



National Transportation Safety Board

Washington, D.C. 20594

Safety Recommendation Report

Uncommanded Nosewheel Steering Anomalies During Landing in Embraer EMB-145 Regional Jets

Accident/Incident Numbers:	DCA13WA123, ENG13IA020, ENG11IA047, CEN11IA234
Operators:	ExpressJet Airlines, China Eastern Airlines
Aircraft:	Embraer EMB-145 Regional Jets
Locations:	Multiple
Dates:	2011 through 2013
Adopted:	January 26, 2017

The National Transportation Safety Board (NTSB) is providing the following information to urge Embraer and the Federal Aviation Administration (FAA) to take action on the safety recommendations in this report. These recommendations are derived from our investigations, as well as our participation in foreign-led investigations, of several runway excursion events involving uncommanded nosewheel steering anomalies during landing in Embraer EMB-145 regional jets.¹ As a result of these investigations, the NTSB is issuing two safety recommendations to Embraer and three safety recommendations to the FAA.

Background and Analysis

Manufacturer Acceptance Tests of the Nosewheel Steering Manifold Assembly and Electrohydraulic Servo Valve

On June 7, 2013, about 0925 coordinated universal time, an EMB-145LR, registration B-3052, operating as China Eastern Airlines flight MU2947, departed the left side of runway 18L onto taxiway A2 while landing at Hongqiao International Airport, Shanghai, China, in moderate rain. The flight originated from Huai'an Lianshui Airport, Jiangsu, China. The

¹ (a) "Uncommanded nosewheel steering anomalies" are categorized as "uncommanded swerving events" by the manufacturer and operators; both terms are used throughout the report. (b) Although we have investigated events involving only EMB-145 airplanes, we note that the cockpit layout and nosewheel steering manifolds are the same for the entire Embraer regional jet family, which includes EMB-135, EMB-140, and EMB-145 airplanes. (c) For directional control on the ground, pilots can activate the hydraulic nosewheel steering system on EMB-135, EMB-140, and EMB-145 airplanes with either the steering tiller located on the captain's side or via the rudder pedals.

5 crewmembers and 44 passengers were uninjured, and the nose landing gear sustained minor damage.² After this incident, the nosewheel steering manifold assembly and electrohydraulic servo valve (EHSV) were tested by the components' manufacturers (Parker Aerospace and Woodward HRT, respectively) according to their returned component acceptance test protocols, which are the same tests that newly manufactured components would undergo before delivery.³

After both components passed their respective acceptance tests, they were removed and disassembled; foreign object debris (FOD) was discovered inside the EHSV housing in an area where it could block a hydraulic port, subsequently leading to an uncommanded left nosewheel turn. Parker Aerospace indicated that the FOD was likely segments of an O-ring left inside the EHSV during the manufacturing process (the O-ring was used during the manufacturing process and then should have been removed). Parker Aerospace's and Woodward HRT's returned component acceptance tests failed to detect the FOD.

FOD was also found in an EHSV from a different aircraft after a series of uncommanded swerving events. Between March 19 and 29, 2013, an EMB-145LR, N12922, operated by ExpressJet Airlines, experienced several uncommanded swerving events during multiple landings. Pilots described the uncommanded swerving as a motion in which the aircraft pulled to the left. After ExpressJet Airlines replaced the nosewheel steering manifold assembly, no additional uncommanded swerving events were reported.⁴ The steering manifold assembly removed from the airplane subsequently passed the manufacturers' acceptance tests. However, additional testing, which is not standard protocol for the acceptance tests, found that cold-soaking the manifold assembly produced a fluid flow that could cause an uncommanded nosewheel turn.⁵ Further examination found a foreign gel-like substance between the armature and the electrical coil of the EHSV. When cold-soaked, this substance likely influenced the movement of the armature such that the EHSV induced an uncommanded left turn.

The NTSB is concerned that, in both of these cases, FOD capable of causing an uncommanded nosewheel turn was not able to be identified during the manufacturers' acceptance tests. We conclude that the acceptance tests used by Parker Aerospace and Woodward HRT should be made more effective for detecting FOD that can cause uncommanded nosewheel steering anomalies. Therefore, the NTSB recommends that Embraer, in cooperation with Parker Aerospace and Woodward HRT, study and revise the acceptance test procedures for the nosewheel steering manifold assembly and EHSV on Embraer EMB-135, EMB-140, and EMB-145 aircraft to adequately identify any FOD that may be present.

² The Office of Aviation Safety of the Eastern Regional Administration of the Civil Aviation Administration of China (CAAC) is investigating this incident. As the state of manufacture of the examined components, the NTSB is assisting the CAAC (NTSB case number DCA13WA123). Information for each event summarized in this report can be searched by case number from the NTSB's [Aviation Accident Database web page](#), which can be accessed from www.nts.gov.

³ The EHSV, which is a subcomponent of the nosewheel steering manifold assembly, converts an electrical steering command input into a hydraulic output that is proportional to the signal applied.

⁴ ExpressJet Airlines notified the NTSB of these events, which we began investigating in April 2013. For more information, see NTSB case number [ENG13IA020](#).

⁵ Cold-soaking is not a standard protocol for the acceptance test, which is conducted at room temperature.

Manufacturing Process and Quality Control Program for the EHSV

On August 29, 2011, about 1236 central daylight time, an EMB-145XR, N27152, operated by ExpressJet Airlines as United Express flight 5821, departed the left side of runway 10 during landing at Quad City International Airport, Moline, Illinois. The 3 crewmembers and 50 passengers on board were uninjured, and the airplane sustained minor damage.⁶ The investigation found that the nosewheel steering manifold assembly had been upgraded per Embraer Service Bulletin (SB) 145-32-0099 and that the EHSV contained degraded O-rings.⁷ Postincident examination of the EHSV revealed that a dimension that is critical to preventing deterioration of the damaged O-ring—and was required to be inspected as part of the upgrade recommended in SB 145-32-0099—was outside of tolerance limits.

The NTSB is concerned that this out-of-tolerance condition was not identified during the upgrade per the SB, as intended. As previously discussed, we are also concerned about the presence of FOD that was likely introduced during the EHSV manufacturing process. We conclude that the manufacturing errors and nonconformances found during our investigations of uncommanded nosewheel steering anomalies in EMB-145 regional jets reflect deficiencies in the manufacturing and assembly processes and quality controls for the EHSV. We note that the FAA intends to publish a notice of proposed rulemaking in 2018 regarding requiring safety management systems (SMS) for design and manufacturing organizations; we view safety assurance, one of the four components of SMS, important to ensure that process changes such as those recommended are validated for effectiveness and compliance. Therefore, the NTSB recommends that the FAA (1) review Woodward HRT's manufacturing process and quality control program for the EHSV and require improvements to eliminate manufacturing or assembly errors and nonconformances that could cause uncommanded nosewheel steering anomalies in Embraer EMB-135, EMB-140, and EMB-145 aircraft; and (2) monitor and verify the effectiveness of any improvements.

EMB-145 Pilots' Unapproved Use of Binder Brackets

During the NTSB's investigation of a March 2011 incident in which an EMB-145XR (operated by ExpressJet Airlines as United Express flight UA5916) veered off the runway while landing, we discovered that some EMB-145 pilots use binder brackets instead of the chart holders installed by Embraer to support their books or binders (some of which can be as large as 2 inches thick and weigh several pounds) containing navigation charts and approach plates.⁸ Figure 1 shows

⁶ For more information about this incident, see NTSB case number [ENG11IA047](#).

⁷ In response to several incidents involving uncommanded swerving on the ground due to FOD (caused by deteriorating or damaged O-rings) that was found in the EHSV, Embraer issued SB 145-32-0099 (current revision 03, dated April 8, 2005) in September 2004. The SB recommended upgrading the nosewheel steering hydraulic manifold, which required inspecting specific dimensions that were considered critical for the proper operation of the O-ring seals within the EHSV to ensure that they were within tolerance limits.

⁸ The airplane stopped about 260 ft left of the runway centerline with all gear on soft ground. The 3 crewmembers and 43 passengers were uninjured, and the passengers disembarked onto the grass. The airplane sustained minor damage. The pilot reported that he had used a binder bracket to support his approach plate book and that, during the landing, the book slid off the bracket and onto his lap. The probable cause of this incident was "The uncommanded left deflection of the airplane's nosewheel for reasons that could not be determined because postincident examination of the nosewheel steering system did not reveal any anomalies that would have precluded normal operation." For more information about this incident, see NTSB case number [CEN11IA234](#).

the Embraer-installed and -authorized chart holder.⁹ The binder bracket clips to the chart holder and holds a chart binder open in view of the pilot, eliminating the need, as occurs with use of the Embraer-installed chart holders, to open the binder and remove the individual charts needed for the approach. The brackets can be removed after each flight. One binder bracket attach point, next to the left (captain's) side window, is located directly above and close to the nosewheel steering tiller (also called a steering handle). These binder brackets are not approved by Embraer, and the EMB-135, EMB-140, and EMB-145 *Airplane Operations Manuals* do not reference their use.

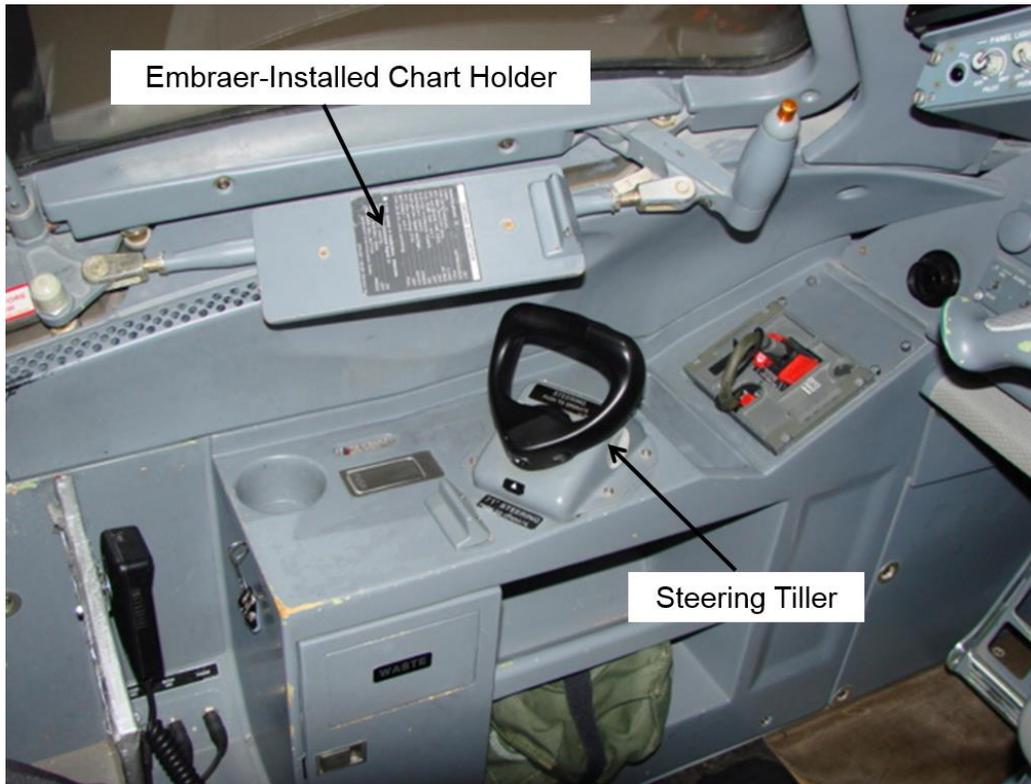


Figure 1. Embraer-installed chart holder and steering tiller locations.

The NTSB is concerned that a binder being held by an unapproved bracket may become dislodged, fall, and strike the tiller, engaging the nosewheel steering system and possibly providing a nosewheel steering input. If this happens during the landing roll, the nosewheel steering input could cause a runway excursion.¹⁰ The NTSB concludes that the use of binder brackets on EMB-135, EMB-140, and EMB-145 airplanes could result in an inadvertent engagement of the nosewheel steering system and a possible runway excursion if a chart binder becomes dislodged from the binder bracket during landing and strikes the tiller. Therefore, the NTSB recommends

⁹ EMB-135, EMB-140, and EMB-145 regional jets are equipped with two chart holders for each pilot that are designed to hold one or several individual charts for reference during flight. One is mounted on the control wheel and one is mounted next to the side window. Some pilots leave their charts in their binder during flight (opened to the needed chart) while others remove the charts from the binder.

¹⁰ The March 2011 incident pilot reported that, at some point, the book may have been in the area of the nosewheel tiller but that it was not on the tiller and that it was clear of the tiller before the airplane exited the runway. Although it is possible that the weight of a book could have engaged the tiller, it could not be determined if the tiller was engaged during the event.

that Embraer issue an operations bulletin informing its operators that the use of binder brackets to hold chart binders is not approved by Embraer and could cause a hazardous condition if a binder becomes dislodged from the bracket. The NTSB further recommends that, after Embraer issues the operations bulletin as recommended in Safety Recommendation A-17-3, the FAA notify operators of Embraer aircraft that the use of binder brackets to hold chart binders could cause a hazardous condition if a binder becomes dislodged from the bracket and encourage operators to comply with the Embraer operations bulletin.

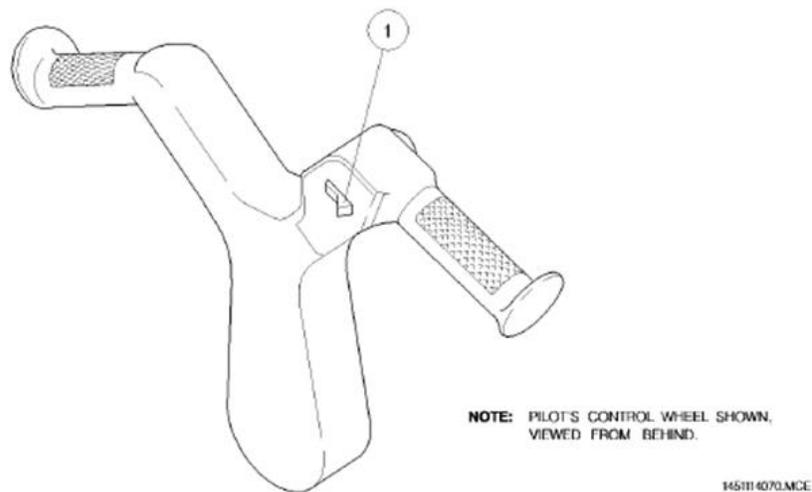
Operator Training for Uncommanded Nosewheel Steering Anomalies

The NTSB reviewed the procedures that US operators of EMB-145 airplanes use for uncommanded nosewheel steering anomalies, with an emphasis on landing roll.¹¹ The procedures recommend that operators disengage the nosewheel steering system by pressing a button on the control wheel if the airplane veers off its intended path (figure 2 shows the control wheel and steering disengage button). However, the NTSB's review revealed that not all operators provide simulator training for such events and that several operators only demonstrate (using Embraer-provided materials) nosewheel steering anomalies during taxi or the low-speed regime of a takeoff, rather than during landing.

CONTROL WHEEL

1 - STEERING DISENGAGE BUTTON

- When pressed disengages the nose wheel steering system.



Source: Embraer.

Figure 2. Pilot control wheel (and steering disengage button) on Embraer regional jets.

¹¹ The procedures for EMB-135 and EMB-140 airplanes are the same as those for EMB-145 airplanes.

While the NTSB believes that, as recommended, improvements to the EHSV manufacturing process are needed to prevent uncommanded nosewheel steering anomalies, enhanced pilot training is still essential to ensure proper management of such a condition should it occur, given its potential to lead to a high-speed runway excursion. We believe that simulator training for this condition would aid pilots in the early recognition of an uncommanded nosewheel steering anomaly and lead to an early disengagement of the system via the steering disengage button, thus giving the flight crew the best opportunity to maintain runway heading should an uncommanded swerving event occur. After the March 2011 incident, ExpressJet Airlines began providing simulator training to its pilots for uncommanded nosewheel steering events on landing. ExpressJet Airlines stated that pilots who experienced actual uncommanded swerving events during line operations and had previously received simulator training for uncommanded nosewheel steering anomalies on landing indicated that the simulator training provided them with valuable experience and the proficiency needed to properly address uncommanded swerving on landing.

The NTSB concludes that the simulator training that ExpressJet Airlines provides to flight crews to disengage the nosewheel steering system if the airplane veers off its intended path during landing could decrease possible loss of directional control and runway excursions. While ExpressJet Airlines currently offers this training, not all other US operators of EMB-135, EMB-140, and EMB-145 airplanes may offer comparable simulator training for uncommanded swerving on landing. The NTSB believes that all US operators of EMB-135, EMB-140, and EMB-145 airplanes would benefit from this simulator training. Therefore, the NTSB recommends that the FAA require operators of Embraer EMB-135, EMB-140, and EMB-145 airplanes to incorporate training for uncommanded swerving on landing in their initial and recurrent simulator training programs.

Recommendations

To Embraer:

In cooperation with Parker Aerospace and Woodward HRT, study and revise the acceptance test procedures for the nosewheel steering manifold assembly and electrohydraulic servo valve on Embraer EMB-135, EMB-140, and EMB-145 aircraft to adequately identify any foreign object debris that may be present. (A-17-2)

Issue an operations bulletin informing your operators that the use of binder brackets to hold chart binders is not approved by Embraer and could cause a hazardous condition if a binder becomes dislodged from the bracket. (A-17-3)

To the Federal Aviation Administration:

(1) Review Woodward HRT's manufacturing process and quality control program for the electrohydraulic servo valve and require improvements to eliminate manufacturing or assembly errors and nonconformances that could cause uncommanded nosewheel steering anomalies in Embraer EMB-135, EMB-140, and EMB-145 aircraft; and (2) monitor and verify the effectiveness of any improvements. (A-17-4)

After Embraer issues the operations bulletin as recommended in Safety Recommendation A-17-3, notify operators of Embraer aircraft that the use of binder brackets to hold chart binders could cause a hazardous condition if a binder becomes dislodged from the bracket and encourage operators to comply with the Embraer operations bulletin. (A-17-5)

Require operators of Embraer EMB-135, EMB-140, and EMB-145 airplanes to incorporate training for uncommanded swerving on landing in their initial and recurrent simulator training programs. (A-17-6)