Inquiry 11-004: Piper PA31-350 Navajo Chieftain, ZK-MYS
landing without nose landing gear extended
Nelson Aerodrome, 11 May 2011

Final Report

Aviation Report 11-004

Piper PA31-350 Navajo Chieftain, ZK-MYS landing without nose landing gear extended

Nelson Aerodrome, 11 May 2011

Approved for publication: July 2013

Transport Accident Investigation Commission

About the Transport Accident Investigation Commission

The Transport Accident Investigation Commission (Commission) is 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 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, 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 1980 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.

Piper PA31-350 Navajo Chieftain, ZK-MYS

Source: mapsof.net

Location of accident

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Abbreviations

°	degree(s)
air2there	air2there.com (2008) Limited
Air West Coast	Air West Coast Engineering Limited
CAA	Civil Aviation Authority
Commission	Transport Accident Investigation Commission
Fieldair	Fieldair Engineering Limited
Piper	Piper Aircraft Inc., USA

Glossary

bushing (or bush)	the most common form of independent plain bearing
instructor rating	an authorisation associated with a pilot's licence and based on their flight experience and training, which has privileges and limitations for the training, testing and examining of other pilots
Interested Person	a specified person to whom the Commission must give the opportunity to comment on or refute any statement or inference in the report that that person's conduct contributed to the cause of the accident or incident being investigated. The Commission also considers the recipient of a safety recommendation to be an Interested Person

Data summary

Aircraft particulars

Aircraft registration:	ZK-MYS
Type and serial number:	Piper PA31-350 Navajo Chieftain, 31-7652032
Number and type of engines:	one Lycoming TIO-540-J2BD and one LTIO-540-J2BD reciprocating
Year of manufacture:	1976
Operator:	air2there.com (2008) Limited (air2there)
Type of flight:	pilot flight test
Persons on board:	2
Pilots' licences:	(both) airline transport pilot licence
Pilots' ages:	pilot under test – 53, examiner – 48
Pilots' flying experience:	pilot under test – approximately 16 115 total hours and 300 hours on type examiner – approximately 10 100 total hours and 40 hours on type
Date and time	11 May 2011, 1301[1]
Location	Nelson Aerodrome latitude: 41°17.8´ south longitude: 173°13.5´ east
Injuries	nil
Damage	substantial to nose section and propellers

[1] Times in this report are New Zealand Standard Time (co-ordinated universal time +12 hours) expressed in the 24-hour format.

1 Executive summary

1.1 On 11 May 2011 the nose landing gear of a Piper PA31-350 Navajo Chieftain (the aeroplane) jammed in a partially retracted position during a training flight at Nelson Aerodrome. The nose landing gear could not be extended again, and in the subsequent landing the aeroplane sustained substantial damage. Neither of the 2 pilots, the only persons on board, was injured.

1.2 The nose landing gear jammed as a result of wrong parts and incorrect maintenance, over a number of years, which allowed the landing gear to turn too far when full rudder was applied during the training exercise. The increased angle and misalignment between 2 key components prevented the nose landing gear centring during the retraction, and the jam ensued.

1.3 This aeroplane had a recent history of nose landing gear defects, including other failures to extend or retract normally. Some of the rectifications of the earlier defects, carried out by various maintenance organisations, had not been in accordance with Civil Aviation Rules, because incorrect parts or unauthorised repairs had been used, and the aeroplane manufacturer's Maintenance Manual procedures had not been followed.

1.4 The Transport Accident Investigation Commission (Commission) made findings related to the cause of the accident, the standard of aircraft maintenance and the limited requirement for duplicate inspections.

1.5 The investigation identified the following safety issues:

- an inadequate standard of maintenance performed by a range of organisations and persons on the aeroplane
- the standard of maintenance for general aviation aircraft in New Zealand needs to be improved.

1.6 The Commission made recommendations to the Director of Civil Aviation that he take action, in concert with the aviation industry, with the goal of improving the level of compliance throughout the general aviation maintenance sector; and that he widen the range of maintenance that requires a duplicate check, at least for aircraft used in air transport operations, in order to reduce the likelihood of recurring defects and incidents.

1.7 The Commission noted the following key lessons from this inquiry:

- persons who work on aircraft must refer to the appropriate technical data and instructions, including maintenance manuals, to ensure that the correct procedures are followed fully. Effective supervision requires that supervisors physically check completed tasks before the tasks are signed off
- a physical check of a part taken off or installed, and comparison with the appropriate reference data, will ensure that the part is correct. Part number errors can arise, and be perpetuated, if reference is made only to the previous log book entry (which might be wrong)
- the correct part name and part number must be used in aircraft maintenance documentation to help avoid installation errors
- defect rectification is not completed just by repairing or replacing the defective part. The cause of the defect must be established and rectified as well. When maintenance is performed away from the usual base, it is important that the engineer is informed of any relevant recent or possible recurring defects
- the prompt receipt and review of loose-leaf log book entries by Maintenance Controllers can help with their recognition of possible recurring defects.

2 Conduct of the inquiry

2.1 The Civil Aviation Authority (CAA) notified the Commission of the accident on 11 May 2011 and the Commission opened an inquiry that day. The Commission appointed an independent licensed aircraft maintenance engineer to assist with the technical investigation.[2]

2.2 The aeroplane was removed from the runway soon after the accident and inspected on 12 May, 24 May and 7 June, after which it was released to the operator for repair. Interviews were conducted with the 2 pilots, the operator's management and those persons and maintenance organisations that had been involved with the maintenance of the aeroplane since 2007.

2.3 The aeroplane manufacturer and the CAA were consulted on aspects of the inquiry.

2.4 On 22 May 2013 the Commission approved the draft final report for circulation to Interested Persons for their comment.

2.5 Submissions were received from the CAA, one of the pilots involved in the accident and 5 of the engineers who had performed maintenance functions in regard to the aeroplane. The Commission has considered all submissions, and any changes as a result of those submissions have been included in this final report.

2.6 On 25 July 2013 the Commission approved the final report for publication.

[2] Mr Owen Stewart is a director of S3 Systems and Safety Solutions Limited, an independent consulting company. He has more than 34 years' experience in aircraft engineering and associated disciplines, including quality assurance and risk compliance in aviation engineering and airport operations; and air safety investigations.

3 Factual information

3.1 History of the flight

3.1.1 The aeroplane was owned and operated by air2there. On 11 May 2011 it was being used for a flight crew operational competency assessment flight. The flight examiner (the examiner) and the pilot being assessed (the pilot) were the only persons on board.

3.1.2 The flight began at Nelson Aerodrome. An engine failure exercise was simulated shortly after the landing gear was retracted on take-off. Later the aeroplane was making an instrument approach back into Nelson. The pilot had extended the landing gear when the examiner again simulated an engine failure by reducing the power to idle on one engine. The pilot continued the approach and applied enough rudder to counter the asymmetric thrust before selecting the landing gear up. The main landing gear retracted, but the landing gear "unsafe" light remained illuminated.

3.1.3 At the minimum altitude for the instrument approach, full power was restored to both engines and the examiner stopped the exercise. The pilot cycled the landing gear twice, but the landing gear unsafe light remained illuminated. The pilot could see in the inspection mirror attached to the left engine cowl that the nose leg was turned about 45 degrees (°), but otherwise it looked normal.

3.1.4 The examiner informed air traffic control, who cleared the pilots to hold clear of the aerodrome while they tried to resolve the problem.

3.1.5 The pilots referred to on-board documents and discussed the situation by telephone with the air2there base at Paraparaumu in an attempt to correct the fault. The hydraulic system, which powered the normal operation of the landing gear, appeared to be working normally. The pilots tried the hydraulic system emergency hand-pump, without success. At 1224 they requested that the aerodrome emergency services be placed on "local standby", but they did not declare a condition of urgency.[3,4]

3.1.6 At 1247 the pilots declared a "full emergency". At 1303 the aeroplane landed and the examiner shut down both engines before the nose was lowered to the runway. Neither pilot was injured, but the aeroplane incurred substantial damage to the propellers and underside of the nose cone (see Figure 1).

3.2 Personnel information

3.2.1 The pilot held a New Zealand airline transport pilot licence, first issued in 1990. He had more than 16 000 flying hours, of which approximately 300 hours were on the Piper PA31 series of aeroplanes that included the Chieftain and the smaller Navajo. His PA31 type rating had been issued in 1988, but he had not flown a Chieftain for many years prior to 11 May 2011.

3.2.2 He was also a designated flight examiner and an A-category flight instructor. He had been contracted by air2there in March 2011 to be the Check and Training Manager for flight operations. In that role he was required to be in current flying practice on both the Chieftain and the Cessna 208 Caravan aeroplanes in the air2there fleet.

3.2.3 In the 7 days prior to the accident the pilot had flown 8 hours in 3 different aeroplane types, but none in a Chieftain. He held a current Class 1 medical certificate and said he had been fit for duty on 11 May 2011.

3.2.4 The examiner was designated by the CAA to provide flight examiner services. He held an airline transport pilot licence, first issued in 2002, and a D-Category flight instructor rating. He had more than 10 100 flight hours, including approximately 40 hours accrued on the Piper PA31 series since 2005.

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[3] "Local standby" and "full emergency" are phases in an aerodrome emergency response plan. In the local standby phase, aerodrome emergency services are in a state of readiness, but a safe landing is expected. A full emergency is declared if there is a danger of an accident, and off-airport emergency services will then attend.

[4] "Urgency" is a condition concerning the safety of an aircraft that does not require immediate assistance.

3.2.5 In the 7 days prior to the accident, the examiner had flown 10 hours in 3 different aeroplane types, but none in a Chieftain. He held a current Class 1 medical certificate and said he had been fit for duty on 11 May 2011.

Figure 1
The aeroplane after landing
(Photo courtesy Nelson Airport Limited)

3.3 Aircraft information

3.3.1 The Chieftain is a twin-engine, 10-seat aeroplane with retractable tricycle landing gear. The aeroplane involved in this accident was manufactured in 1976 in the United States by Piper Aircraft (Piper).[5] Production of the type ceased in 1984. The aeroplane was imported to New Zealand in 1982 and since then it had been operated on air transport flights. In November 2004 it was purchased by the predecessor to air2there and the registration was changed to ZK-MYS. The aeroplane's maximum certificated take-off weight was 3175 kilograms.

3.3.2 The aeroplane had a Standard category airworthiness certificate that was non-terminating if the aeroplane was "maintained and operated in accordance with the [Civil Aviation Rules] and pertinent operating limitations". air2there could not find the log books for maintenance performed on the aeroplane prior to 19 November 2004. Those that were available indicated that the aeroplane had been maintained in accordance with the air2there maintenance programme.

3.3.3 The most recent annual review of airworthiness had been completed on 5 December 2010. The most recent scheduled maintenance completed was a 50-hour check carried out by Air West Coast Engineering Limited (Air West Coast) on 26 April 2011 at 23 157.8 airframe hours, and since then the aeroplane had been operated without incident. Immediately prior to the accident flight, the aeroplane had accrued 23 184.3 flight hours.

Nose landing gear description

3.3.4 The main and nose landing gear legs are hydraulically actuated and when retracted they are enclosed by doors. The 2 nose landing gear doors remain open when the nose landing gear is extended. The nose landing gear has a single wheel and retracts rearwards into the fuselage.

[5] The current type certificate holder was Piper Aircraft, Inc.

3.3.5 The nose wheel is mounted within the nose wheel fork, which is attached to a shock-absorbing piston. The piston and its cylinder are contained within the nose landing gear housing. A steering arm and a nose wheel alignment guide are bolted to the top of the cylinder. The steering arm has a protruding bushing on each side. The steering arm and alignment guide rotate with the cylinder during nose wheel steering.

3.3.6 When the pilot pushes on the rudder pedals, this causes a steering bell-crank to turn. This bell-crank is located at the top of the nose wheel well. The bell-crank is connected to the rudder via cables, thus pushing on the rudder pedals moves the rudder. Rudder pedal movement is limited by "travel stops" mounted on the rudder.

3.3.7 When the nose landing gear is locked down, the bushings on the steering arm on top of the housing contact the bell-crank. In this condition, when the pilot moves the rudder pedals the bell-crank turns and, through contact with the steering arm, the nose wheel turns at the same time as the rudder. Thus the rudder pedals control the heading of the aircraft both in the air and on the ground (see Figure 2).[6] The nose wheel steering angle is limited by stops on the lower rim of the housing. On early-build Chieftains, the nose wheel can turn up to 20° either side (±20°) of the aeroplane centreline when the aeroplane is towed or taxied.

3.3.8 Piper Service Spares Letter No. 352, issued in 1980, described a modification to allow the nose landing gear to disengage temporarily from the rudder pedal steering and permit the steering angle to increase to ±40°.[7] The increased angle was primarily to allow for easier towing, but also allowed tighter taxi turns by using differential brakes and power. With that modification embodied, as the nose wheel was straightened after making a tight turn, the normal steering range returned to ±20°. The modification involved the replacement of the housing and piston, the steering arm and other components. The replacement parts were substantially different and had different part numbers, according to the Piper Parts Catalogue.

3.3.9 The modification had not been embodied on the aeroplane or, as far as could be ascertained, on any other Chieftain in New Zealand. This modification is mentioned because following the incident investigators found that the housing installed on the aeroplane was of the type that allowed an increased steering angle. The significance of this is discussed later in the report.

3.3.10 When the pilot retracts the landing gear it is possible that the nose wheel will not be centred, depending on whether the pilot is applying any rudder at the time. The nose wheel system is designed to ensure that the nose wheel centres as it retracts. This is achieved by means of a fixed alignment bracket mounted below the pivot point of the steering bell-crank. As the nose wheel begins to retract, a bushing on the end of this bracket is captured within the wider "mouth" of the alignment guide mounted on the top of the nose landing gear assembly. As the retraction continues, the fixed bushing is channelled down the narrowing slot of this guide, forcing the nose landing gear leg to centre.

3.3.11 The aeroplane flight manual contained procedures for the operation of the landing gear in the event of failure of the engine-driven hydraulic pumps, and for landing with no landing gear extended, but it did not have a procedure for jammed landing gear.

[6] Rudder pedal movement is interconnected with the aileron system to improve turn co-ordination.

[7] The feature was standard on Chieftains after serial number 31-782150, and also available as a modification kit.

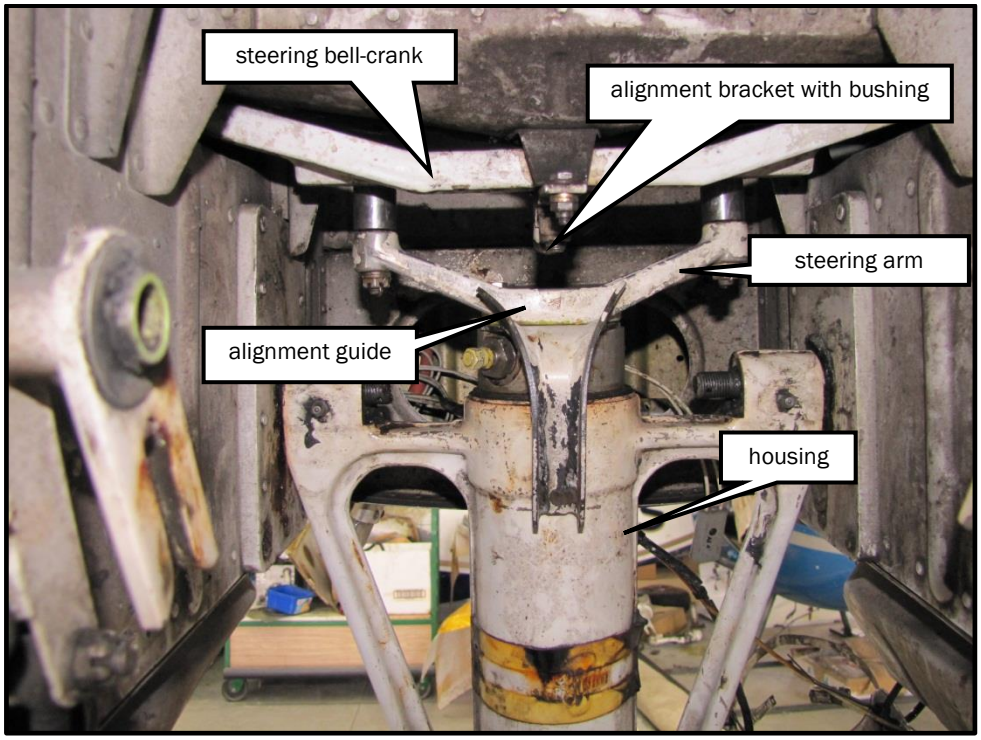

Figure 2
Head of nose landing gear, looking forward

Initial examination

3.3.12 Repaircraft Limited was an aircraft maintenance company based at Nelson that had previously worked on the aeroplane. Staff from Repaircraft assisted with its recovery from the runway. When the aeroplane nose was lifted, the engineers noted that the nose wheel was rotated to the left and that the alignment bracket bushing was jammed about 2 centimetres to the left of and outside the mouth of the alignment guide.

3.3.13 There was minor scoring on some nose landing gear components and evidence of tyre rub on the rear bulkhead of the nose wheel well. There was minor buckling and scoring on the support structure for the steering bell-crank assembly above the nose leg attachment points. The nose landing gear idler link, a component of the extension-retraction hardware that was not connected with the steering, was found fractured. An on-site inspection determined that the idler link had failed in tensile overload, which is thought to have occurred during the pilots' attempts to cycle the landing gear after it jammed.

3.3.14 Owing to the circumstances of this accident, the engines were not examined. There was no indication that the hydraulic system caused the nose landing gear jam.

Examination of the aeroplane, 7 June 2011

3.3.15 The nose landing gear housing was stamped with the casting number 45315 and also engraved 05332. A torn servicing placard on the housing had the text "Piper PA-42".[8]

3.3.16 The aeroplane was jacked up and the nose wheel steering tested with the rudder pedals. The range achievable with full rudder pedal travel was ±20°. However, the nose wheel could be manually turned to ±40°, which matched the towing angle limit lines painted on the housing.

3.3.17 When the nose leg was turned 20° then manually retracted, the alignment bracket bushing[9] was captured within the mouth of the alignment guide[10] as it should, although it was higher than the

[8] This appears to refer to the Piper Cheyenne model. The relevance of this is discussed in paragraph 3.3.46.

guide sides. When the nose leg was manually retracted with the wheel manually turned to 40°, the alignment bracket bushing did not enter the mouth of the guide, but instead went outside the guide, as it had been found during the initial inspection after the accident.

3.3.18 The steering arm bushings, which contacted and rolled against the steering bell-crank when the nose landing gear was extended, contacted the bell-crank by less than half of their depth. This small overlap suggested a misalignment or misrigging of the nose landing gear.

3.3.19 The pivot bolt[11] for the steering bell-crank was found loose and bent (see Figure 3). This caused the alignment bracket bushing to sit about 6 millimetres further above the alignment guide than it would have if the bolt had been tightened and straight. There was supposed to be a washer installed between the steering bell-crank and the alignment bracket, but this washer was missing (see Figure 3).

Figure 3
Bent pivot bolt (left), with bell-crank and alignment bracket (right)

3.3.20 The gap between the steering arm bushings and the steering bell-crank exceeded the allowable limit stated in the Maintenance Manual. There were hollows on the face of the bell-crank that looked as if they had been caused by the steering arm bushings striking the bell-crank as a result of this larger gap.

3.3.21 Witness marks on the alignment guide showed that the alignment bracket bushing had not been engaging with the guide until the bushing was about one-quarter of the way along the guide, and even then the bushing only protruded about halfway into the channel of the guide (see Figure 4).

3.3.22 The nose landing gear housing was removed from the aeroplane. There were 3 “cap bolts” that secured the steering arm and alignment guide to the top of the housing. The Parts Catalogue showed that 2 of these bolts should have been type AN3H-7A and the third a type AN3H-10A.[12] All 3 were found to be type AN3H-10, with 2 or 3 flat washers and a spring washer under the heads. The bolts were not lock-wired.

Previous nose landing gear defects

3.3.23 The available log books showed that the aeroplane had had a history of, sometimes recurring, nose landing gear defects in the previous 5 years. Those that appeared to be relevant to the accident are described below.

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[9] Part number 14976-15. Part numbers in this report are taken from the PA31-350 Piper Parts Catalogue, revised 10 March 1994.
[10] Part number 21719-11.
[11] Part number 401410P.
[12] The dash number, e.g. -7, is the bolt length in eighths of an inch up to 7/8. For lengths of more than one inch the first digit is the number of inches and the second digit is the number of eighths. So a -10 bolt is one inch long. The suffix “H” indicated that the bolt had a hole through the head for lock-wire.

January 2007

3.3.24 On 11 January 2007, when the aeroplane had accrued 21 419 flight hours, the nose wheel steering was reported to be stiff to operate. The log book recorded that the "nose gear trunnion[13] part number 45316-03" was cracked and that Fieldair Engineering Limited (Fieldair) had fitted a replacement housing loaned by Air West Coast.[14] The part number quoted was for housings fitted to Chieftains built more recently than the aeroplane, and those fitted to nose landing gear modified to allow a greater range of steering angle, as described earlier.

3.3.25 The correct housing part number for the aeroplane's serial number and modification status was 40273-00. The 2 part numbers were shown on adjacent lines in the Parts Catalogue. The correct number was recorded in the log book for work done in September 2005. There was no record in the available log books of the housing having been changed at any other time.

3.3.26 On 31 January 2007 the borrowed housing was replaced with one ordered from a United States company. The release certificate for the new housing had the same, incorrect part number as that recorded in the log book when the housing had been removed (45316-03) and the serial number 05332. This was the housing found on the aeroplane on 11 May 2011 after the accident.

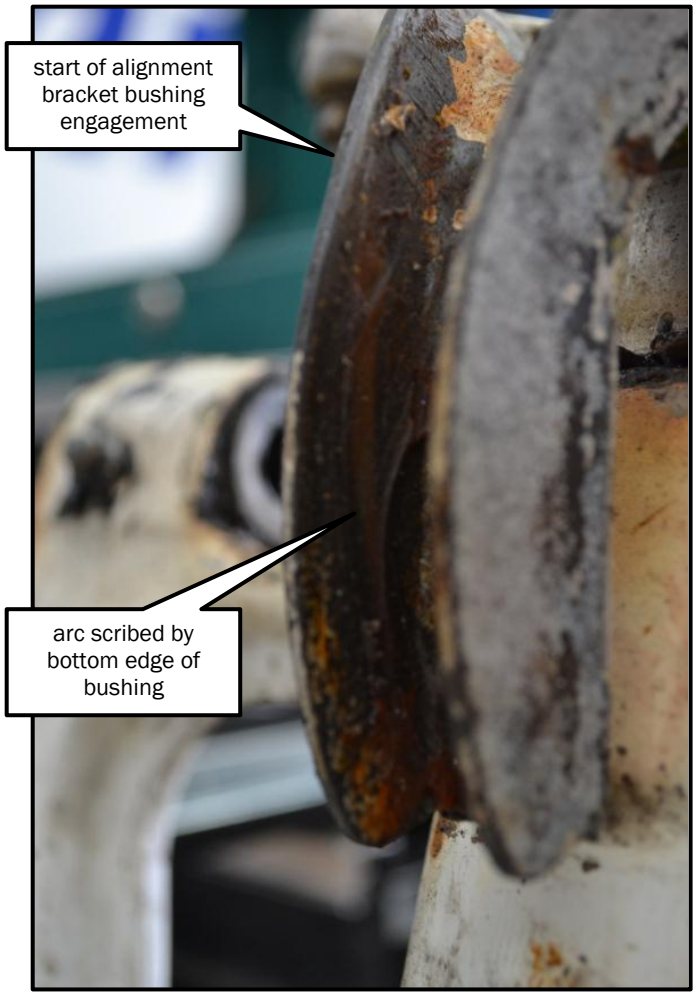

Figure 4
Alignment guide witness marks

3.3.27 The engineer who had certified the installation of the new housing said his normal practice was to transcribe part and serial numbers from release certificates to the work sheets and log books, or

[13] "Trunnion", as used here, meant the nose landing gear housing.

[14] The use of borrowed parts was not uncommon and was acceptable if the parts were approved and the respective removals and installations were documented correctly.

from previous log book records. He said he usually physically checked numbers when fitting and removing parts from an aircraft.

November 2008

3.3.28 On 11 November 2008 a pilot reported that the nose landing gear would not retract completely. The log book recorded that the steering mechanism was found to be loose – both steering arm bushings were bent and the "centring bushing aligner" (which most likely referred to the alignment bracket bushing) was damaged. There was no record of what had caused this damage. Fieldair manufactured and fitted "oversize" steering [arm] bushings, and a "top hat" central bushing[15] for the steering bell-crank. The nose landing gear hydraulic actuator and the nose wheel shimmy damper were also serviced.

3.3.29 The work sheets recorded that the "retaining bolts" had been replaced. As only one bolt secured the "top hat" bushing to the steering bell-crank, the bolts referred to were most likely to have been the bolts securing the 2 protruding bushings to the steering arm. However, as the steering mechanism was found to be loose, the reference could have been to the 3 cap bolts. The work sheets showed that an alignment bracket assembly (part number 21725-00) had been ordered from Air West Coast, but it did not say whether it had been fitted.

September 2009

3.3.30 On 9 September 2009, during a scheduled inspection by Fieldair, the steering arm was found to be loose and its 3 attachment bolts (the cap bolts) found to have damaged threads. The log book recorded that the rectification had been done in accordance with "Chieftain Maintenance Manual section 7-8", but recorded the part numbers for 2 of the replacement bolts as LW-2-1-00 and for the third, AN4H-6A.[16] Bolts of these types were found installed prior to the rectification of the April 2011 defect (see below). The correct bolts should have been 2 AN3H-7A bolts and one AN3H-10A bolt, tightened to a specific torque and secured with lock-wire. The job sheet recorded that the fitted bolts had been secured with Loctite 620.[17]

3.3.31 The engineer who certified this work was the same engineer who had carried out the work in November 2008. He had been the air2there Maintenance Controller at the time.[18] He said he could not recall the detail of the jobs or whether the Maintenance Manual had specified the use of lock-wire, but he suggested that the bolts used might have replaced similar bolts. He said that he had thought the ongoing problems with the nose wheel steering were caused by nose wheel shimmy, a view perhaps supported by the impact marks on the steering bell-crank (see paragraph 3.3.20).

3.3.32 The engineer said he thought that manufacturers did not always update their parts catalogues, particularly for older aircraft, and therefore he thought the catalogues might not have listed the parts actually used or acceptable for use. He said it was not unusual to use alternative parts and methods for a repair, such as the un-listed bolts and Loctite.

December 2010

3.3.33 On 22 December 2010 the nose landing gear did not extend fully when selected down on approach to Nelson. The pilot selected the landing gear up, but the nose wheel appeared to turn about 45° as it retracted and jammed against the landing gear doors, which punctured the tyre. The pilot said the jammed nose landing gear caused a rudder deflection that rolled the aeroplane slightly.[19] The

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[15] Part number 21831-02.

[16] Fieldair later confirmed that LW-2-1-00 bolts were held in its store for use in Lycoming engines.

[17] Loctite is the proprietary name of a range of sealants and thread lockers, each with a specified purpose and application. The manufacturer's website describes Loctite 620 as a high-strength, high-temperature compound for bonding metal cylindrical assemblies. It is not a thread locker, used to prevent the release or loosening of thread joints due to mechanical vibrations or environmental factors such as corrosion and temperature fluctuations.

[18] The Maintenance Controller is a Senior Person required by the Civil Aviation Rules for air operator certification to be responsible for the direction and control of maintenance. Further information is given in section 3.4.

[19] The roll was likely to have been a consequence of the turn co-ordination feature. See footnote 6, page 5.

nose landing gear was selected down again and after an odd sound it extended more quickly than normal and with a "thump". The CAA assessed this occurrence as minor and did not investigate it.

3.3.34 Rectification was carried out by an unlicensed engineer from Repaircraft who was working under supervision. He found that the alignment guide was loose and that the alignment bracket bushing and screw were missing. The engineer recorded on the work sheet, "nose gear steering guide found loose & retightened", but the loose-leaf log book entry returned to air2there after the rectification stated "loose steering guide retightened and secured".[20] The loose-leaf log book entry also referred to the alignment bracket (part number 21725-00) as the "steering roller assembly".

3.3.35 The engineer later said he did not know that the bolts on the strut head should have been secured with lock-wire. He said he was unlikely to have noticed the prior absence of lock-wire because, apart from the repair done, an aircraft was generally released to service in the same condition in which it had arrived.

3.3.36 Repaircraft did not have a replacement alignment bracket bushing, and without one fitted the nose landing gear would not centre when it was retracted. Therefore air2there arranged for the aeroplane to be flown with the landing gear extended to Air West Coast's facility where the repair was completed.

3.3.37 On 29 December Air West Coast fitted a complete alignment bracket assembly, borrowed from a "mothballed" Chieftain. The part number of the replacement assembly was incorrectly shown on the work sheet and in the loose-leaf log book entry as 55220-02. That part number was for the equivalent part on a modified nose landing gear. The Air West Coast engineering manager said he might have misread the Parts Catalogue, because the 2 parts were shown on adjacent lines (see Figure 5).

3.3.38 Air West Coast refitted the original bracket, complete with a new bushing, on 14 January 2011. The log book entry for that task did not state the bracket part number, but the part numbers shown for the replacement bushings were incorrect, being those for the modified nose landing gear. The retaining screw for the bushing was secured with Loctite 243.[21]

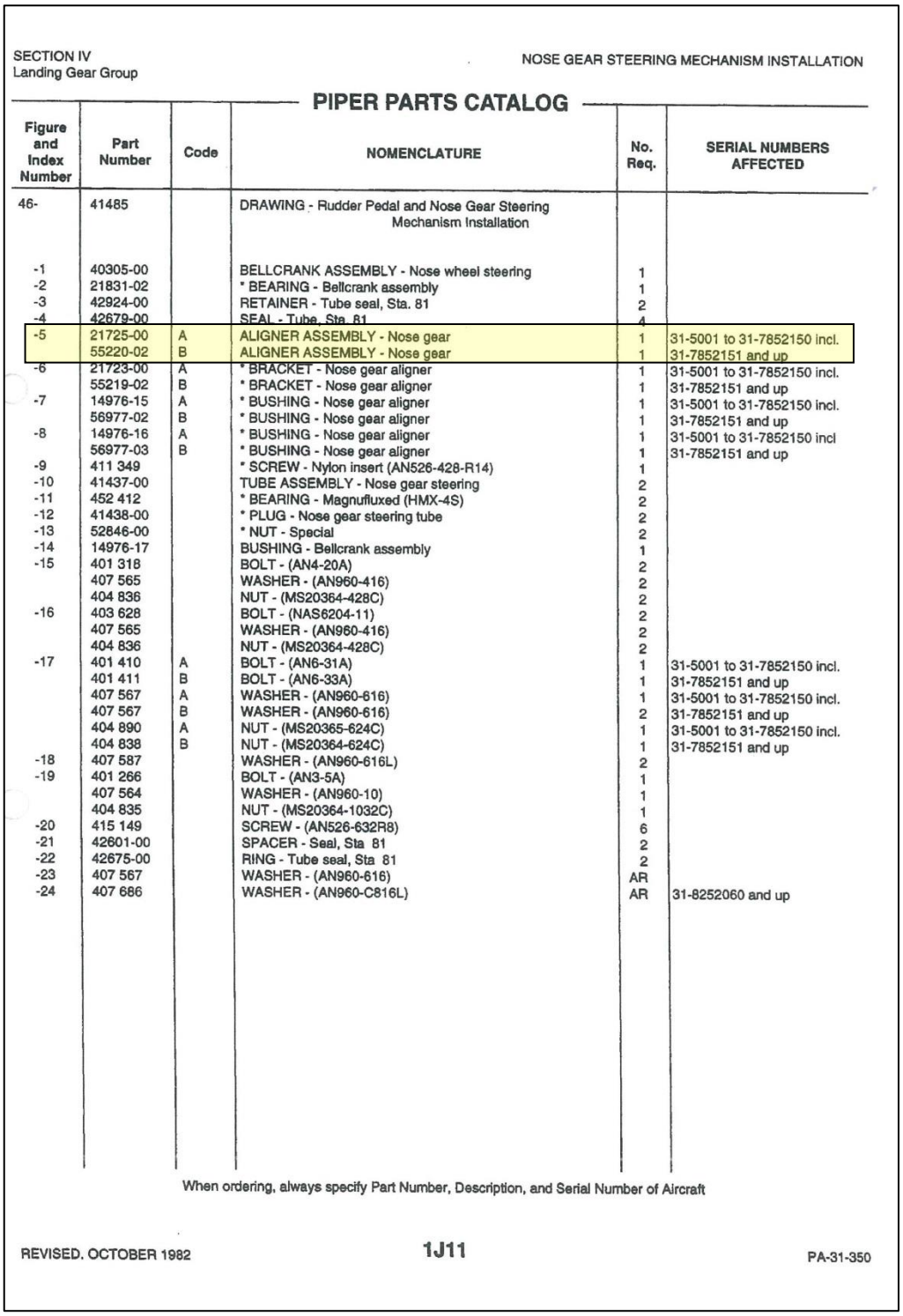
April 2011

3.3.39 On 14 April 2011 the nose landing gear again did not extend fully when it was selected down before landing at Wellington. The pilot said that he had "felt the rudder pedals starting to engage", so he wiggled the pedals and the nose landing gear then extended fully.

3.3.40 The contracted engineer who rectified this defect found that the cap bolts that attached the steering arm and alignment guide to the top of the housing were loose and not the correct parts. The bolts were two ¼-inch coarse-thread bolts and one AN4-6A fine-thread bolt (see Figure 6, which was taken at the time). The bolts were not lock-wired, as required by the Piper Maintenance Manual. The bolt holes in the steering arm, alignment guide and strut inner cylinder had been drilled out to ¼-inch diameter and helical inserts[22] put into the cylinder.

3.3.41 The log book indicated that these were the bolts installed during the rectification in September 2009. The log book did not refer to helical inserts being used then to accommodate the larger bolts.

[20] A loose-leaf log book entry is completed for maintenance performed away from the base where the log books are kept, and added to the log book later.
[21] The product manufacturer's website describes Loctite 243 as a medium-strength thread locker designed for the locking and sealing of threaded fasteners that require normal disassembly with standard hand tools.
[22] Helical inserts are a type of threaded insert, usually made of stainless steel, and often used to repair a stripped thread. Helical inserts are often referred to by a prominent brand name, Heli-coil



SECTION IV
Landing Gear Group

NOSE GEAR STEERING MECHANISM INSTALLATION

PIPER PARTS CATALOG

Figure and Index Number	Part Number	Code	NOMENCLATURE	No. Req.	SERIAL NUMBERS AFFECTED
46-	41485		DRAWING - Rudder Pedal and Nose Gear Steering Mechanism Installation		
-1	40305-00		BELLCRANK ASSEMBLY - Nose wheel steering	1	
-2	21831-02		* BEARING - Bellcrank assembly	1	
-3	42924-00		RETAINER - Tube seal, Sta. 81	2	
-4	42679-00		SEAL - Tube, Sta. 81	4	
-5	21725-00	A	ALIGNER ASSEMBLY - Nose gear	1	31-5001 to 31-7852150 incl.
	55220-02	B	ALIGNER ASSEMBLY - Nose gear	1	31-7852151 and up
-6	21723-00	A	* BRACKET - Nose gear aligner	1	31-5001 to 31-7852150 incl.
	55219-02	B	* BRACKET - Nose gear aligner	1	31-7852151 and up
-7	14976-15	A	* BUSHING - Nose gear aligner	1	31-5001 to 31-7852150 incl.
	56977-02	B	* BUSHING - Nose gear aligner	1	31-7852151 and up
-8	14976-16	A	* BUSHING - Nose gear aligner	1	31-5001 to 31-7852150 incl
	56977-03	B	* BUSHING - Nose gear aligner	1	31-7852151 and up
-9	411 349		* SCREW - Nylon insert (AN526-428-R14)	1	
-10	41437-00		TUBE ASSEMBLY - Nose gear steering	2	
-11	452 412		* BEARING - Magnufluxed (HMX-4S)	2	
-12	41438-00		* PLUG - Nose gear steering tube	2	
-13	52846-00		* NUT - Special	2	
-14	14976-17		BUSHING - Bellcrank assembly	1	
-15	401 318		BOLT - (AN4-20A)	2	
	407 565		WASHER - (AN960-416)	2	
	404 836		NUT - (MS20364-428C)	2	
-16	403 628		BOLT - (NAS6204-11)	2	
	407 565		WASHER - (AN960-416)	2	
	404 836		NUT - (MS20364-428C)	2	
-17	401 410	A	BOLT - (AN6-31A)	1	31-5001 to 31-7852150 incl.
	401 411	B	BOLT - (AN6-33A)	1	31-7852151 and up
	407 567	A	WASHER - (AN960-616)	1	31-5001 to 31-7852150 incl.
	407 567	B	WASHER - (AN960-616)	2	31-7852151 and up
	404 890	A	NUT - (MS20365-624C)	1	31-5001 to 31-7852150 incl.
	404 838	B	NUT - (MS20364-624C)	1	31-7852151 and up
-18	407 587		WASHER - (AN960-616L)	2	
-19	401 266		BOLT - (AN3-5A)	1	
	407 564		WASHER - (AN960-10)	1	
	404 835		NUT - (MS20364-1032C)	1	
-20	415 149		SCREW - (AN526-632R8)	6	
-21	42601-00		SPACER - Seal, Sta 81	2	
-22	42675-00		RING - Tube seal, Sta 81	2	
-23	407 567		WASHER - (AN960-616)	AR	
-24	407 686		WASHER - (AN960-C816L)	AR	31-8252060 and up

When ordering, always specify Part Number, Description, and Serial Number of Aircraft

REVISED. OCTOBER 1982 1J11 PA-31-350

Figure 5
Piper Parts Catalogue, excerpt

3.3.42 The alignment guide was also found to be bent and the sides built up by welding that had left sharp edges on the inside faces of the channel (see Figure 7). The available log books gave no indication of when that repair had been made.

3.3.43 None of the Repaircraft and Air West Coast engineers who had worked on the nose landing gear after the December 2010 incident had noticed the sharp, built-up edges on the alignment guide, nor had they noticed that the cap bolts were not lock-wired.

3.3.44 The inner cylinder, the steering arm and the alignment guide were replaced, along with the cap bolts. After functional ground and flight checks, the aeroplane was returned to service.

3.3.45 On 20 April 2011 the CAA, having been notified of the engineer's observations of incorrect bolts and a suspected unapproved repair, opened an investigation into this occurrence, but it had not started its investigation before the accident on 11 May.

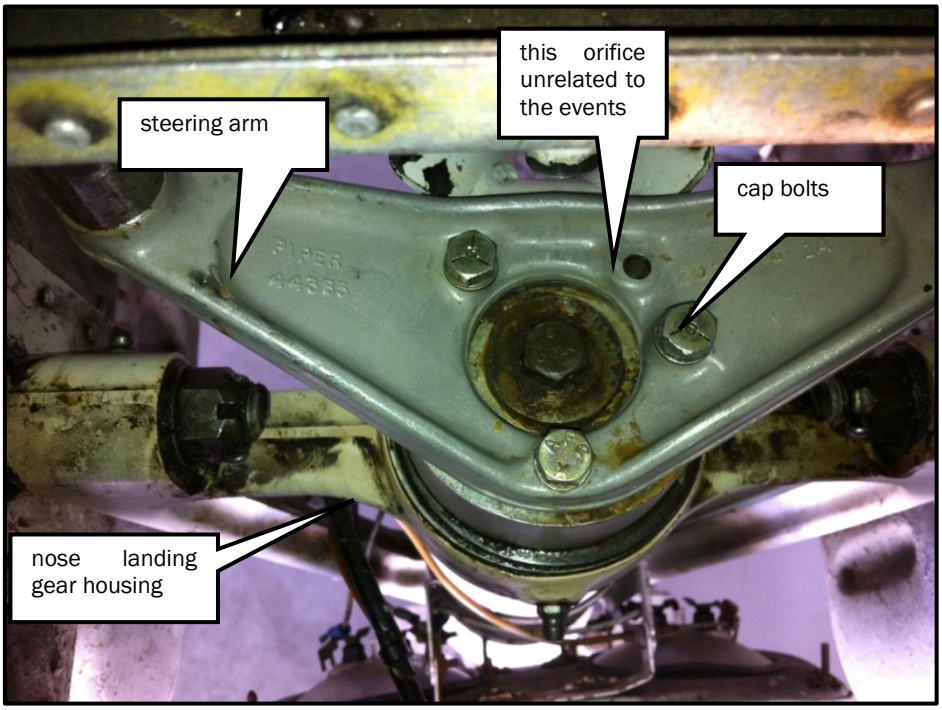


Figure 6
Nose landing gear cylinder cap bolts, as found installed, 11 April 2011

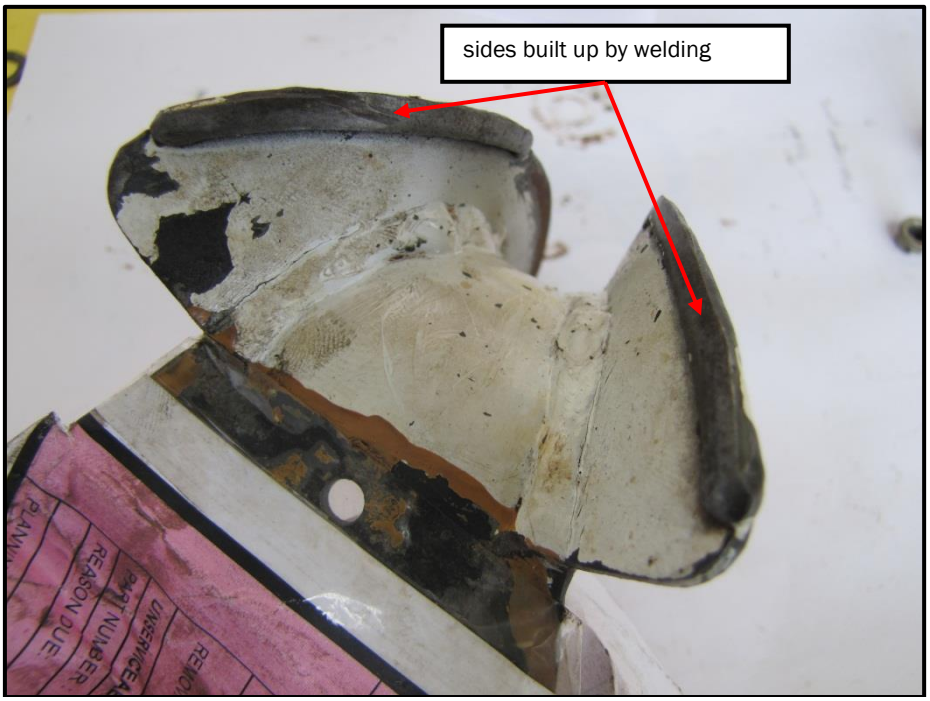


Figure 7
Alignment guide after removal, 11 April 2011, showing built-up sides

The PA-42 servicing label on the nose landing gear housing

3.3.46 The PA-42 Cheyenne was a turbo-prop development of the Chieftain. The nose landing gear housings for the Chieftain and Cheyenne were made from the same casting stock, but the finished housings for the different models had physical differences and different part numbers. The part number for the Cheyenne housing was 45316-00; the number for later-model Chieftains and those with the modified nose landing gear was 45316-03.

3.3.47 Until the accident there had been only one Piper PA-42 Cheyenne on the New Zealand aircraft register, but that aeroplane had been de-registered in April 2008. It had been operated by a company that also operated Piper PA-31 Navajo and other Chieftain aeroplanes in its fleet. That company had, at various times, loaned Chieftain parts for use on the aeroplane. The most recent was the alignment bracket in December 2011. The company said that as it had not stocked major spare parts for the Cheyenne, it was not possible that a Cheyenne housing had been inadvertently loaned to the aeroplane.

3.4 Maintenance

Maintenance requirements

3.4.1 The aeroplane was operated under the authority of an Air Operator Certificate issued under Part 135 of the Civil Aviation Rules. The operator was responsible for the airworthiness of the aeroplane. The Maintenance Controller was the "Senior Person" of an airline who was responsible for the control and scheduling of maintenance. The Maintenance Controller for a general aviation airline need not be a licensed aircraft maintenance engineer, but often will be. air2there had at least 4 different Maintenance Controllers between 2005 and 2011.

3.4.2 The minimum regulatory requirements, applicable to the maintenance of all aircraft, are given in Rule Part 43. Any additional maintenance requirements for aircraft that are used for air transport operations are specified in other Rules (Part 135 in the case of the aeroplane).

3.4.3 The Introduction to Advisory Circular 43-1, Aircraft maintenance, stated, in part (CAA, 2009, p.3):

> The objective of [Rule] Part 43 is to establish, for all aircraft, the minimum standard of maintenance considered necessary to ensure the continued validity of their Airworthiness Certificate... This is achieved by prescribing—
>
> - the minimum standard of maintenance required for aircraft:
> - the minimum standards for the performance of maintenance:
> - the persons who may certify maintenance:
> - the manner in which maintenance is to be recorded and certified.
>
> Part 43 provides the performance standard for persons and companies providing maintenance services for operators of—
>
> - air transport aircraft of less than 5700 kg [maximum certificated take-off weight] or having nine or less passenger seats...
>
> There is no requirement for these maintenance providers to be certificated.

3.4.4 Fieldair was certificated under Rule Part 145.[23] Air West Coast had held a Part 145 certificate until its associated airline ceased operating the larger Dornier aeroplane that required maintenance by a Part 145 organisation.

3.4.5 The engineers outside those 2 organisations who had released the aeroplane to service had been exercising the privileges of their personal licences and ratings. All aircraft maintenance had to be certified by licensed aircraft maintenance engineers before aircraft could be released to service. The actual maintenance actions need not have been done by licensed engineers, but in each such

[23] Certification under Rule Part 145, Aircraft Maintenance Organisations, is required for an organisation that performs maintenance on air transport aircraft with more than 9 passenger seats or a maximum certificated take-off weight greater than 5700 kilograms, or that conducts overhauls or other specified major maintenance. Maintenance on smaller aircraft may be authorised if personnel with the requisite ratings and currency are employed.

case the Rules required that the work be done under the direct supervision of a licensed engineer who was rated on the aeroplane. Direct supervision required, among other things, the checking and approval of the work at important stages, such as the completion of the task.

3.4.6 Civil Aviation Rule 43.53, Performance of maintenance, required persons who performed aircraft maintenance to be familiar with the components being worked on and understand the technical data that was required to accomplish tasks correctly and thereby allow aircraft to be released to service in an airworthy condition. An understanding of the technical data and procedures required for a task was typically acquired by direct reference to the relevant manufacturer's current manuals.

3.4.7 Acceptable general maintenance practices were learned through engineering training, and any specific to a particular aircraft would be stated in the applicable maintenance manual or other publication of the manufacturer. Advisory Circular AC43-1 stated that if there were any doubt about the acceptability of a practice, advice should be sought from the CAA.

3.4.8 Civil Aviation Rule 43.113 required a duplicate safety inspection before an aircraft was released to service after the disturbance of any part of a control system of the aircraft. The associated advisory circular, AC43-1, stated, in part (CAA, 2009, p.17):

> a control system is a system by which the attitude, direction of flight, or aerodynamic characteristics of the aircraft may be changed. A control system includes all associated units, whether mechanical, electrical, electronic, hydraulic, or pneumatic.

3.4.9 The advisory circular stated that the control systems for aeroplanes included the attachments of, and means of actuating, the primary control surfaces (that is, the elevators, ailerons and rudder), air brakes and flaps. Duplicate inspections were not required for work on landing gear systems.

Maintenance arrangements

3.4.10 From approximately 2004 until late 2009, the scheduled maintenance of the aeroplane had been performed by Fieldair at Palmerston North Aerodrome. Fieldair was also certificated under Civil Aviation Rule Part 148.[24]

3.4.11 For most of that period the aeroplane had been owned by the predecessor company. A licensed engineer employed by Fieldair had been, at the request of the then operator of the aeroplane, contracted as the operator's Maintenance Controller. Present Fieldair management acknowledged that it was not ideal for one person to perform the maintenance and conduct the annual reviews of airworthiness of an aeroplane, and also be the Maintenance Controller for the aeroplane's operator.

3.4.12 Successive routine audits by the CAA had shown that Fieldair was in the lowest risk category for maintenance organisations. However, 2 findings made during recent audits of Fieldair had some relevance to previous maintenance performed on the aeroplane: the use of the wrong Loctite product (on a job unrelated to air2there), and the lack of a procedure for certifying the conformity of major modifications and repairs using acceptable technical data.[25] Fieldair had taken prompt corrective actions.

3.4.13 In 2009 air2there had changed its maintenance provider to Air West Coast, based near Greymouth. Air West Coast had an associated company that operated a Chieftain on air transport operations. The CAA's reports on audits of Air West Coast in the 3 years to April 2011 were unremarkable.

3.4.14 In 2012 air2there shifted its maintenance to a company based at Feilding Aerodrome and the principal of that company was appointed Maintenance Controller.

3.4.15 If the rectification of a minor defect were required when an aeroplane was away from base, the work was contracted to a convenient company or licensed engineer. air2there faxed or emailed to

[24] A Part 148 certificate permits the holder to manufacture aircraft or carry out limited manufacturing tasks in the production of aircraft components.
[25] CAA audits 10/ROUA/92 (21 October 2009) and 11/ROUA/164 (28 March 2011) respectively.

the contractor a Technical Directive that detailed the work required and the reference document(s), usually the Piper Maintenance Manual.

3.4.16 Repaircraft at Nelson Aerodrome was one maintenance contractor that had been used prior to the accident. The company employed one licensed engineer. On 20 May 2011 (about 9 days after the accident), in accordance with section 15(1) of the Civil Aviation Act 1990, the CAA conducted a routine safety inspection of the engineer to check his compliance with the Rules for the performance of maintenance.[26] The safety inspection was not undertaken because of the accident. The maintenance practices were noted to be in compliance and no finding was made.

3.4.17 air2there demonstrated that in accordance with its Exposition, its Maintenance Controller and/or Quality Manager had performed annual audits of its suppliers, including maintenance providers. These had been done to satisfy the operator about the workshop and maintenance standards of suppliers.

Maintenance record-keeping

3.4.18 Civil Aviation Rule 91.623 required log books to be retained for at least 12 months after the date an aircraft was withdrawn from service. However, air2there could not find the aeroplane log books for the period prior to 19 November 2004.

3.4.19 When an aircraft was repaired away from its normal base, a formal loose-leaf log book entry of the work done was prepared by the licensed engineer and sent to the Maintenance Controller for adding to the log book. This record was required to describe the defect and how it had been rectified, including the reference manuals used. Neither the Civil Aviation Rules nor the operator's Exposition specified how soon after receipt a loose-leaf entry had to be affixed in the log book. The operator kept loose-leaf log book entries yet to be affixed in the log book in a separate folder.

3.4.20 The operator's practice was to transfer the daily flight hours recorded in the technical log (carried on the aeroplane) into a computer at the end of each day. When the aeroplane was due for scheduled maintenance, a consolidated list of flight hours since the last log book update would be printed and pasted into section 2 (Service Record) of the log book. The details of defects that had occurred during that period were also written into section 2, and any related loose-leaf entries were pasted into section 3 (Maintenance Record) on the facing page. This practice meant that the recorded defects were not always aligned with their corresponding dates or the actions taken to repair them. The correlation of defects with the corresponding maintenance actions was difficult to follow. In one extreme example there were 16 loose-leaf entries pasted onto one page.

3.4.21 Prior to the accident, the aeroplane log book had been last updated on 8 April 2011. The most recent scheduled maintenance had been completed on 26 April 2011, but not recorded in the log book. The record of service since that date was shown in a new technical log carried in the aeroplane.

3.4.22 An inspection of the available log books revealed a series of loose-leaf entries dating back over 6 years in which the aeroplane serial number had been incorrectly recorded, and examples of incorrect times in service and dates of maintenance. The incorrect serial numbers had most likely begun with a simple transposition error on the template for the loose-leaf forms, which had then been perpetuated because of a failure to cross-check. In at least one case, an error in time in service and date of maintenance suggested that the loose-leaf entry had not been completed at the time of the associated maintenance.

[26] CAA Safety Inspection Report 11/SPTT/46.

3.5 Organisational and management information

The operator

3.5.1 air2there was established in 2008, and continued the scheduled air transport operations of its predecessor from the same base at Paraparaumu Aerodrome. At the time of the accident the fleet consisted of the aeroplane and another Piper Navajo, both operated under a Part 135 Air Operator Certificate, and a Cessna 208 Caravan single turbo-prop aeroplane that was operated under a Part 125 certificate.[27]

3.5.2 At the time of the accident, air2there did not employ any maintenance staff. Maintenance was overseen by a part-time Maintenance Controller and a part-time Quality Manager. A licensed engineer was usually readily available at Paraparaumu.

Audits by the Civil Aviation Authority

3.5.3 The 2 audits of air2there by the CAA prior to the accident were unremarkable.[28] The company completed a scheduled re-certification audit for its Air Operator Certificate in November 2011.

The role of annual reviews of airworthiness

3.5.4 The aeroplane was subject to an annual review of airworthiness, which the CAA described as a periodic review of the condition and conformity of an aircraft, and a separate process from the ongoing inspection and maintenance requirements (CAA, 2009, pp.19, 20). The annual review had 3 elements: confirmation of the type conformity, a logbook audit and an inspection of the aircraft's general condition. The log book audit involved a check of all the log book (and associated records if required) since the last review. The review had to check, among other things, that modifications and repairs since the last review had been "correctly recorded and certified".

3.5.5 An annual review of airworthiness can be conducted only by a licensed engineer who holds a Certificate of Inspection Authorisation. It would be impractical for, and the CAA did not expect, a reviewing engineer to inspect physically all of the work done since the last review. The annual review was a review of the maintenance processes only – in essence a paperwork audit – but it was not a check of the standard of any specific maintenance. The responsibility for the standard of maintenance was that of the licensed engineer(s) who released the aircraft to service after the maintenance.

3.5.6 The standard of annual reviews of airworthiness and their relation to prior maintenance has been considered by the Commission before. On 15 February 2012, in an interim report on the investigation into a balloon accident, the Commission made an urgent safety recommendation to the Director of Civil Aviation in regard to the maintenance and airworthiness of hot-air balloons.[29] The recommendation followed the finding that some of the maintenance performed on the balloon had not met the requirements of Civil Aviation Rule Part 43. For example, the licensed engineer had not always followed the manufacturer's maintenance procedures. The licensed engineer who had maintained the accident balloon had also conducted its annual reviews of airworthiness.

3.5.7 On 6 March 2012, in response to the above urgent safety recommendation, the CAA provided the Commission with a report on its "Inspections of Standards for Balloon Maintenance". The inspection team found that most balloon maintenance providers had good maintenance practices and generated no concerns, but there were "various levels of performance in respect of adherence to the manufacturer's maintenance manual and [to the Civil Aviation Rules]".

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[27] Civil Aviation Rule Part 135, Air Operations – Helicopters and Small Aeroplanes, prescribes the operating requirements for air operations using aeroplanes that seat 9 passengers or fewer. Part 125, Air Operations – Medium Aeroplanes, applies to air operations with aeroplanes that have 10-30 passenger seats, and single-engine aeroplanes that carry passengers under instrument flight rules.

[28] CAA audit 11/ROUG/80 of 15 Nov 2010.

[29] Commission Interim Report 12-001: Cameron Balloons A210, ZK-XXF, collision with power line and in-flight fire, Carterton, 7 January 2012; published April 2012.

4 Analysis

Introduction

4.1 There are 2 safety issues discussed below in the analysis of this accident:

- the standard of maintenance performed on the aeroplane
- the standard of maintenance generally in general aviation in New Zealand.

4.2 The nose landing gear did not lower normally because it jammed in a partially retracted position while the pilot was applying substantial rudder input at the same time as retracting the landing gear. Applying substantial rudder to counter the yaw created when one engine fails, or in this case is simulated to fail, is a normal action that should not have resulted in the nose landing gear jamming. The reasons for its jamming are discussed in the following analysis.

4.3 Civil Aviation Rules described the minimum requirements for maintaining and repairing aircraft. They also placed responsibility on individuals and organisations for ensuring that repair and maintenance were performed in a proper way that did not compromise safety. The following analysis describes how failures by participants in the system resulted in certain defects with the nose landing gear, which contributed to its jamming during the accident flight.

What caused the nose landing gear to jam?

4.4 On the approach to Nelson, the nose landing gear was locked down when the flight examiner simulated the engine failure by reducing the power on one engine to idle. At the minimum altitude for the approach, the pilot applied full power on the other engine to carry out a missed approach. This had the effect of the aeroplane tending to yaw, which the pilot counteracted by applying up to maximum rudder pedal deflection before selecting the landing gear up. This was the normal way to deal with the situation – a situation with which the aeroplane landing gear systems were designed to cope.

4.5 When full rudder was applied with the landing gear extended, the nose wheel also turned. When the landing gear was then retracted the bushing on the end of the alignment bracket should have been captured by the flared mouth of the alignment guide. This bushing on the bracket should have then moved down into the narrowing throat of the guide, thereby centring the nose wheel as it retracted. Instead the bushing missed being captured by the guide and jammed outside it. The nose wheel did not centre and the system jammed in a half-retracted condition. Repeated attempts by the pilot to cycle the landing gear failed to free the nose landing gear from this jammed state.

4.6 There are a number of reasons for the alignment bracket not being captured by the alignment guide. These range from the wrong parts being fitted to the nose wheel assembly to improper maintenance of parts within the assembly. These are now discussed in more detail.

Fitting of incorrect parts

4.7 One reason for the alignment bracket not being captured by the alignment guide was that the nose leg could turn past the nominal 20° because the wrong housing had been installed. After the nose wheel was turned to its nominal maximum of 20°, the slipstream may have turned it further (possibly up to 40°) once the steering arm had disengaged from the steering bell-crank as the nose landing gear started to retract. Had it been intended to fit the modified housing, the strut head parts associated with Piper Service Spares Letter No. 352 (the modification) should also have been fitted. If those parts had been fitted, the nose leg would have been brought back to the ±20° range (see paragraph 3.3.8) where the alignment bracket would have engaged with the alignment guide.

4.8 The PA-42 label found on the housing after the accident strongly suggested that a Cheyenne housing (part number 45316-00) had been mistakenly supplied and installed in January 2007, after part number 45316-03 had been wrongly used when describing the defect and to order the replacement housing. The last log book reference to the housing, prior to the January 2007 repair, had quoted part number 40273-00, which was correct for an aeroplane with an unmodified nose landing gear. There was no other record of maintenance during which the incorrect housing might

have been fitted to the aeroplane. The 2 different housing part numbers were listed on adjacent lines in the Parts Catalogue, so the use of the incorrect part number could have been a simple case of misreading the Catalogue or not checking the applicable aeroplane serial number range. The remnant of the PA-42 label also illustrated the need for manufacturers to use more permanent methods to identify individual parts.

4.9 The part number error was repeated in subsequent maintenance log book entries. The likely reason was that those making the entries referred to the part number used previously in the log book, rather than physically checking for a part number on the item and comparing that with the Maintenance Manual or Parts Catalogue. There was no further maintenance recorded on the housing that might have drawn attention to it being the wrong part.

4.10 The physical differences between the housings did not prevent re-assembly of the strut, but the effect on the other nose landing gear components and their geometric relationship was unclear. The fitted housing would have been suitable had the nose landing gear modification described in Piper Service Spares Letter No. 352 been embodied on the aeroplane, but it had not been. However, the original steering arm and other components on the strut head were still fitted, so, in effect, the aeroplane was half-modified. Piper advised that the mismatch of components was a non-conforming and unapproved assembly that could have contributed to the non-engagement of the bushing. In particular, the gap between the alignment bracket and alignment guide might have been greater than it would have been with the correct parts installed.

4.11 It is possible that this greater gap between the alignment bracket and alignment guide was the reason for someone welding extensions to the sides of the alignment guide. During the repair in April 2011, the alignment guide with the welded sides was replaced with the correct part. As the sides of the correct guide were less high, the replacement had the unanticipated effect of increasing the vertical separation between the guide and the bracket.

4.12 Wear marks on the alignment guide observed after the accident indicated that the alignment bracket (replaced in January 2011) had only partially engaged with the guide during recent nose landing gear retractions. Reports by pilots of incidents in December 2010 and April 2011 suggested that the alignment bracket bushing had not been engaging with the guide fully for some time, even under normal flight conditions.

4.13 A retraction and extension check of the nose landing gear, as described in the Maintenance Manual, was performed with the nose wheel aligned fore and aft. Therefore the effectiveness of the alignment guide in centring the nose wheel when it was turned was rarely, if ever, checked. On the aeroplane, the separation between the alignment bracket bushing and the alignment guide was too great, a situation that almost certainly had existed before the accident.

4.14 The steering bell-crank pivot bolt (part number 401410), which secured the alignment bracket, was bent in such a way as to increase the separation between the bracket and guide. The bolt could have been bent in the same event that damaged the other steering system parts that had been repaired in November 2008. However, the pivot bolt secured the steering bell-crank central bushing too, and that was replaced then. Presumably the bolt's condition was considered satisfactory at that time. The pilots cycled the landing gear several times during the accident flight to try to resolve the problem. With the assembly jammed, it is possible that the pivot bolt was bent at this time.

4.15 The flat washer (part number 407587), which the Parts Catalogue shows installed between the steering bell-crank and the alignment bracket, was found to be missing after the accident. The washer could have been left out at the November 2008 rectification or at any of the 3 subsequent occasions when the alignment bracket was disturbed. Each of those occasions involved a different maintenance provider.

4.16 Regardless of when and where the washer was omitted, its absence resulted in the alignment bracket bushing being raised farther away from the alignment guide, in addition to the increased separation caused by the bent bolt. The missing washer also meant that the contact areas of the steering arm bushings on the steering bell-crank were reduced.

Findings:

1. The nose landing gear did not lower normally because it had jammed in a partially retracted position. The landing gear jammed because the nose wheel alignment bracket lodged outside (instead of slotting into) the alignment guide as the landing gear retracted.

2. The nose wheel alignment bracket lodged outside the alignment guide for the following reasons:

   a. the incorrect nose landing gear strut housing that had been fitted to the aeroplane allowed the nose wheel to turn in excess of the nominal 20°

   b. the replacement of the modified alignment guide in April 2011 increased the vertical separation between the guide and the alignment bracket

   c. the pivot bolt securing the steering bell-crank was bent and missing a washer, which meant the alignment bracket was less likely to engage fully with the alignment guide.

Repair and maintenance of the nose landing gear

4.17 The aeroplane had a recent history of similar nose landing gear defects, the most recent being less than one month before this accident. The records showed that some of the maintenance had not been performed in accordance with Civil Aviation Rules, particularly in regard to compliance with prescribed maintenance procedures.

4.18 Since November 2008 there had been recurring occurrences of the steering arm being found loose. Nose wheel shimmy had been a suspected cause, because during shimmy the bushings on the steering arm "hammered" against the steering bell-crank. Evidence of hammering was found on the bell-crank after the accident.

4.19 Fieldair's records showed that during the rectification of the November 2008 damage to the steering system, an alignment bracket had been ordered to replace the one damaged, but the log book did not show that the replacement had been fitted. Therefore the damaged bracket might have stayed on the aeroplane until December 2010, when the log book showed that it had next been replaced.

4.20 Reference has already been made to the washer missing between the steering bell-crank and the alignment bracket. It was not established when the washer had been left out, but if the various engineers who had worked on that assembly in recent jobs had referred to the Maintenance Manual and/or Parts Catalogue, as good practice would have required, they should have seen that the washer was missing.

4.21 The reason for the steering arm loosening on previous occasions was that it had been installed with the wrong cap bolts, which could not be lock-wired. The various attempts to rectify the recurring defect had failed because the wrong bolts were not noticed.

4.22 Had the Maintenance Manual been followed at each repair, the absence of lock-wiring, and hence the incorrect bolts, should have been noticed before April 2011. In spite of having seen these errors, the engineer involved in the April 2011 repair inexplicably omitted to install lock-wire. This was discovered when the aeroplane was examined after the accident.

4.23 The observations made in April 2011 illustrated the following deficiencies in maintenance practices:

- unapproved repairs – the alignment guide being built up with poor welding and the use of helical inserts

- the use of the wrong parts – the cap bolts
- a failure to refer to, or to comply with, the appropriate technical data – for example, the lack of lock-wire on the cap bolts.

4.24 The April 2011 incident appeared, from the pilot's description, to have been caused by the alignment bracket bushing catching on a sharp edge of the modified (welded) alignment guide as the landing gear extended. As the same alignment guide had been in place the previous December, it was likely that the bushing had caught on the alignment guide edge on that occasion too, causing it to break off.

4.25 The welded "repair" to the alignment guide, possibly done to correct an earlier problem of non-engagement of the alignment bracket, was to an unacceptable standard and should not have been approved. The sharp and ragged inner edges of the welding clearly had a high potential for preventing the alignment bracket bushing rolling smoothly in the guide. As not all of the maintenance logs for the aeroplane could be found, contrary to a Civil Aviation Rule requirement, the date of that repair could not be determined.

4.26 The log book showed that the incorrect cap bolts found in April 2011 had been installed during the September 2009 repair. The engineer who had certified that repair said he thought that the large bolts might have replaced similar bolts. If that was so, it was likely that helical inserts had been installed during a previous repair. The available log books did not show that.

4.27 Two of the bolts were for Lycoming engines and none of the 3 had provision for lock-wiring. Therefore their use in the September 2009 repair had not been "in accordance with the Chieftain Maintenance Manual section 7-8", as had been certified in the log book. In the event, these repairs proved ineffective, because the steering defects recurred.

4.28 To accommodate the larger bolts, bigger holes had been drilled in the alignment guide mounting flange and the steering arm, and also into the inner cylinder. Helical inserts had been used to provide the thread inside the cylinder, but their use had not been recorded in the log book. The investigation could not determine whether the September 2009 repair had been the first occasion that helical inserts were used for this repair.

4.29 CAA staff said that the larger bolts and helical inserts were not a repair option shown in the Piper Maintenance Manual and were therefore unapproved. Their use would have required the prior approval of the CAA or a design organisation certificated by the Authority, and any such approval to be recorded with the other details in the maintenance log book.

4.30 The rectification of the December 2010 defect illustrated the following examples of inadequate or incorrect maintenance:

- failure to investigate fully the cause of a defect
- failure to refer to, or to comply with, the appropriate technical data
- inaccurate statement in a loose-leaf log book entry of the maintenance performed
- ineffective supervision of an unlicensed engineer's work.

4.31 The engineer who had investigated and corrected the loose steering arm in December 2010 had not noticed that the alignment guide was in poor condition and that it might have caused the alignment bracket bushing to break off. It is difficult to comprehend that he would not have noticed the inappropriate repair to the guide, because he was working on that component at the time.

4.32 It is good aeronautical engineering practice not only to effect proper repairs and parts' replacement, but to identify the causes of defects. This is especially relevant when dealing with recurring defects. Proper supervision should ensure that appropriate fault-finding is carried out.

The Commission has previously commented on the importance of establishing the underlying causes of system defects, rather than making isolated repairs on each occasion.[30]

4.33 The unlicensed engineer said he had "torqued" the bolts securing the steering arm and alignment guide, meaning that he applied the torque specified in the Maintenance Manual. The Piper Manual was available on-line at the hangar, but the engineer cannot have read the relevant procedure carefully, otherwise he would have seen that the next step was to lock-wire the bolts. The absence of holes in the head of the bolt to take lock-wire should then have led him to question his supervisor about the suitability of the bolts.

4.34 The engineer later explained the lack of lock-wire by saying, in effect, "the condition of the aeroplane when it comes in is how it goes out". In other words, there was no lock-wire on the bolts when it came in, so none was used when it went out. This thinking is not consistent with the requirements of Civil Aviation Rules or with best aviation engineering practice.

4.35 Following the December 2010 rectification, the alignment bracket was replaced by a different organisation. The incorrect part number stated in the log book entry for the subsequent replacement of the loaned alignment bracket might have been a simple mistake, but it showed the importance of reading manuals and catalogues very carefully. Once an incorrect part number is quoted, even though the correct part might actually have been fitted, there is a high risk of the number error being repeated subsequently – when ordering a replacement part or when determining the applicability of an airworthiness directive, for example. The error could then have more serious consequences, such as in the ordering and fitting of the incorrect strut housing in 2007. Careful reference to the acceptable technical data and physical checks of parts and comparisons with their release notes will minimise that risk.

4.36 Other examples of careless and incorrect maintenance practices identified during this inquiry included the loss or misplacement of the aeroplane log books and the use of a thread sealing product (e.g. Loctite) that was not suited to the task.

The overall standard of general aviation aircraft maintenance

4.37 The Civil Aviation Rules and the associated Advisory Circulars stated the responsibilities of persons engaged in aircraft maintenance. The continued airworthiness of aircraft depended, among other things, on all participants following the published procedures and accepted practices, and meeting the responsibilities of their licences and approvals; and upon diligent supervision. These requirements included the duplicate (independent) checking of control systems that were critical to safety before they and aircraft were released to service after any disturbance or adjustment. However, the landing gear was not a control system that needed independent checking after maintenance.

4.38 The investigation of this one event identified a variety of inadequate maintenance practices by a variety of persons in different maintenance organisations over 4 or 5 years. In the same period, routine audits of those organisations by the CAA did not identify any indications of such maintenance issues. The Commission accepts that it is probable that most aircraft maintenance was performed correctly and to the required standards, but it is concerned that the identified poor maintenance on the aeroplane was not limited to one person or one organisation.

4.39 The Commission has previously found similar issues with the practices of a maintenance provider for commercial balloons and recommended that the Director of Civil Aviation address this safety issue. The Commission believes that these new findings could indicate that the quality of general aviation aircraft maintenance, particularly that performed by other than certificated maintenance organisations, needs to be improved if it is to meet the requirements of Civil Aviation Rules. The Commission recommended the Director of Civil Aviation to take the necessary action to address this wider safety issue.

4.40 air2there had 4 maintenance controllers during the period of the recurring nose landing gear defects and incidents, but the underlying cause of the defects was found only after this accident. It

[30] Report 10-010, Bombardier DHC-8-311, ZK-NEB, landing without nose landing gear extended, Woodbourne (Blenheim) Aerodrome, 30 September 2010.

was likely that the high turnover of maintenance controllers hindered the recognition of an emerging trend with the performance of the aeroplane nose wheel landing gear. Earlier recognition of the problem should have prevented this accident.

4.41 When maintenance is performed on an aircraft away from its maintenance base, the engineer will be unlikely to have access to the aircraft's maintenance records. This could contribute to a recurring defect not being recognised. Therefore advice of any relevant recent defects – which will aid in the identification of the root cause of the present defect – should be supplied by the usual engineer or the Maintenance Controller. The loose-leaf log book entry that records the defect and rectification should be entered promptly into that aircraft's log book. An immediate review of the past maintenance will help with the recognition of possible recurring defects.

4.42 The best time to detect a maintenance error is at or close to the time that it is made, as the possibility of noticing the error diminishes with time. Audits and annual reviews of airworthiness are not intended to be safety nets to catch such errors. Even if an annual review is conducted by someone independent of all maintenance carried out during the review period, it is unlikely that it will detect a physical maintenance error– such as the installation of a wrong part – made during that period.

4.43 The incorrect strut housing had remained on the aeroplane for more than 4 years. The Commission is concerned that such a maintenance error, in a significant system of an aeroplane used for air transport operations, could remain undetected unless and until it was discovered by chance or as a result of an incident or accident. The Commission accepts that most participants in the aviation system carry out their work conscientiously. However, much aircraft maintenance is performed by individuals and is not subject to duplicate checks.

4.44 The Commission believes that more safeguards should be in place to detect and correct maintenance errors, at least in aircraft used for air transport operations. Accordingly, the Commission recommended the Director of Civil Aviation to widen the scope of aircraft systems that require duplicate checks after specified maintenance, at least for those aircraft used in air transport operations, in order to reduce the likelihood of recurring defects and incidents.

Findings:

3. Improper repair and maintenance practices spanning several maintenance organisations and individual maintenance engineers over several years contributed to a series of defects and incidents involving the nose landing gear assembly on the aeroplane.

4. Repairing and replacing defective components without identifying the reason for their failure in the first place is a serious safety issue that will likely result in repeat accidents and incidents for the same reasons.

5. Although much aircraft maintenance is done under supervision, the requirement for a duplicate check after maintenance is limited to a few defined control systems. The landing gear is not one of those systems, but an undetected maintenance error in the landing gear system has the potential to cause a serious incident or accident.

5 Findings

5.1 The nose landing gear did not lower normally because it had jammed in a partially retracted position. The landing gear jammed because the nose wheel alignment bracket lodged outside (instead of slotting into) the alignment guide as the landing gear retracted.

5.2 The nose wheel alignment bracket lodged outside the alignment guide for the following reasons:

a. the incorrect nose landing gear strut housing that had been fitted to the aeroplane allowed the nose wheel to turn in excess of the nominal 20°

b. the replacement of the modified alignment guide in April 2011 increased the vertical separation between the guide and the alignment bracket

c. the pivot bolt securing the steering bell-crank was bent and missing a washer, which meant the alignment bracket was less likely to engage fully with the alignment guide.

5.3 Improper repair and maintenance practices spanning several maintenance organisations and individual maintenance engineers over several years contributed to a series of defects and incidents involving the nose landing gear assembly on the aeroplane.

5.4 Repairing and replacing defective components without identifying the reason for their failure in the first place is a serious safety issue that will likely result in repeat accidents and incidents for the same reasons.

5.5 Although much aircraft maintenance is done under supervision, the requirement for a duplicate check after maintenance is limited to a few defined control systems. The landing gear is not one of those systems, but an undetected maintenance error in the landing gear system has the potential to cause a serious incident or accident.

6 Safety actions

General

6.1. The Commission classifies safety actions by 2 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.

6.2. No relevant safety actions were identified during this inquiry.

7. Recommendations

General

7.1. 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, 2 recommendations have been issued to the Director of Civil Aviation.

7.2. In the interests of transport safety it is important that these recommendations be implemented without delay to help prevent similar accidents or incidents occurring in the future.

Recommendations

The standard of general aviation maintenance practices

7.3. The findings from 2 separate inquiries show that general aviation maintenance practices in New Zealand are not always in accordance with Civil Aviation Rules or accepted industry practice. The findings show that non-compliance occurs in certificated maintenance organisations and by individual maintenance engineers exercising their individual licence privileges. This is an indication that the safety issue is not specific to just one sector of aviation maintenance. If left unchecked this situation is likely to have significant implications for aviation safety.

7.4. On 25 July 2013 the Commission recommended to the Director of Civil Aviation that he take action, in concert with the aviation industry, to improve the level of compliance with Civil Aviation Rules and conformance with industry best practice throughout the general aviation maintenance sector (018/13).

7.5. On 20 August 2013 the Director of Civil Aviation replied:

> The CAA will not implement the recommendation as worded. However, the CAA will adopt the safety surveillance practices as described in our final draft report response letter 14 June 2013.

7.6. The relevant portion of the CAA letter of 14 June 2013 stated:

> The CAA considers a recommendation that would address the relationship issues in terms of communications and record keeping between CAA Rule Part 43 maintenance providers and Part 135 AOC holders would be more effective. To this end, the CAA intends to profile Part 43 maintenance providers in order to identify poor performance or other risk issues. It is envisaged that increased surveillance and education programs would follow.

Duplicate inspections after maintenance

7.7. The requirement for duplicate inspections after maintenance is performed on critical aircraft systems reduces the risk of a maintenance error remaining undetected and causing an accident. However, there are only a few specified control systems that are deemed critical and that require duplicate inspections. There are other important systems – for example, the landing gear and brakes – that are not subjected to the same level of scrutiny. This is a safety issue, particularly for aircraft used in air transport operations where the consequences of an accident could be greater.

7.8. The findings from 2 separate inquiries show that because duplicate inspections are currently confined to critical control systems only, the risk of undetected maintenance errors in important, but non-critical, aircraft systems is not sufficiently mitigated. This accident was a prime example of how maintenance errors that are made in an important system and that are not detected then or during subsequent maintenance can become causal factors in an accident. The risks were higher in this case because the relevant maintenance events had been performed by independent engineers on parts of an aeroplane sub-system that were not subject to duplicate inspections.

7.9. On 25 July 2013 the Commission recommended to the Director of Civil Aviation that he widen the range of aircraft systems that require duplicate checks after specified maintenance, at least for those aircraft used in air transport operations, in order to reduce the likelihood of recurring defects and incidents (019/13).

7.10. On 20 August 2013 the Director of Civil Aviation replied:

> The CAA considers that widening the scope of aircraft systems requiring duplicate inspections [is] not sufficiently supported by the Commission's investigation. In this regard, the CAA prefers to remain in keeping with current world regulatory practice and therefore will not implement the recommendation.

8. Key lessons

8.1. Persons who work on aircraft must refer to the appropriate technical data and instructions, including maintenance manuals, to ensure that the correct procedures are followed fully. Effective supervision requires that supervisors physically check completed tasks before the tasks are signed off.

8.2. A physical check of a part taken off or installed, and comparison with the appropriate reference data, will ensure that the part is correct. Part number errors can arise, and be perpetuated, if reference is made only to the previous log book entry (which might be wrong).

8.3. The correct part name and part number must be used in aircraft maintenance documentation to help avoid installation errors.

8.4. Defect rectification is not completed just by repairing or replacing the defective part. The cause of the defect must be established and rectified as well. When maintenance is performed away from the usual base, it is important that the engineer is informed of any relevant recent or possible recurring defects.

8.5. The prompt receipt and review of loose-leaf log book entries by Maintenance Controllers can help with their recognition of possible recurring defects.

9. Citations

CAA. (2009). Advisory Circular 43-1, Aircraft maintenance. Wellington.

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