin in the pilot's control yoke assembly. The rudder control system gust lock mechanism is actuated through an electromechanical actuator.

When the gust lock safety pin is inserted into the pilot's control wheel to lock the aileron and elevator control system, two switches are activated, providing automatic engagement of the rudder gust lock system.

When the aileron and elevator control systems are unlocked by the removal of the gust pin, the rudder gust lock system is designed to be automatically disengaged. As designed, the rudder gust lock system in a locked position is evident to the pilots because of the following conditions:

• Gust lock pin is inserted in its hole.
• Both pedals are locked in a deflected position.
• Aircraft cannot taxi with rudder surface locked.

Meteorological Information and Flight Plan

Conditions at Accident Site:	Visual (VMC)	**Condition of Light:**	Day
Observation Facility, Elevation:	PSP,477 ft msl	**Distance from Accident Site:**	
Observation Time:	10:53 Local	**Direction from Accident Site:**	
Lowest Cloud Condition:	20000 ft AGL	**Visibility**	10 miles
Lowest Ceiling:	Broken / 20000 ft AGL	**Visibility (RVR):**	
Wind Speed/Gusts:	4 knots /	**Turbulence Type Forecast/Actual:**	/ None
Wind Direction:		**Turbulence Severity Forecast/Actual:**	/
Altimeter Setting:	30.2 inches Hg	**Temperature/Dew Point:**	23°C / 16°C
Precipitation and Obscuration:	No Obscuration; No Precipitation		
Departure Point:	Palm Springs, CA (PSP)	**Type of Flight Plan Filed:**	IFR
Destination:	(CYBW)	**Type of Clearance:**	IFR
Departure Time:	10:52 Local	**Type of Airspace:**	Class D

At 1052, the PSP automated weather reporting facility indicated wind calm, visibility 45 miles, sky clear, temperature 19°C, dew point 10°C, and an altimeter setting of 30.08 inches of mercury.

Airport Information

Airport:	Palm Springs International PSP	**Runway Surface Type:**	Asphalt
Airport Elevation:	477 ft msl	**Runway Surface Condition:**	Dry
Runway Used:	31L	**IFR Approach:**	Visual
Runway Length/Width:	10001 ft / 150 ft	**VFR Approach/Landing:**	Forced landing;Full stop;Traffic pattern

Wreckage and Impact Information

Crew Injuries:	1 None	**Aircraft Damage:**	Minor
Passenger Injuries:	4 None	**Aircraft Fire:**	None
Ground Injuries:	N/A	**Aircraft Explosion:**	None
Total Injuries:	5 None	**Latitude, Longitude:**	33.833332,-116.5(est)

The only reported damage to the airplane, which occurred during the landing rollout, was a minor scrape on the underside of the left wingtip, and some damage to the associated strobe light.

Tests and Research

Computed Tomography (CT Scanning)

Under the supervision of a lead aerospace engineer assigned to the NTSB's Aviation Engineering Division, located at NTSB Headquarters, Washington, D.C., the rudder gust lock actuator was subjected to x-ray computed tomography (CT) scanning to document its internal condition. The scanning was conducted from December 24, 2014 to March 23, 2015. The scans were performed by Varian Medical Systems, Inc. (formerly Bio-Imaging Research, Inc. (BIR) using a combination of the Varian Actis 500/225 microfocus CT system and the Actis 500/450 standard focus CT system.

For the CT scans, the component was loaded into the imaging unit and placed on a turntable. It was then rotated in front of the x-ray source, and the x-rays were captured by a detector after they went through the part. The x-ray source produced a fan beam of x-rays, and the portion of the part imaged was adjusted slightly after each scan was completed until the entire assembly was scanned. The x-ray energy levels captured by the detector were recorded at several thousand different points during each rotation. This information was then converted into slice images using a reconstruction algorithm.

The actuator was scanned using a total of 6,421 slices. The total size of the combined data sets was 50.26 Gb. The actuator was scanned multiple times with different scanning protocols using both the microfocus imaging system and the standard focus imaging systems. The microfocus scans provided the best possible spatial resolution, but this type of imaging was constrained to a lower power level that resulted in streaking artifacts within the images. The standard focus scans used a higher power level (with a lower spatial resolution), but these higher power levels eliminated the streak artifacts, and had an inherently higher contrast resolution. Target CT imaging using the microfocus system was used for selected areas to get the highest possible resolution. In addition, the entire part scans and the limit switch scans were re-reconstructed using different reconstruction parameters in an effort to highlight the low density components within the scans.

Each data set of slice images was evaluated using the VGStudioMax software package to create orthogonal slice images and a three-dimensional reconstructed image of the component. As part of the evaluation, some sections of the components were digitally removed or rendered transparent to allow closer observation of interior parts. In the images, the high density areas were shown as brighter shades of gray and lower density areas were shown as darker shades of gray. The pointers shown in some of the images denote specific areas of interest within that image. The images of the actuator were examined for any signs of missing or damaged parts, contamination, obstructed passages or any other anomalies.

Computed Tomography results revealed the following:

• The extend limit switch contacts appeared to be closed during the standard focus scans, and open during the microfocus scans. Whether this difference was due to an actual position change of the contacts or due to the resolution differences of the two scanning methods, could not be determined.

• The extend and retract limit switch plungers were extended different lengths (0.87 mm and 1.26 mm respectively).

• High and medium density particles were found in various locations throughout the actuator.

• A low density indication within one of the extend limit switch screws was only visible in the standard focus scans and not the microfocus scans – this indication is consistent with the apparent low density area being a scanning artifact.

• Indications of a crack in the ball screw that were noted in the standard focus scans were more completely resolved in the microfocus scans as the balls and groove located on the ball screw. However, there was an indication of a discontinuity within one of the balls shown on the microfocus images.

• There were indications of two areas with distorted windings within the solenoid. Neither of these areas appeared to contain breaks in the windings, nor did either area contact the solenoid plunger

• Review of the solenoid images using enhanced contrast methods indicated that there was material containing voids within the passages of the solenoid.

• A high density particle was noted within the solenoid within the area of the piston to housing gap.

(Refer to the Computed Tomography Specialist's Factual Report, which is appended to the docket for this report.)

Rudder gust lock actuator examination by Umbra Cusinetti

The rudder gust lock actuator was examined by the manufacturer, Umbra Cusinetti, in the presence of an Italian ASNV representative on June 16, 2015.
According to the Umbra Failure Analysis Report, dated November 11, 2015, the results of the examination revealed the following:

Initial Visual Inspection

• It was observed during the visual inspection that the actuator was locked in a position close to the extended one.

Disassembly and Reported Observations

• when the actuator was placed on a test rig, it did not move when maximum current at rated voltage was supplied.

• when the actuator cover was removed the solenoid/locking system was exposed.

• the electrical board was moved to the side but remained connected.

• the cam that operates the microswitch was observed closed to the microswitch actuating lever, but did not operate it.

• the solenoid was not disassembled.

• the solenoid/locking system was observed locked in the extended position.

• the Pin position was observed close to the full extended position. Measurement of the exact position was prevented by Pin misalignment due to the distortion of the solenoid plastic reel.

• functionality of the microswitch was checked, with positive results.

• when the cap was removed it was observed that the ballscrew moved freely. The cap did not show any signs of interference with closed items.

• resistance of the three windings were acceptable.

• the motor brushes were not checked.

• the rotor OD showed signs of possible interference with the stator.

• the bearings were found operative with no axial play.

Conclusion of the Umbra Cusinetti Examination

The solenoid/locking system was found seized at approximately the full extended position

Rudder Gust Lock Circuit Board Examination

The electronic circuit board within the actuator was examined by the manufacturer, Umbra Cusinetti, on October 14, 2015, in the presence of an Italian ASNV representative. According to the Umbra Failure Analysis Report, dated November 11, 2015, the results of the examination revealed that no evidence of a mechanical failure on components and PCB. Surface coatings have been found damaged.

According to the NTSB Systems Group Chairman's Factual Report, Embraer provided the following comments relative to the Umbra Cusinetti examination:

Rudder Gust Lock Actuator Position Determination

Embraer determined that the rudder gust lock actuator dimensional information gathered during the Umbra Cusinetti examination revealed that with the screwshaft in the "as found" position, the bellcrank would be in contact with the rudder quadrant. It could also engage in the slots on the rudder quadrant.

Rudder Gust Lock Actuator Irreversibility, Spring Forces, and Component Replacement - Embraer Evaluation

Additionally, Embraer commented that the irreversibility of the gust lock actuator is provided by a plunger that is commanded by a solenoid. In normal operation, the spring is not able to overpower the actuator, since the plunger provides an irreversibility function. The below listed information summarizes the forces required to overpower the actuator motor, assuming the solenoid fails in the energized position which prevents the plunger actuation (resulting in a loss of irreversibility), and the forces provided by spring:

• The force required to overpower the energized motor to extend the actuator is approximately 130N;

• The force required to overpower the de-energized motor to extend the actuator is approximately 40N;

• The spring force is at a maximum when the actuator is in the retracted position and the spring is in its maximum extended position (on the order of 40N), and it decreases linearly to its minimum when the actuator is in the extended position (~3N). Considering an actuator stroke of 22.4mm, as observed in this event, the spring force would be in the order of 7N.

• Embraer also stated that, "90% of Phenom 300 fleet has incorporated a new gust lock actuator, which is same PN from ERJ-145 family, with successful operation history and simplified architecture – irreversible jack screw actuation, which does not require solenoid/plunger. Embraer is also about to release an Avionics software update which includes a CAS message that alerts the crew when gust lock actuator is not completely retracted."

(Refer to the NTSB Systems Group Chairman's Factual Report, which is appended to this accident report.)

The investigation failed to conclusively reveal the reason for the failure of the gust lock actuator solenoid.

Administrative Information

Investigator In Charge (IIC):	Little, Thomas
Additional Participating Persons:	Anthony L Wood; Federal Aviation Administration; Riverside, CA Jason Kobi; Transport Safety Board of Canada; Gatineau Ivan Santos de Lima; Centro de Investigacal e Prevencao de Acidentes Vittorio Borsi; ANSV; Rome Alessandro Cometa; ANSV; Rome
Original Publish Date:	January 18, 2017
Last Revision Date:	
Investigation Class:	Class
Note:	The NTSB did not travel to the scene of this incident.
Investigation Docket:	https://data.ntsb.gov/Docket?ProjectID=90419