Final Report AO-2013-011: Runway excursion, British Aerospace Jetstream 32, ZK-VAH, Auckland Airport, 2 November 2013

The Transport Accident Investigation Commission is an independent Crown entity established to determine the circumstances and causes of accidents and incidents with a view to avoiding similar occurrences in the future. Accordingly it is inappropriate that reports should be used to assign fault or blame or determine liability, since neither the investigation nor the reporting process has been undertaken for that purpose.

The Commission may make recommendations to improve transport safety. The cost of implementing any recommendation must always be balanced against its benefits. Such analysis is a matter for the regulator and the industry.

Final Report

Aviation inquiry AO-2013-011

Runway excursion
British Aerospace Jetstream 32, ZK-VAH
Auckland Airport
2 November 2013

Approved for publication: February 2017

Transport Accident Investigation Commission

About the Transport Accident Investigation Commission

The Transport Accident Investigation Commission (Commission) is a standing commission of inquiry and an independent Crown entity responsible for inquiring into maritime, aviation and rail accidents and incidents for New Zealand, and co-ordinating and co-operating with other accident investigation organisations overseas. The principal purpose of its inquiries is to determine the circumstances and causes of the occurrences with a view to avoiding similar occurrences in the future. Its purpose is not to ascribe blame to any person or agency or to pursue (or to assist an agency to pursue) criminal, civil or regulatory action against a person or agency. The Commission carries out its purpose by informing members of the transport sector and the public, both domestically and internationally, of the lessons that can be learnt from transport accidents and incidents.

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Important notes

Nature of the final report

This final report has not been prepared for the purpose of supporting any criminal, civil or regulatory action against any person or agency. The Transport Accident Investigation Commission Act 1990 makes this final report inadmissible as evidence in any proceedings with the exception of a Coroner's inquest.

Ownership of report

Citations and referencing

Information derived from interviews during the Commission's inquiry into the occurrence is not cited in this final report. Documents that would normally be accessible to industry participants only and not discoverable under the Official Information Act 1982 have been referenced as footnotes only. Other documents referred to during the Commission's inquiry that are publicly available are cited.

Photographs, diagrams, pictures

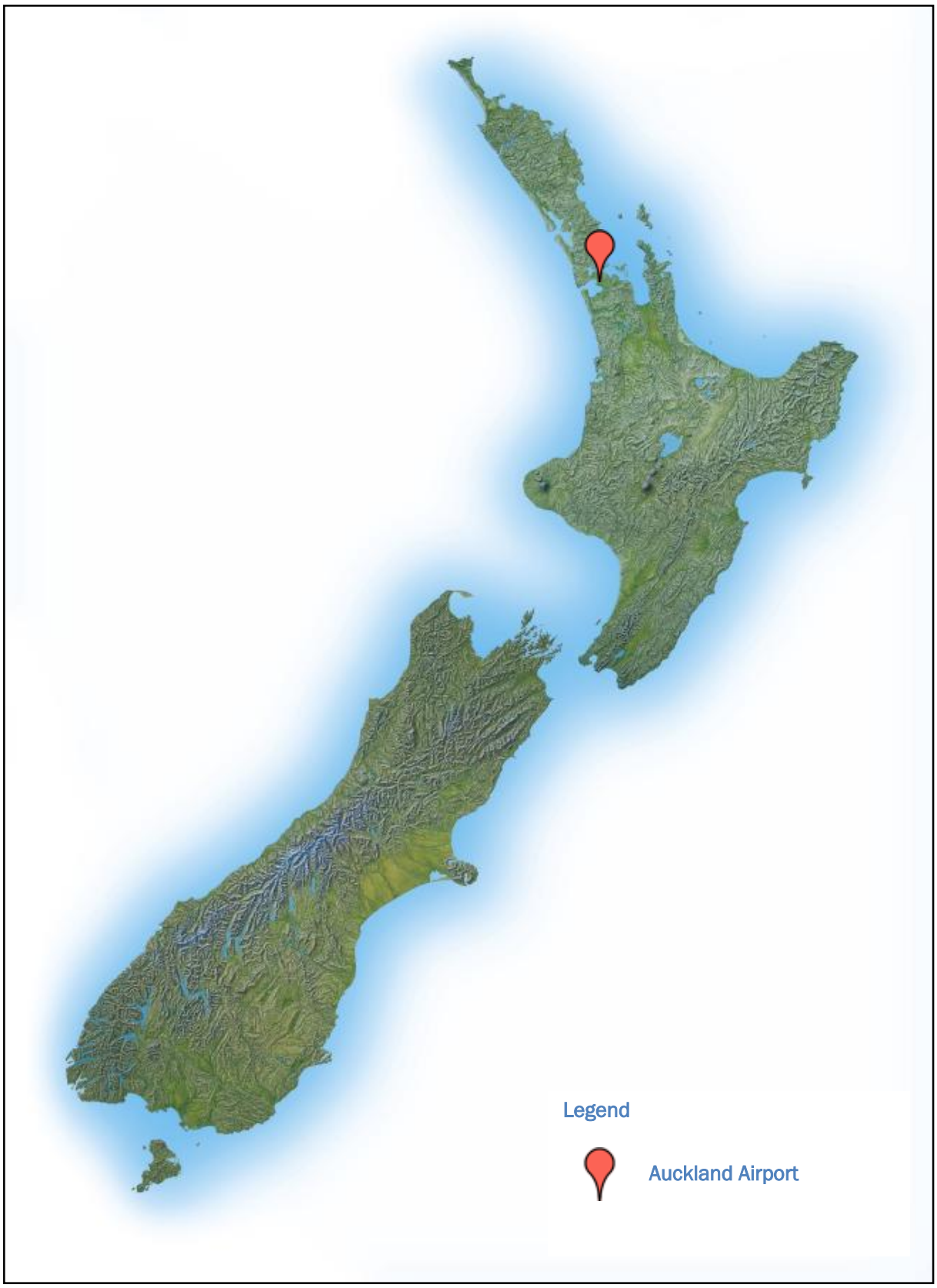
Unless otherwise specified, photographs, diagrams and pictures included in this final report are provided by, and owned by, the Commission.

Verbal probability expressions

The expressions listed in the following table are used in this report to describe the degree of probability (or likelihood) that an event happened or a condition existed in support of a hypothesis.

Terminology (Adopted from the Intergovernmental Panel on Climate Change)	Likelihood of the occurrence/outcome	Equivalent terms
Virtually certain	> 99% probability of occurrence	Almost certain
Very likely	> 90% probability	Highly likely, very probable
Likely	> 66% probability	Probable
About as likely as not	33% to 66% probability	More or less likely
Unlikely	< 33% probability	Improbable
Very unlikely	< 10% probability	Highly unlikely
Exceptionally unlikely	< 1% probability	

British Aerospace Jetstream 32, ZK-VAH



Source: mapsof.net

Location of the incident

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Abbreviations

Commission	Transport Accident Investigation Commission
m	metre(s)
V_1	take-off decision speed

Glossary

asymmetric power or braking	a difference in engine power or braking between the left and right engines or brakes
knot	a speed of one nautical mile per hour, equal to 1.85 kilometres per hour
runway excursion	when an aeroplane leaves the runway surface, either at the end of the runway (an overrun) or off the side (a veer-off)
take-off decision speed	the speed by which a decision to reject a take-off must be made, usually referred to as V_1

Data summary

Aircraft particulars

Aircraft registration:	ZK-VAH
Type and serial number:	British Aerospace Jetstream 32, 967
Number and type of engines:	two Garrett AiResearch TPE331 turbo-propeller
Year of manufacture:	1992
Operator:	Vincent Aviation Limited
Type of flight:	scheduled domestic passenger
Persons on board:	16
Pilot's licence:	airline transport pilot licence (aeroplane)
Pilot's age:	38
Pilot's total flying experience:	5,131 hours (2,212 hours on type)

Date and time	2 November 2013, 1501[1]
Location	Auckland Airport
	latitude: 37° 00.5′ south
	longitude: 174° 47.5′ east
Injuries	nil
Damage	nil

[1] Times in this report are in New Zealand Daylight Time (Co-ordinated Universal Time + 13 hours) and expressed in the 24-hour format.

1. Executive summary

1.1. On 2 November 2013 a British Aerospace Jetstream 32 aeroplane taking off from Auckland Airport started to veer left from the runway centreline. The captain was initially able to correct the heading change, but at about 90 knots the turn became uncontrollable. The aeroplane slowly ran off the left side of the runway before the captain could bring it to a stop. No-one was injured and there was no damage to the aeroplane or any airport infrastructure.

1.2. The Transport Accident Investigation Commission (Commission) made the following findings:

- the uncommanded turn to the left during take-off was caused by a faulty steering selector
- the defective component within the steering selector could not be determined because of incomplete overhaul records
- the isolated nature of the component failure in this occurrence, and the actions the manufacturer had previously undertaken, meant that additional changes to the relevant maintenance procedures were not warranted.

1.3. The Commission made no recommendation as a result of its inquiry.

1.4. The key lesson identified from the inquiry into this occurrence was:

- prompt action by a pilot on recognising a loss of directional control during take-off or landing will minimise the risk of a runway excursion.

2. Conduct of the inquiry

2.1. The Civil Aviation Authority of New Zealand notified the Transport Accident Investigation Commission (Commission) of the incident at 1520 on Saturday 2 November 2013, approximately 20 minutes after it had occurred. The Commission gave permission for the aeroplane to be removed from the side of the runway and to be taken to a secure hangar. Two Commission investigators travelled to Auckland the next day to examine the aeroplane.

2.2. The steering jack and steering selector, two components of the nose wheel steering system, were removed and sent to repair and overhaul facilities in the United States for examination. Samples of the steering system hydraulic fluid were taken for analysis. The flight data recorder was sent to a facility in Sydney, Australia, for downloading. Relevant records were obtained from air traffic control and the aerodrome operator.

2.3. On 4 November 2013 the two pilots were interviewed at the operator's base in Wellington, and various aeroplane and operator records obtained.

2.4. In early 2014 the reports on the examinations of the two steering components were received and follow-up enquiries were made.

2.5. On 28 September 2016 the Commission approved this report for circulation to interested persons for comment. One submission was received and the final report has considered that submission.

2.6. On 22 February 2017 the Commission approved this final report for publication.

3. Factual information

3.1. The flight

3.1.1. On Saturday 2 November 2013, a British Aerospace[2] Jetstream 32 ZK-VAH (the aeroplane) was being used for scheduled services to and from Auckland. At about midday a replacement crew arrived from Wellington to complete the remainder of the day's flying. The outgoing crew informed the replacement crew that there were no faults or concerns with the aeroplane.

3.1.2. At 1455, with 14 passengers on board, the engines were started for a flight to Taupo. A tight turn to the left through about 180° was required in order to leave the terminal parking area. The captain said a combination of full nose wheel steering, asymmetric power[3] and asymmetric braking was required to turn the aeroplane. The aeroplane was then taxied to runway 23 Left (see Figure 1).

Figure 1
Taxi path to the runway

3.1.3. At about 1501 the aeroplane was given clearance to take off. The weather was fine with a light crosswind from the left. The captain said that the power was increased progressively on both engines and the aeroplane accelerated normally. She kept the aeroplane on the runway centreline initially by the use of nose wheel steering.

3.1.4. After the first officer had made the standard '70 knots'[4] airspeed check call, the captain transferred directional control from the nose wheel steering to the rudder pedals. At about this time the crew noticed a slight swing to the left. This was corrected by applying some right rudder. The aeroplane subsequently started to veer left again. The captain was unable to counter the second veer to the left using full right rudder, and the aeroplane drifted towards the edge of the runway.

3.1.5. The captain called "stopping" as she closed both power levers. She then used a combination of nose wheel steering and asymmetric braking to try to keep the aeroplane on the runway. The first officer relayed the "stopping" call to the control tower during this time. The aeroplane came to a stop in the grass about 15 metres (m) from the runway (see Figure 2).

[2] British Aerospace merged with Marconi Electronic Systems in 1999 to become BAE Systems.
[3] A difference in power or thrust between the left and right engines.
[4] A knot is a speed of one nautical mile per hour, equal to 1.85 kilometres per hour.

3.1.6. The engines were shut down and the passengers kept on board until emergency services arrived. No-one was injured and there was no damage to the aeroplane or ground installations as a result of the runway excursion.[5] The aeroplane was later towed to a hangar to await the arrival of Commission investigators.

Figure 2
The aeroplane where it stopped

3.2. Personnel information

3.2.1. The captain held an air transport pilot licence (aeroplane) issued in 2007 and a current class one medical certificate. She had obtained her Jetstream 32 type rating in November 2005 and joined the operator in July 2012 as a captain. At the time of the occurrence she had accrued 5,131 flight hours, including 2,212 hours on the Jetstream 32.

3.2.2. The captain's previous line check had been on 18 June 2013. She had flown 22 hours in the preceding 30 days and 2.2 hours in the preceding seven days. She had had a rest day on the day before the occurrence and said that she had been well rested and fit to fly on the day of the occurrence.

3.2.3. The first officer held a commercial pilot licence (aeroplane) issued in 2008, and a current class one medical certificate. He had obtained his Jetstream 32 rating in September 2012, soon after joining the operator. At the time of the occurrence the first officer had accrued 1,250 flight hours, including 320 hours on the Jetstream 32.

3.2.4. The first officer's previous line check had been on 17 December 2012. He had flown 32 hours in the 30 days preceding the occurrence and 10 hours in the preceding seven days. The two days prior to the occurrence had been free of duty. He said he had been well rested and fit to fly on the day of the occurrence.

[5] A runway excursion occurs when an aeroplane leaves the runway surface, either at the end of the runway (an overrun) or off the side (a veer-off).

3.3. Aircraft information

3.3.1. The Jetstream 32 was a development of the Jetstream 31 that had been first certificated in 1982. It was powered by two Garrett AiResearch[6] TPE331 turbo-propeller engines and capable of carrying a two-pilot crew and 19 passengers.

3.3.2. The aeroplane had been manufactured in the United Kingdom in 1992 and flown for seven years in the United States before being sold to an operator in New Zealand and then to one in Australia. In June 2012 the aeroplane had been returned to New Zealand, registered as ZK-VAH and joined with three other Jetstream aeroplanes in the operator's fleet.[7]

3.3.3. Nose wheel steering was controlled through a tiller (handle) located on the left side of the cockpit next to the captain's seat. A mechanical linkage connected the tiller to the steering selector, which directed hydraulic pressure to a steering actuator mounted on the nose gear housing (see Figure 3). The actuator turned the nose wheel. A feedback loop ensured that the nose wheel position matched the tiller movement and position.

Maintenance defect history

3.3.4. On 8 February 2013, 10 months before the incident, a pilot had reported that during take-off the aeroplane "yawed [turned] left significantly". Full right rudder had been used to keep the aeroplane aligned with the runway. During an examination of the aeroplane a nose wheel axle nut was found to be cracked and the steering jack determined to be faulty. Those items were replaced. No other fault was found with the steering system, so the aeroplane was returned to service. At the time it had flown 18,724 hours and completed 29,646 landings (cycles).

3.3.5. On 9 August 2013, three months before the incident, a crew had reported that during take-off the aeroplane drifted left. Loose play was found in several components of the nose wheel steering system. The steering jack was bled of any trapped air and the main wheel brake units were swapped around. The flight deck steering handle was also replaced. Testing was unable to replicate the problem and the aeroplane was returned to service. Pilots were asked to report any further concerns. On 18 October 2013, two months before the incident, with no further problems reported, the defect was recorded as rectified.

3.3.6. On the day of the occurrence, 2 November 2013, the aeroplane had accrued 18,909 flight hours and 29,978 landings.

3.4. Recorder information

3.4.1. The aeroplane was fitted with a flight data recorder that recorded 11 parameters, including the heading, airspeed and the torque and propeller speed of both engines. The recorder was removed and sent for downloading of the data. The cockpit voice recorder was not accessed.

3.4.2. The data showed that the first veer to the left occurred as the aeroplane speed approached about 70 knots. The second veer left started at about 90 knots. The engine power was reduced to flight idle at about 100 knots.

3.4.3. The data showed that power was increased simultaneously on both engines for the take-off and that there was no asymmetric power as the aeroplane accelerated. After the captain commenced the rejected take-off, more reverse power was applied to the right engine than to the left engine as the captain attempted to turn the aeroplane back to the right.

3.4.4. Aerodrome ground surveillance data showed that during the attempted take-off the aeroplane maintained the runway centreline for about 200 m before starting to move left. The move to the left was corrected for about 100 m and the aeroplane was returned to near the centreline,

[6] Later Honeywell Aerospace.
[7] In October 2014 the operator ceased all operations.

where it stayed for about the next 200 m. The aeroplane then veered increasingly to the left and ran off the runway about 600 m from the start of the take-off roll.

3.5. Testing of nose wheel steering system

3.5.1. An initial examination of the aeroplane identified no engine, main undercarriage or brake system anomalies. The focus of the investigation then moved to the nose wheel steering system.

3.5.2. The nose wheel was placed on a greased plate to enable it to turn easily while it supported a normal load. The hydraulic system was then pressurised. Repeated movements of the nose wheel tiller were unable to produce an uncommanded left turn. No abnormalities were identified by this test.

3.5.3. Samples of hydraulic fluid were taken for analysis, including from the hydraulic line close to where the steering jack and steering selector were located. The samples were subjected to a spectroscopic analysis, which confirmed that the fluid was of the correct type with no anomalies.

3.5.4. The steering jack and steering selector were then removed for detailed examination by two different approved overhaul facilities in the United States.

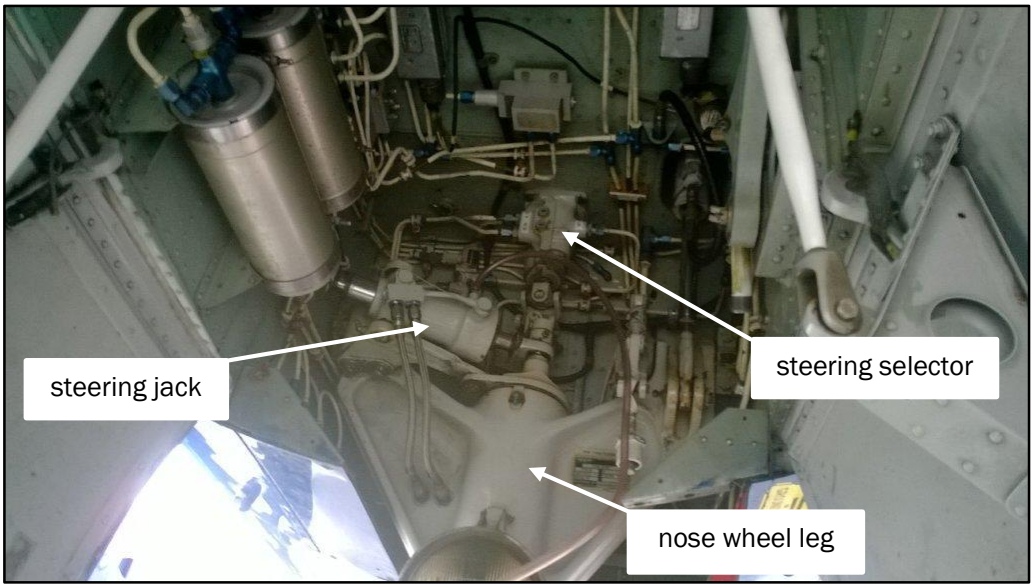

Figure 3
Steering components
(looking rearward)

3.5.5. A functional check and disassembly of the steering jack found no fault that may have contributed to the uncommanded left turn.

3.5.6. The overhaul facility that examined the steering selector identified two related faults during testing. Following "full counter-clockwise input to the selector, upon release the valve would stick and allow fluid to continually flow from [a] port"[8]; and "excessive internal valve leakage was observed". The overhaul facility then disassembled the selector and found that the faults were caused by 'spring boxes' being out of adjustment. The spring boxes balanced the hydraulic pressure between the control pressure commanded by the pilot and the resultant steering forces from the nose wheel position.

3.5.7. The overhaul facility stated that because the steering selector locking tabs were still intact before disassembly, the misadjustment "must have been directly related to the springs". These faults would direct hydraulic pressure to go to the left-turn side of the steering actuator. The overhaul facility further commented in its report that "the probable cause of the spring

[8] This was the port that commanded a left turn.

boxes being out of adjustment is due to fatigue of the spring" and that from its experience this was "an isolated incident".

4. Analysis

Runway excursions

4.1. The International Civil Aviation Organization considers a runway excursion, which can occur during take-off or landing, to be a 'serious incident'[9], because it has the potential to cause significant damage and fatal injuries.

4.2. In this incident there were no injuries or damage because the crew responded appropriately and the aeroplane departed the runway at slow speed. There was also a flat, grassed area, free of obstructions, beside the runway, which provided a safe run-off area.

4.3. The following analysis discusses what happened and why the steering system failed.

What happened

4.4. The taxi from the parking spot, which included several tight turns, and the initial line-up on the runway were normal. During the take-off the captain used the nose wheel steering tiller to control the heading and remain on the runway centreline. Small directional changes during the early phase of a take-off roll are not unusual and can have a number of causes, including starting the take-off with the nose wheel not aligned with the runway heading, an uneven application of engine power, and a crosswind. There was no indication of a control problem until the aeroplane started to veer left at about 70 knots.

4.5. The uncommanded and unexpected turn to the left occurred below the take-off decision speed.[10] The captain's decision to stop the take-off was timely and correct. The captain then controlled the aeroplane using a combination of nose wheel steering, rudder, asymmetric braking and asymmetric reverse thrust as it approached the edge of the runway. The prompt response ensured that the aeroplane was at a slow speed when it left the runway.

Steering system failure

4.6. The uncommanded turn to the left was determined to have been caused by a faulty steering selector. The steering selector had been installed on 20 July 2012 to replace another selector removed for scheduled overhaul.[11] At the time of the incident the selector had accrued 575.7 hours in service over a period of 16 months and 931 landings. The allowable service life was 10,000 landings or six years, whichever came first.

4.7. The examination of the steering selector after the incident traced the fault to incorrect spring tensions within the spring box of the steering selector, which affected the internal hydraulic pressure. This fault intermittently allowed uncontrolled hydraulic fluid to flow from the selector to the steering actuator, but only in the direction that turned the aeroplane to the left.

4.8. The spring tensions and differential pressure can only be adjusted before the final assembly of the steering selector during manufacture or after overhaul. To ensure that the steering selector operates as intended, it is subjected to a full functional test after assembly. If the spring tension is incorrect, it should be identified during the functional test and be corrected before the steering selector is released for service.

Steering selector overhaul history

4.9. The operator held records for the selector that dated back to June 2006. The steering selector had been most recently overhauled in the United States by the same approved overhaul facility that did the examination after the occurrence. The overhaul facility's records stated that the steering selector had been received on 13 January 2012, disassembled and cleaned. All seals, O-rings and backing rings had been replaced. There was no record that the

[9] International Civil Aviation Organization Annex 13 to the Convention on International Civil Aviation, Attachment C: List of Examples of Serious Incidents.
[10] The speed by which a decision to reject a take-off must be made, usually referred to as V_1.
[11] The overhaul returned the selector to an 'as new' condition.

springs in the spring box were replaced at this time. According to the overhaul facility the reuse of springs was common practice and permitted by the maintenance manual. Therefore, it was virtually certain that the previously fitted springs were reused. On 22 May 2012 the selector was reassembled, tested and "found to be operating within all prescribed limits". It was then returned to the operator.

4.10. The overhaul facility advised that it was not its practice to retain test records following reassembly. If a steering selector failed the functional test, it was disassembled and any fault rectified before reassembly and a second test. If the springs had been incorrectly adjusted during the reassembly of the steering selector, this would very likely have been detected during the functional testing, which was not the case. The overhaul facility stated that the only other reason for the spring tensions to be out of limits was that the springs had become worn or had lost their elasticity.

Similar incident

4.11. The investigation was able to identify only one other similar occurrence. On 30 June 1998 a Jetstream 31 was taking off from London (Stansted) Airport in England when it started to veer to the left. The pilot was unable to correct the left veer and the aeroplane ran off the side of the runway.[12]

4.12. The investigation of that occurrence had determined the fault to be "worn rocker spring plungers" in the steering selector. (The springs and rocker spring plungers are both contained within the steering selector and work in conjunction, but are separate components.) The wear resulted in excess clearances that resulted in a small valve offset and allowed fluid to continue to flow to the actuator. This prevented the rocker returning to a null position from left steer inputs by the pilot. As a result of that incident, the aeroplane manufacturer had amended the time between overhauls of the steering selector from 10,000 hours to 10,000 landings or six years, whichever came first.[13]

The 2 November 2013 failure

4.13. The fault was confirmed as originating in the steering selector. The overhaul facility stated that the fault was with the springs and in its experience an isolated occurrence. However, British Aerospace stated that there was "no data that suggests any issue with the life of the spring[s]". The aeroplane manufacturer further advised that the manufacturer of the steering selector had stated that since 2006 it had not had to replace the springs because of fatigue or any other fault.

4.14. Because the overhaul facility's test and inspection reports lacked sufficient detail, it could not be determined whether the springs or the rocker spring plungers were the cause of the steering incident at Auckland.

4.15. This occurrence was the only recorded such failure of a steering selector since 1998. Therefore there was insufficient evidence to warrant a change in maintenance practices beyond the changes made in 1999.

[12] Air Accident Investigation Branch Bulletin No:1/2000, Jetstream 31, G-LOVA runway excursion at London (Stansted) Airport on 30 June 1998.
[13] British Aerospace, Jetstream Series 3100 & 3200 Service Bulletin, Civil Aviation Authority Mandatory, 32-JA980841 effective 15 July 1999.

5. Findings

5.1. The uncommanded turn to the left during take-off was caused by a faulty steering selector.

5.2. The defective component within the steering selector could not be determined because of incomplete overhaul records.

5.3. The isolated nature of the component failure in this occurrence, and the actions the manufacturer had previously undertaken, meant that additional changes to the relevant maintenance procedures were not warranted.

6. Safety issues

6.1. No safety issues were identified.

7. Safety actions

General

7.1. The Commission classifies safety actions by two types:

(a) safety actions taken by the regulator or an operator to address safety issues identified by the Commission during an inquiry that would otherwise result in the Commission issuing a recommendation

(b) safety actions taken by the regulator or an operator to address other safety issues that would not normally result in the Commission issuing a recommendation.

Safety actions addressing safety issues identified during an inquiry

7.2. Nil.

Safety actions addressing other safety issues

7.3. Nil.

8. Recommendation

General

8.1. The Commission may issue, or give notice of, recommendations to any person or organisation that it considers the most appropriate to address the identified safety issues, depending on whether these safety issues are applicable to a single operator only or to the wider transport sector. In this case no recommendation was made.

9. Key lesson

9.1. Prompt action by a pilot on recognising a loss of directional control during take-off or landing will minimise the risk of a runway excursion.

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Price $13.00

ISSN 1179-9080 (Print)
ISSN 1179-9099 (Online)