Addendum to Final Report AO-2010-009: Walter Fletcher FU24, ZK-EUF
loss of control on take-off and impact with terrain,
Fox Glacier aerodrome, South Westland, 4 September 2010

Addendum to Final Report

Aviation inquiry 10-009

Walter Fletcher FU24, ZK-EUF

loss of control on take-off and impact with terrain

Fox Glacier aerodrome

South Westland

4 September 2010

Approved for publication: September 2015

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 this addendum

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Citations and referencing

Information derived from interviews during the Commission's inquiry into the occurrence is not cited in this addendum. 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 addendum are provided by, and owned by, the Commission.

Walter Fletcher FU24, ZK-EUF
(Courtesy of Super Air Limited)

Source: mapsof.net

Location of accident

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Abbreviations

CAA	Civil Aviation Authority of New Zealand
Commission	Transport Accident Investigation Commission
G	the acceleration on a body due to the force of gravity

Glossary

controllability	the ability of an aircraft to respond to flight control displacement and achieve the desired condition
datum	a reference point for measurements on the fore and aft axis of an aircraft, about which centre of gravity calculations can be performed. For the Fletcher FU24-950 series of aeroplanes, which includes the Walter Fletcher, the datum point was the leading edge of the wings
manoeuvre neutral point (stick-free)	the centre of gravity position where the control stick force per G is zero. The required stick force per G reduces as the centre of gravity moves rearward
pitch attitude	(as used in this report) an aeroplane's climb angle
rotate, rotation	to raise, or the raising of, an aeroplane's nose to the take-off pitch attitude
stick force	the force that a pilot applies to the control stick to move the elevator or ailerons to alter the aeroplane attitude. Hence, low or high stick forces
tandem	two parachutists under a single parachute. The pair normally comprises a 'tandem master' and a 'rider' attached by a harness
trim	an attachment to a flight control that eases the control forces felt by a pilot when moving that control

Data summary

Aircraft particulars

Aircraft registration:	ZK-EUF
Type and serial number:	Walter Fletcher FU24, 281
Number and type of engines:	one Walter M601D-11NZ turbo-propeller
Year of manufacture:	1980
Operator:	Skydive New Zealand Limited
Type of flight:	commercial – parachuting
Persons on board:	nine
Pilot's licence:	commercial pilot licence (aeroplane)
Pilot's age:	33
Pilot's total flying experience:	4,554 hours (41 on type)

Date and time	4 September 2010, 1325 NZST[1]
Location	Fox Glacier aerodrome, South Westland latitude: 43° 27´ 39" south longitude: 170° 00´ 53" east
Injuries	nine fatal
Damage	aeroplane destroyed

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

1. Executive summary

1.1. General

1.1.1. On 4 September 2010 the pilot of a Walter Fletcher aeroplane (the aeroplane) with eight parachutists on board lost control during take-off from Fox Glacier aerodrome. The aeroplane, registered ZK-EUF, crashed in a paddock adjacent to the runway, killing all nine occupants.

1.1.2. The aeroplane had been modified from an agricultural aeroplane into a parachute-drop aeroplane three months before the accident. The modification had been poorly managed, and discrepancies in the modification documentation were not detected by the Civil Aviation Authority of New Zealand, which approved the change in role.

1.1.3. The operator of the aeroplane had not completed any weight and balance calculations for any flights before the accident. As a result the aeroplane was flown outside its loading limits every time it carried a full load of eight parachutists. On the accident flight the centre of gravity of the aeroplane was rear of its aft limit. After take-off the aeroplane continued to pitch up, before it rolled left and dived into the ground.

1.1.4. On 9 May 2012 the Transport Accident Investigation Commission (Commission) published Final Report 10-009 (final report) on its inquiry into the causes and circumstances of the accident.

1.1.5. The Coroner conducted his inquest into the deaths of the aeroplane's occupants between 13 and 17 August 2012 and published his findings on 3 May 2013. Some witnesses at the inquest questioned some of the processes followed by the Commission during its investigation, and questioned the validity and accuracy of some of the findings in the Commission's published report.

1.1.6. The witnesses' concerns were also the subject of a television documentary that was broadcast on 26 March 2014. Following the television documentary, some next of kin of the accident victims also expressed their concerns directly to the Commission.

1.1.7. The Commission was not formally requested to re-open its inquiry, nor did any party offer any new and significant evidence that the Commission had not already considered in its initial inquiry. However, on 15 April 2014 the Commission decided to "review the evidence relating to its findings as to the causes and circumstances of the accident, including evidential matters that have arisen since the publication of its report into the matter".

1.1.8. This addendum to the final report discusses the conduct and results of the review of evidence (the review). The addendum should be read in conjunction with the final report.

1.2. Findings

1.2.1. As a result of the review, the Commission made the following additional findings:

- ZK-EUF was 110 kilograms over its maximum permissible weight on the accident flight, but was still 149 kilograms lighter than the maximum all-up weight for which it had been certified in its previous agricultural role. Therefore the excess weight alone would have been exceptionally unlikely to have caused the accident
- the aeroplane's centre of gravity is estimated to have been at least 0.120 metre rearward of the flight manual limit
- the aeroplane had been flown routinely without its pilots knowing the weight and balance for the flights. The centre of gravity position affects how controllable an aeroplane is.[2] Therefore the risk associated with the parachuting flights was increased by the pilots not knowing accurately the centre of gravity position

[2] Controllability, as used in this report, means the ability of an aircraft to respond to flight control displacement and to achieve the desired condition.

- flight tests indicated that the aeroplane should have been controllable at take-off, in the absence of any adverse factor such as adverse elevator trim, and with the centre of gravity position estimated for the accident flight. Therefore the centre of gravity position alone should not have caused the accident. However, in combination with any other adverse factor, a very rearward centre of gravity increased the risk of the pilot losing control of the aeroplane
- it was exceptionally unlikely that the pilot had attempted the take-off with the control stick locked
- the engine was delivering power throughout the short flight and at the time of impact. No relevant pre-existing technical defect with the aeroplane was identified, but the possibility of such a defect cannot be excluded
- the Commission considered various adverse factors that might have been present singly or in combination, but could not determine the cause of the excessive pitch-up at take-off that preceded the steep climb and the subsequent stall.

1.3. Recommendations

1.3.1. No new safety issues were identified by the review. Therefore the Commission has made no new recommendations.

1.3.2. In its final report the Commission made six recommendations to the Director of Civil Aviation. Three of them related to the operation of parachute-drop aircraft, two related to the process for converting aircraft to another purpose and one related to seat restraints. A recommendation was made to the Minister of Transport regarding the need for a drug and alcohol detection and deterrence regime for the various transport modes.

1.4. Safety actions

1.4.1. Section 10 of this addendum shows the safety actions that have been taken since the accident date.

2. Conduct of the review

2.1. The ‘review team’ comprised the Deputy Chief Investigator of Accidents of the Transport Accident Investigation Commission (Commission) and another of the Commission’s air accident investigators, neither of whom had been directly involved in the original investigation. Contracted and invited experts participated at various stages of the review (see Appendix 1 for a list of participants).

2.2. The main aspects of the Commission’s report that were questioned were as follows:

- whether the Commission had given due consideration to the fracture in the control stick
- whether the control stick had been inadvertently locked for the take-off
- whether the setting of the stabiliser trim[3] at take-off was a factor contributing to the accident
- whether the Commission gave due consideration to the power setting at take-off being a factor contributing to the accident
- whether a mechanical failure could be ruled out as a factor contributing to the accident.

2.3. This addendum is structured to show the stages of the review, in the following order:

- a re-examination of the wreckage, paying particular attention to the points made in paragraph 2.2 above
- a conference of experts, of whom most were independent of the Commission. The experts were assembled to assess the conclusions of the wreckage re-examination and other evidence gathered by the review, and to suggest aspects that required further work. The experts reconvened to assess the results of the further work
- a re-measurement of the seating positions in a similar aeroplane used during parachuting operations
- an independent and more extensive statistical analysis of the possible positions for the aeroplane’s centre of gravity
- flight tests to assess the centre of gravity position at which a similar aeroplane would become uncontrollable in pitch.

2.4. In particular the review team looked for evidence that might explain the excessive angle of climb the aeroplane reached immediately on take-off and when climbing away from the aerodrome, a climb that ended in an apparent stall. Evidence relating to the regulatory aspects of parachuting and the modification of the aeroplane for the parachuting role had not been questioned and was not therefore reviewed.

2.5. On 14 April 2014 the Commission reclaimed all of the available aeroplane wreckage. This included:

- all of the wreckage that had been originally retained for further inspection and analysis by the Commission, and subsequently returned to the aeroplane owner on completion of the Commission’s inquiry
- most of the wreckage that had been released and buried near the accident site after the initial site investigation.

2.6. The wreckage was re-examined on 5 and 6 May 2014 by a team of four, which included two contracted licensed aviation maintenance engineers, of whom one had been involved in the production of the television documentary.

2.7. The Commission engaged a metallurgist to examine the aeroplane’s control stick to determine the mechanism of its failure.

2.8. The Commission obtained an opinion from GE Czech, the manufacturer of the aeroplane’s engine and its fuel control unit, on the performance of the fuel control unit in failure mode.

[3] A trim is an attachment to a flight control that eases the control forces felt by a pilot when moving that control.

2.9. On 16 June 2014 the Commission held an expert conference involving experienced Walter Fletcher pilots and aviation engineers to consider the main conclusions of the review and to test them against the hypotheses on which the Commission had relied in making its published findings. The participants agreed on a statement at the conclusion of the meeting, which recommended that additional enquiries be made into matters on which they could not agree.

2.10. During July 2014 the Commission conducted an exercise that aimed to measure exactly the seating positions of tandem pairs[4] in a Walter Fletcher parachuting aeroplane.

2.11. In August 2014 the Commission engaged a statistics expert from Victoria University of Wellington to conduct a broader analysis of the potential range of locations for the aeroplane's centre of gravity on the accident flight.

2.12. In November 2014 the Commission engaged an aeronautical design engineer from Flight Structures Limited, Hamilton, and an experienced agricultural pilot to conduct flight tests to assess the 'manoeuvre neutral point'[5] of the Walter Fletcher aeroplane. An appreciation of the position of the manoeuvre neutral point informed the experts' discussion of the margin of controllability that might have been available to the pilot on the accident flight.

2.13. Two additional eyewitnesses to the accident were interviewed in July and August 2014. They gave accounts of the take-off flight path of the aeroplane from different perspectives.

2.14. On 28 January 2015 the Commission held a second expert conference with all but one of the experts involved in the first conference, to consider the results of the additional testing and enquiries referred to above.

2.15. The Commission approved a draft addendum on 14 April 2015 for circulation to interested persons for comment. The accident investigation agencies of Australia, Ireland and the United Kingdom assisted the Commission by liaising with next of kin of crew and passengers.

2.16. Submissions were received from the aeroplane owner, the next of kin of one tandem master, the next of kin of three passengers, and the Civil Aviation Authority of New Zealand (CAA). The submissions were considered fully by the Commission.

2.17. In July 2015 the Commission contracted the Department of Aerospace Engineering at Cranfield University, United Kingdom, to review the report on the November 2014 flight tests. Commission staff held a teleconference on 25 August 2015 with the Cranfield University engineers and the engineer who conducted the Gore flight test to discuss the conduct of the flight tests.

2.18. On 24 September 2015 the Commission approved the publication of this addendum.

[4] A tandem pair is two parachutists under a single parachute. The pair normally comprises a 'tandem master' and a 'rider' attached by a harness.

[5] The manoeuvre neutral point is the centre of gravity position where the control stick force per G is zero.

3. Re-examination of the wreckage

3.1. General

3.1.1. Following the examination of the accident site in September 2010, a substantial part of the wreckage, including the cabin floor and lower fuselage that had been completely destroyed in the fire, was released by the Commission and subsequently buried nearby. The Commission removed the remainder of the wreckage, which included the engine and propeller, the cockpit and all of the tail, from the accident site for further inspection and analysis. These parts were returned to the owner at the completion of the inquiry. The buried wreckage was exhumed on 1 March 2014 for the television documentary, and later returned to the owner. The Commission reclaimed all of the available wreckage on 14 April 2014.

3.1.2. Four persons, who were not involved with the initial site investigation, examined every item of the reclaimed wreckage on 5 and 6 May 2014, at the Commission's facility near Wellington. Special attention was given to those items that could affect pitch attitude[6] control and engine power, in particular:

- whether a fracture in the aeroplane control stick existed prior to the accident
- whether the control stick was inadvertently locked for the take-off
- whether the setting of the horizontal stabiliser trim at take-off was a factor contributing to the accident
- whether the power setting at take-off was a factor contributing to the accident
- whether any mechanical failure contributed to the accident.

3.1.3. The wreckage re-examination was subject to the following limitations:

- it was not possible to recreate accurately the layout of the wreckage as it was at the scene of the accident, although photographs of the wreckage in situ were available (see Figure 1)
- most of the aeroplane was affected by the fire, which destroyed some components
- it was very likely that some components were damaged further when the wreckage was moved (three times since the accident) and/or as a result of it being buried for three and a half years
- the aeroplane owner had disconnected some components in order to transport and store the wreckage
- not all of the components were located.

Control stick

3.1.4. At the accident site, the investigator in charge determined by visual examination of the fracture surfaces that the control stick had broken in the crash, but that conclusion was omitted from the final report. An independent metallurgist who examined the control stick as part of the review determined that the failure was typical of "tensile overload"[7] and was "consistent with damage occurring as a result of the accident". He found that the fracture "did not occur as a result of fatigue or any other pre-existing defect" (see Appendix 2). The wreckage re-examination showed that the control stick had struck the rudder pedal assembly during the crash (see Figure 2).

3.1.5. The Coroner's inquest was told of two other control stick failures. One of them, on a Walter Fletcher, originated near a wiring hole and was caused by improper maintenance. The other involved a different aeroplane type with a different control stick design. These events did not indicate a potential systemic issue with the Walter Fletcher control stick.

[6] As used in this report, pitch attitude is an aeroplane's climb angle.
[7] That is, forces that had exceeded the material strength.

Figure 1
Photograph of wreckage at original accident site (taken 5 September 2010)

Figure 2
Relative positions of base of control stick and rudder pedal at impact

Control stick lock

3.1.6. The final report stated that the possibility of the pilot having commenced the take-off with the control stick lock in place was unlikely, but it was not excluded (TAIC, 2012, paragraph 4.2.9). Flight tests conducted by Super Air Limited in August 2012 confirmed that the aeroplane nose could not be raised for take-off when the control stick was locked in the forward position.

3.1.7. The lock was not recovered during the initial site investigation or during the exhumation of the buried wreckage. However, during the review the lock was identified in a photograph that had been taken on site. The lock was not completely visible in the photograph, but an analysis of the dimensions indicated that the steel lock was not distorted, which one would expect to see if great force had been applied by the pilot to free a locked control stick.

3.1.8. The brackets that had attached the control stick lock to the horizontal bulkhead in the cockpit were received with the recovered wreckage. The final report referred to holes in the brackets having been “torn open” (TAIC, 2012, paragraph 3.2.6), this having “most likely occurred during the impact” (TAIC, 2012, paragraph 4.2.10). A further examination of the brackets showed that the damage had been caused by the steel control stick lock having pulled (under the effect of gravity) through the aluminium brackets, which had been softened in the fire that followed the crash. That finding showed that the lock was not connected at impact.

The horizontal stabiliser trim setting

3.1.9. The aeroplane was controlled in pitch by movement of the horizontal stabiliser, although the report used the more usual term, ‘elevator’. Unlike most light and medium-weight aeroplanes, the Fletcher does not have an elevator hinged to a fixed tail plane. Instead, when the pilot moves the control stick forwards and backwards, the complete horizontal stabiliser moves. By adjusting a trim tab attached to the stabiliser, the pilot can reduce the effort required to hold the control stick in that position.

3.1.10. The horizontal stabiliser trim tab screw-jack was bent at a position that was confirmed, by comparison with a similar aeroplane during the wreckage examination, to correspond with the cockpit trim position indicator having been about halfway between neutral and fully nose down at impact. A substantially nose-down trim was normal for a take-off with four tandem pairs on board.

The engine power setting

3.1.11. The Coroner’s inquest was told that Walter Fletchers had experienced uncommanded power increases in the past because of fuel control unit malfunctions, the inference being that such a failure could have caused or contributed to the loss of control at take-off.

3.1.12. An independent New Zealand-based aircraft maintenance engineer with considerable experience of Walter engines told the review that he knew of no case in which the Walter engine fuel control unit had failed and caused an uncommanded application of full power.

3.1.13. The manufacturer of the engine, GE Czech, advised that it was “unaware of any method for an uncommanded power increase within the fuel control unit of the M601D engine model. The fuel control unit limits [the maximum] operating speed and it is equipped with mechanical failsafe”.

3.1.14. GE Czech also wrote that, as the engine and accessories had not been inhibited for nearly four years:

> … the engine and controls will likely have environmental damage (rusting, pitting, etc.) from exposure. It would be difficult to distinguish this type of post-accident damage from any pre-existing damage. Also, disassembly of the hardware may cause additional damage which may also be difficult to distinguish from pre-existing damage or may mask or destroy pre-existing damage. For these reasons, any further investigative work will be difficult and may be inconclusive.

3.1.15. The re-examination of the propeller damage confirmed that the engine had been delivering high power at impact. For this reason, and noting the advice from GE Czech that the fuel control unit could not cause an uncommanded increase in power, a further examination of the engine and its accessories was not undertaken.

Other flight control system failures

3.1.16. The wreckage re-examination did not disclose any evidence of pre-existing mechanical damage or failure. However, the limitations of the re-examination (refer paragraph 3.1.3) cannot be overlooked.

3.1.17. Before the wreckage re-examination took place, the review considered the 28 flight control system defects on Fletcher aeroplanes that had been notified to the CAA between 2005 and 2014. None of the defects was relevant to the circumstances of this accident.

3.1.18. The elevator cables with attached turnbuckles were examined. Not all of the elevator system pulleys were recovered. The elevator mass balance assembly weight of about 19 pounds (8.6 kilograms) was within the maintenance manual limit for the assembly. No evidence was found of pre-impact damage or jamming within the elevator control system.

Other mechanical failures

3.1.19. The failure of an engine mount was mentioned at the Coroner's inquest as a possible cause of the loss of control, because a failed mount would likely alter the engine thrust line. One of the aeroplane's engine mounts had fractured, but that was an overload fracture that was almost certainly a result of the crash. The CAA database included seven notifications of previous Fletcher engine mount defects. These were considered prior to the wreckage re-examination and none was found to be relevant to the circumstances of this accident.

Flap setting

3.1.20. Neither the investigation notes held on file nor the final report referred to the flap setting of the aeroplane during the take-off or at impact. The flap setting was not reported by any witness and could not be determined at the wreckage re-examination.

4. Conference of experts

4.1. General

4.1.1. A conference of experienced Walter Fletcher pilots and aviation engineers (the experts) was assembled to assess the results of the review and to test them against the evidence previously available to the Commission. For matters on which the experts could not agree, additional enquiries were undertaken, and a second conference was held to consider the additional results.

4.2. First meeting, 16 June 2014

4.2.1. The conclusions of the first expert conference are shown in Appendix 3.

4.2.2. The experts briefly discussed, without reaching a conclusion, the possibilities of the pilot having been distracted or incapacitated, or having deliberately selected an excessive pitch attitude on take-off and, as a result, having inadvertently lost control.

4.2.3. The experts recognised the importance of knowing the actual position of the centre of gravity on the accident flight, but they could not agree on whether the estimated position in the final report was reliable. They cited uncertainties with the actual seating order and positions and the occupants' weights. The conference recommended that a comparison be made using a similar aeroplane. This exercise was carried out on 8 July 2014 at Wanaka, but did not produce a reliable result (see Section 5).

4.2.4. The experts agreed that the controllability of the aeroplane at the estimated position for the centre of gravity was unproven, because none of the aeroplanes in the cited Walter Fletcher flight tests had had its centre of gravity that far rearward. It was possible that the centre of gravity on the accident flight was so far to the rear of the allowable range that the aeroplane was uncontrollable in pitch. In order to answer that question, a flight test was arranged to assess this aspect of controllability (see Section 7).

4.3. Second meeting, 28 January 2015

4.3.1. The second expert conference considered the results of the seating re-measurement, the additional flight tests that assessed the manoeuvre neutral point position, a statistical review of the possible range of locations for the centre of gravity, and those topics not agreed at the first conference. The conclusions of the second conference are in Appendix 4.

4.4. Other discussion topics

Aeroplane flight path

4.4.1. The flight path from take-off to impact was highly unusual; in particular, the unusually steep climb angle that was achieved immediately after the aeroplane left the ground. The Coroner was equivocal about whether the aeroplane was under control at any stage after the pilot commenced the take-off, but the Commission's report suggested that the pilot "was attempting to manoeuvre [the aeroplane] out of the dive" (TAIC, 2012, paragraph 4.2.1). The observation that the aeroplane took off earlier than it normally did (but only by about one aeroplane length) led to the finding in the final report that "the aeroplane probably became airborne early and at too low an airspeed to prevent uncontrollable nose-up pitch" (TAIC, 2012, paragraph 5.2). The experts considered that if the take-off speed had been too low, a stall would have been expected to occur earlier in the climb, even if the take-off power exceeded the nominal limit. In any event, there was no way of knowing what the airspeed had been at any point.

4.4.2. The majority of witnesses said that the take-off looked normal. Some said that the aeroplane became airborne after the intersection of the runway and hangar access road; some said at about the intersection. The evidence of the two witnesses interviewed in July and August 2014 was not new or significantly different from what was previously known. Overall, the evidence was not clear on whether the aeroplane was rotated[8] or took off earlier on the accident flight than it normally had done with eight passengers on board.

4.4.3. Many witnesses said the turn after the pitch-up appeared to have been "controlled".[9] However, the experts noted that the aeroplane's behaviour near the apex of the climb was consistent with that of an aeroplane fully stalled with engine power on. The observed flight path did not necessarily indicate that the pilot was in control of the aeroplane.

4.4.4. The experts also noted that although the pilot was said to have been fit and in good health (TAIC, 2012, paragraph 4.2.1), the possibility that he was incapacitated in some way could not be excluded as a factor in the excessive pitch up when the aeroplane took off and the subsequent loss of control.

Load shift

4.4.5. The tandem masters employed by the operator told the Coroner's inquest that the plastic floor covering in the aeroplane had not been slippery and there had been no load shifts on any previous take-offs. The inquest was also told that the jumpsuits had leather seats that increased their friction with the floor. These points were noted, but they did not exclude the very likely possibility that at an extreme nose-up attitude, like that seen after the aeroplane took off, unrestrained occupants would have shifted rearward, exacerbating an already rearward centre of gravity condition. That was not to say that a load shift precipitated the loss of control, but if a loss of control had occurred a load shift would have made recovery more difficult.

Weight of the aeroplane

4.4.6. The empty aeroplane was substantially heavier, and had a centre of gravity position more rearward, than similarly modified Walter Fletchers. The work sheets for the previous three re-weighs of the aeroplane were inspected, but no relevant errors were found. The review team accepted that the empty weight and the centre of gravity position used in the final report were correct.

4.4.7. The final report was based on the aeroplane having an estimated take-off weight of 4,896 pounds (2,221 kilograms) and the centre of gravity position at 30.2 inches (0.767 metre) rearward of the datum.[10,11] As part of the review, the following weights were amended for the weight and balance calculations:

- the fuel weight was increased by 39 kilograms, because the fuel gauge calibration allowed for the unusable fuel
- 11 kilograms were added for the oxygen system
- seven kilograms were added for the pilot's parachute
- the weight of each tandem parachute was increased by nine kilograms.

4.4.8. After making these changes, the revised estimated take-off weight was 5,102 pounds (2,314 kilograms); that is, 206 pounds (93 kilograms) heavier than the 4,896 pounds (2,221 kilograms) used in the final report. The aeroplane would have been 110 kilograms over its maximum permissible weight on the accident flight, but 149 kilograms under the maximum all-up weight for which it had been certified in its previous agricultural role. The revised centre of gravity position, after the above weight changes, was 30.1 inches (0.765 metre) aft of datum, which is two millimetres forward of the position given in the final report (0.767 metre).

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[8] Rotation is the raising of an aeroplane's nose to the take-off pitch attitude.

[9] One of the witnesses, an aviation medical examiner and experienced aeroplane pilot, made two statements to Police after the accident. His statements were considered along with those of all witnesses.

[10] All references to centre of gravity position are 'aft of datum'. Datum is a reference point for measurements on the fore and aft axis of an aircraft, about which centre of gravity calculations can be performed. For the Fletcher FU24-950 series of aeroplanes, the datum point was the leading edge of the wings.

[11] The length and weight are given in both imperial and metric units to allow comparisons with the values shown in the final report.

4.4.9. The operator had modified the floor of the aeroplane after it was delivered to Fox Glacier, by adding foam-backed plastic liners and a raised squab down one side of the cabin. This addition to the aeroplane's empty weight was not recorded in the aeroplane log book or accounted for in any centre of gravity calculations. Although the weights are not known, the changes would have caused the centre of gravity to be slightly more rearward than was estimated in the final report.

5. Re-measurement of seating positions

5.1. The position of the centre of gravity depended on the amount and the distribution of the various masses that comprised the aeroplane. For example, the pilot was seated well forward, the fuel was located in the forward part of the wings, and the passengers were distributed throughout the cabin. The centre of gravity estimated for the accident flight was based on the assumption that the tandem masters and their passengers had been seated in the order given in the operator's procedure, that is, with the heaviest pairs forward. Comments made at the Coroner's inquest and received since from industry participants challenged that assumption.

5.2. The television documentary (see paragraph 1.1.6) had included a reconstruction of the seating of eight parachutists in a Fletcher parachuting aeroplane. One conclusion of the reconstruction was that the occupants could not have moved more than 6 inches (0.15 metre) rearward in the event of the aeroplane pitching up steeply. However, even a shift of that amount in the seating positions would have moved the centre of gravity on the accident flight more than one inch (0.025 metre) further rearward, when it was already well rear of the limit.

5.3. The seating positions used by the Commission in its calculations for the final report were those said to have been used by the operator. These had been provided to the operator by another skydiving company that also used a Walter Fletcher. The experts considered that the seating positions used on the accident flight may have been different. Therefore the review considered the degree to which different seating positons were possible, and might affect the centre of gravity position.

5.4. A loading trial was made using a similar Walter Fletcher at Wanaka aerodrome. Staff from a local skydiving operator filled the roles of tandem masters and passengers, but were not directed where to sit. The exercise confirmed that the actual seating positions were likely to vary between flights, and therefore that it was not possible to know precisely where the centre of gravity had been on the accident flight.

6. Statistical analysis of weight and balance

6.1 A question frequently asked after the accident was, "If the aeroplane had always been loaded the same way when four tandem pairs were carried, and that was known to produce a very rearward centre of gravity, why had control issues not been apparent before?". The *Monte Carlo* statistical analysis referred to in the final report was intended to answer that question.

6.2 If very few of the simulated flights had had their centres of gravity at or more rearward than that of the accident flight, one might conclude that the accident flight was an extreme case and perhaps the loading arrangement contributed to the accident. If, on the other hand, a sizeable proportion of the simulated flights had their centres of gravity more rearward than that of the accident flight, the likelihood that such a centre of gravity position had occurred on a previous flight (which we know did not crash) would be relatively high.

6.3 The analysis in the final report showed that all of the random loads had centres of gravity that were rearward of the flight manual limit, and that about 5% of them exceeded the rear limit by more than 0.120 metre. The final report concluded that the centre of gravity on the accident flight, estimated to have been 0.122 metre rearward of the limit, "was possibly the most rearward of any of the … previous flights" (TAIC, 2012, paragraph 4.2.16).

6.4 In August 2014 the School of Mathematics, Statistics and Operations Research at Victoria University of Wellington was contracted to perform a more extensive *Monte Carlo* analysis,[12] using a more refined range of passenger weights than was used for the final report.[13]

6.5 The Victoria University analysis considered 10,000 samples of four scenarios that covered variations in the seating order of the tandem pairs (compared with the operator's stated procedure of putting the heaviest pairs on first, at the front of the cabin) and the use of Normal Distributions[14] of weights versus the presumed weights of the tandem masters. The seating positions and weights used were those in Appendix 1 of the final report.[15]

6.6 The first simulation scenario duplicated that shown in the final report, except that passenger weights were bounded between 45 kilograms and 105 kilograms, which was thought to be a more realistic weight range. In this simulation, 7.7% of the cases had centres of gravity at or further rearward than that estimated for the accident flight (0.122 metre rear of the datum). The Victoria University analysis concluded that, under this scenario, the accident centre of gravity position "was a relatively rare event".

6.7 The other scenarios produced greater numbers of flights on which the centres of gravity would have been more rearward than that on the accident flight. The Victoria University report summarised the analysis, in part, as follows:

> We would conclude that the likelihood that the centre of gravity was 0.122 m or more aft [rearward] of datum on a typical flight of this aircraft was at least 25.89%. If the additional scenario, having the two lightest pairs varying between the two rear positions is also a realistic scenario of what typically happened in these flights, then the likelihood would be increased to 40.87%, making it quite a common occurrence.
>
> We conclude then that the amount of imbalance (distance of the centre of gravity aft of datum) observed on the accident flight would have occurred quite frequently (approximately 26% of the time) in previous flights of this aircraft with these Tandem Masters. The likelihood that this amount of imbalance alone caused the accident must therefore be assumed to be quite low, as there must

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[12] Statistical review of TAIC report 10-009, Dalice A Sim and Lloyd Pledger, August 2014.

[13] For example, the weight range was limited to 45 kilograms to 105 kilograms, because young and over-weight people are not taken on such flights.

[14] The Normal Distribution is a statistical function that gives the probability of a real observation (sample) falling between any two values. It is often shown as a 'bell curve', with a peak at the mean value and the distribution tapering evenly to zero on each side of the mean.

[15] The subsequent corrections to the estimated aeroplane weight as a result of the review of evidence, in particular the revised weight of 29 kilograms for the tandem parachute rigs and equipment, did not alter the estimated centre of gravity position. These changes did not invalidate the statistical study or its conclusion, that the centre of gravity position quite frequently would have been as far, or further, aft than that estimated for the accident flight.

have been previous flights with this level of imbalance and they did not have accidents.

6.8 Knowing that every time the aeroplane carried four tandem pairs the centre of gravity was well rearward of the flight manual limits had invited the question, "How far to the rear could the centre of gravity be before a pilot lost control?". The answer to that question came from the flight tests conducted to assess the centre of gravity position that was associated with the manoeuvre neutral point.

7. Controllability of the aeroplane with a rearward centre of gravity

7.1. The review accepted that the actual weight of the aeroplane at take-off, although over the maximum permissible weight for the 'normal' certification category, was not a critical factor in the accident, as the Fletcher aeroplane was known to perform well at the much heavier weights permitted in the agricultural role. In the agricultural role, the centre of gravity generally remained within the permitted range. The key issue for controllability was the location of the centre of gravity.

7.2. Many participants in the parachuting industry disagreed with the Commission's finding that the rearward centre of gravity "would have caused serious handling issues for the pilot and was the most significant factor contributing to the accident" (TAIC, 2012, finding 5.7). Their rejection of the finding was partly based on the fact that the aeroplane (like other Walter Fletchers used for parachuting) had flown with similar loads on more than 70 occasions without any reported control issues during take-off.

7.3. The Coroner's inquest heard of flight tests conducted in August 2012, after the Commission's final report was published. The purpose of these tests, conducted by Super Air, was to evaluate the pitch control characteristics of the Walter Fletcher, and to determine whether:[16]

- the pitch control forces [primarily the use of the stabiliser] could override the pitch trim control
- an excessively steep climb with take-off power was predictable and manageable
- the pitch could be controlled from a nose-high attitude, and how effectively the aeroplane responded to control stick inputs at lower airspeeds and with a rearward centre of gravity [up to 4.11 inches (.104 metre) rearward of the rear limit]
- the aeroplane could become airborne with the pitch control forward (simulated control column lock position) and when loaded so that the weight and centre of gravity [approximated those of the accident flight]. This test was repeated with the trim in the most adverse (nose-up) position.

7.4. Super Air's report on the August 2012 flight tests concluded, in part:[17]

- at this [weight and balance] the aircraft did not appear to show a flight characteristic that was unpredictable, or that the aircraft was uncontrollable when operating with adverse pitch trim at lower flight speeds (90 knots or less) with the flap settings of 0, 20 and 40 degrees. The control stick forces[18] were not beyond the capability of a normal person to control with their right arm
- if raising the nose for take-off was delayed, by maintaining the control stick in a fully forward position, the aircraft [main landing gear would try to fly off first] but the propeller wash and increasing airspeed increased the effectiveness of the tail plane capability to keep the nose pitched down and in contact with the runway. The pitch control forces in this attitude were manageable
- the delayed take-off was repeated with the pitch trim set to [maximum] aft (nose-up) and gave similar results with similar control stick forces. Attitude on take-off appeared to be around 20 degrees nose-up
- the flight handling characteristic of the aircraft in an excessive climb attitude stall with maximum continuous power and take-off power appears to show the aircraft is fully controllable
- the excessive nose-up attitude with low airspeed just prior to the stall was further explored to see what form of pitch control was effective to lower the nose and prevent a stall. Take-off power improved the effectiveness of any forward pitch control input and

[16] Paraphrased from Super Air report A401-02R, August 2012, p.1.
[17] *Ibid,* pp.2-4.
[18] The stick force is the force that a pilot applies to the control stick to move the elevator or ailerons to alter the aeroplane attitude.

the use of 20 degrees flap also improved the effectiveness. Control was not difficult [nor] were the control forces on the control stick unmanageable

- three take-offs were completed with the pitch trim set to take-off position with a rearward centre of gravity; with flap set at 20 degrees (take-off position) and the control stick held forward on the stop until the airspeed indicated 62 [knots] (2 runs) and 70 [knots] (one run), before being eased back and the aircraft allowed to take off. For all runs the nose wheel maintained contact with the runway, but it was possible to feel the main wheels lightening as the aircraft attempted to become airborne. The aircraft was controllable at all times. Repeating the take-offs with a fully [nose-up] pitch trim[19] resulted in a similar response from the aircraft and similar control forces on the control stick.

7.5. The Coroner's inquest heard of other flight tests conducted in a Walter Fletcher in 2000 as part of the programme to certificate the type in the normal category for parachute operations. These tests showed that, with the centre of gravity position within the flight manual limits, the Walter Fletcher would not enter a true, sustained spin condition. However, the tests did produce instances of incipient spin, which was possibly the condition observed by witnesses before the aeroplane dived into the ground.

7.6. A question often asked after the accident was, "Where would the centre of gravity have to be for the aeroplane to be uncontrollable in pitch?". As the centre of gravity moved further rearward, the control 'stick force' needed to move the stabiliser reduced. Reduced stick forces can lead to a pilot over-controlling in pitch, because the aeroplane is more responsive.

7.7. The answer to the question was to be found by assessing the likely position of the manoeuvre neutral point; that is, the centre of gravity position where the control stick force per G was zero. An indication of this point was found during the flight tests conducted at Gore on a Walter Fletcher configured for agricultural operations. The aeronautical engineer who conducted the tests assessed that the configuration differences between the agricultural and parachuting versions of the aeroplane would not be significant in terms of aerodynamic characteristics of interest.[20]

7.8. The test results conformed to conventional aerodynamic theory (see Figure 3, which reproduces Figure 2 of Appendix 5). Measurements of the control stick force were taken at two power settings, one of which was the nominal take-off power for the Walter Fletcher. The plotted results produced straight-line graphs showing that the stick force per G (measured on the vertical axis) decreased as the centre of gravity moved rearward. At the points where the extensions of the plotted graphs cut the horizontal axis, the stick force per G was zero. The corresponding centre of gravity positions (on the horizontal axis) were the manoeuvre neutral points for the respective engine power settings.

7.9. For the test aeroplane using take-off power, the results indicated that there was a margin of approximately 3.5 inches (0.089 metre) between the manoeuvre neutral point and the centre of gravity position that had been estimated for the accident flight. Consequently there would likely be acceptable control stick forces for that centre of gravity position. The aeronautical engineer noted that, in his experience with the design and flight testing of Fletchers, the manoeuvre neutral point found for the test aeroplane represented a likely forward limit for the aeroplane type; that is, the manoeuvre neutral point for a typical Walter Fletcher would be further to the rear, which would give a greater margin of controllability.

7.10. The National Flying Laboratory Centre of the School of Aerospace, Transport and Manufacturing, Cranfield University, United Kingdom, was asked to appraise the method and results of the Gore flight test. Its report (see Appendix 6) commented on the test having been in the nature of a 'spot check' and thereby having had some limitations.

7.11. In summary, the Cranfield review concluded:

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19 This would be the worst case when the centre of gravity was located well to the rear.

20 The configuration differences included, for example, a projecting hopper gate on the agricultural version, and a cabin door air defector and external steps on the parachuting version. Refer to Appendix 5.

> Overall, the test methods and techniques are satisfactory and the investigators have highlighted the effects of experimental sensitivity and uncertainties due to lack of flight test data.
>
> The objectives of the flight tests are clear [and] we are in overall agreement with the assessment.

7.12. The manoeuvre neutral point moves forward at higher engine power settings, which will reduce the stick force per G. The engine manufacturer advised that the engine fuel control unit could not produce an uncommanded increase in power above normal take-off power. However, the engine control system on the Walter Fletcher did not prevent pilots exceeding the nominal power limit, because they had to have the ability to adjust the maximum power according to the environmental conditions on the day. Therefore the possibility could not be excluded that at the point of take-off the pilot inadvertently or deliberately exceeded the nominal take-off power, which would have reduced the stick force and might have been a cause of the steep climb.

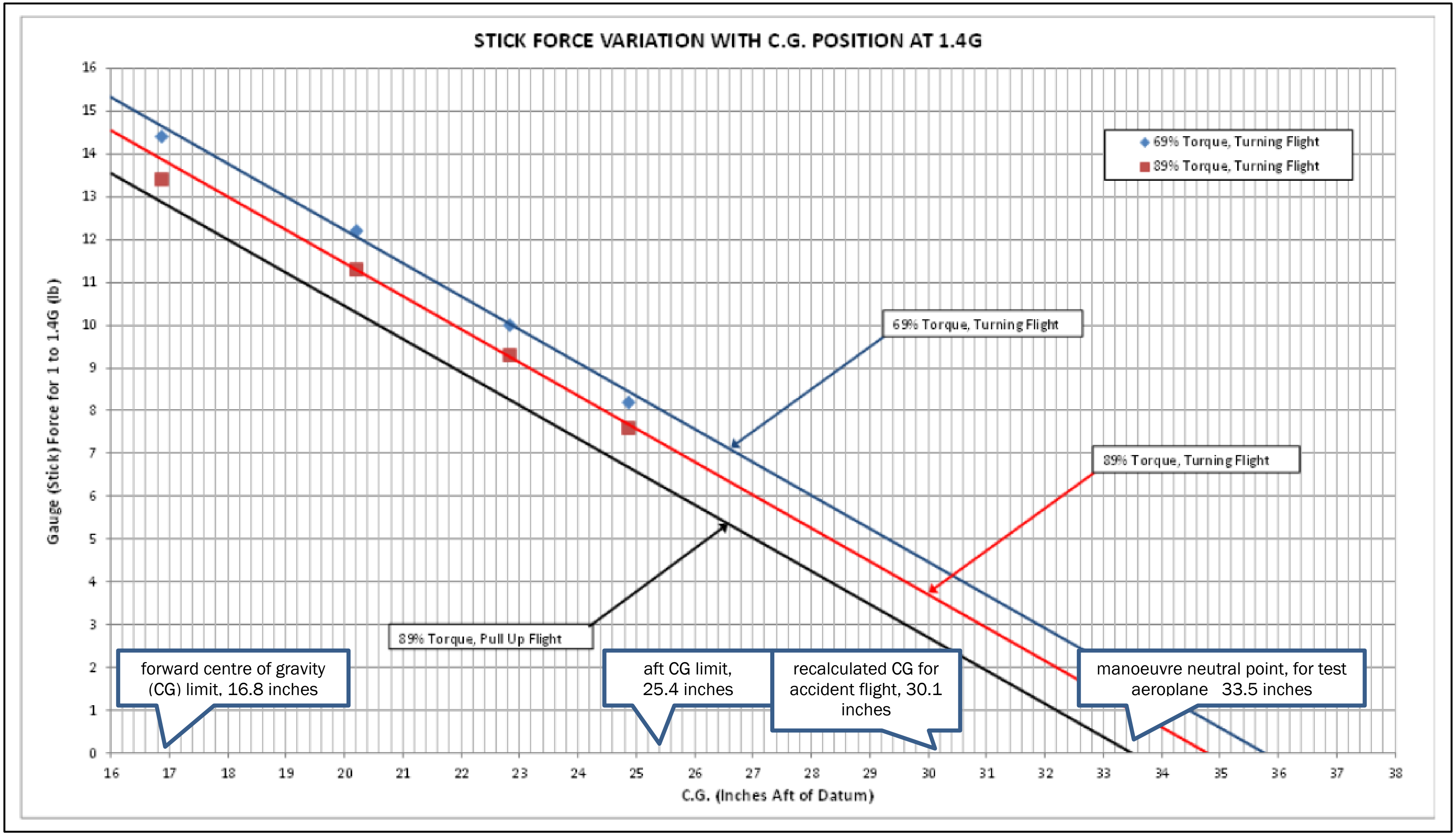

Figure 3
Flight test results used for finding the manoeuvre neutral point

8. Analysis

8.1. General

8.1.1. This review of the evidence relating to the Commission's findings as to the causes and circumstances of the accident involving the Walter Fletcher aeroplane on 4 September 2010 was limited to the following broad areas:

- technical and operational factors that were suggested as possible causes of the loss of control
- other evidential matters that had arisen since the publication of the final report.

8.1.2. The results of the various aspects of the review were assessed by two expert conferences, composed of people who had not been involved in the Commission's original inquiry. The expert conferences themselves led to further avenues of investigation, for example the flight tests to assess the position of the manoeuvre neutral point.

8.2. Possible causes of the loss of control

8.2.1. When the aeroplane took off, instead of adopting a normal, relatively shallow climb angle, it continued to pitch up to a very nose-high attitude. That unusually steep climb angle, the cause of which was not determined, was maintained until, towards the apex of the climb, the aeroplane rolled left and headed towards the runway briefly. According to some witnesses the aeroplane flew straight for a short period but was sinking. There was no disagreement that it then rolled further left and descended rapidly.

8.2.2. A stall was almost inevitable when the excessive climb angle was maintained after a heavy-weight take-off with a very rear centre of gravity. Test pilots said that the observed flight path from the apex of the climb was similar to that encountered during power-on stalls. A successful recovery from a low-altitude stall under these conditions was exceptionally unlikely.

8.2.3. The technical aspects of the final report that were questioned by various parties are discussed below. The discussion takes into account the conclusions of the two expert conferences (see Appendices 3 and 4).

How did the control stick break?

8.2.4. An independent metallurgist confirmed the conclusion, originally reached at the accident site, that the control stick had fractured as a result of impact damage. The wreckage re-examination showed that the control stick had struck the rudder pedal assembly. Therefore the control stick fracture did not occur before the impact and it was not a factor in the accident.

Was the control stick locked for the take-off?

8.2.5. Flight tests conducted in August 2012 confirmed that the aeroplane nose could not be raised for take-off if the control stick was locked. The possibility that the control lock was in place at the start of the take-off roll cannot be excluded. However, if that were the case, the lock must have been removed for the pilot to have pulled back for the take-off. As the aeroplane left the ground close to the normal take-off point, it was very unlikely that the pilot had been distracted by having to remove the lock.

8.2.6. The apparent lack of distortion of the control stick lock, as judged from a photograph taken at the site and the fire damage to the attachment bracket, showed that the control stick lock was disconnected at impact.

8.2.7. Therefore the Commission now finds that it was exceptionally unlikely that the pilot attempted the take-off with the control stick locked.

Was the stabiliser trim set incorrectly for the take-off?

8.2.8. It was very likely that the pilot had used significant nose-up trim for the landing after the parachute drop conducted before the lunch break. If he had not re-set the trim for the next take-off (which he had forgotten to do on a previous occasion), he should still have been able to control the aeroplane with his right hand holding the control stick, while he re-set the trim with his left hand.

8.2.9. The August 2012 flight tests showed that the Walter Fletcher was controllable when the centre of gravity was at a similar location as that estimated for the accident flight and with the trim set at fully nose-up (the most adverse position for a take-off).

8.2.10. The screw-jack that moved the horizontal stabiliser trim tab was bent in the crash. A comparison of the screw-jack extension with one in a similar aeroplane showed that the screw-jack would have been in a position that corresponded with the cockpit trim position indicator being about halfway between neutral and fully nose-down. A substantially nose-down trim was normal for a take-off when the position of the aeroplane's centre of gravity was well rear, as it would have been with four tandem pairs on board.

8.2.11. Therefore, if the trim had been set incorrectly before take-off, the pilot must have been able to adjust it before impact. As mentioned above, the aeroplane would have been controllable with the trim set at fully nose-up. Moving the trim tab nose-down after take-off should have made the aeroplane more controllable, which was not consistent with the aeroplane climbing more steeply to the point of stalling.

Was the engine power setting on take-off a factor?

8.2.12. Witnesses reported that the engine was operating throughout the flight, and the review confirmed that at impact the engine was delivering substantial power to the propeller. The observed take-off and climb could not have been achieved without maximum or near-maximum power.

8.2.13. The engine manufacturer, GE Czech, advised that it was "unaware of any method for an uncommanded power increase in the engine", and that was also the view of a highly experienced aircraft maintenance engineer with substantial experience of Walter engines. The experts considered it exceptionally unlikely that an engine fuel control unit defect occurred during the take-off and caused an uncommanded power increase.

8.2.14. The engine power on the Walter Fletcher aircraft can be set, either deliberately or unintentionally, to more than the take-off limit for the environmental conditions. Opinions varied among Walter Fletcher pilots as to whether using more-than-nominal engine power on take-off would result in control difficulties. This matter is discussed further in the section below on controllability.

Did any mechanical failure contribute to the accident?

8.2.15. The wreckage re-examination, like the initial site examination, did not disclose any evidence of pre-impact mechanical damage or failure. The experts considered possible causes of the loss of pitch control and assessed the causes individually to be very unlikely or even exceptionally unlikely. Nothing in the aeroplane's recent maintenance or operational history indicated an imminent defect with catastrophic potential.

8.2.16. Therefore it was very unlikely that a mechanical failure was a factor in the accident. However, due to the limitations of the wreckage examination,[21] that possibility cannot be excluded.

8.2.17. The flap setting on take-off was not determined at the accident site, and the reason for that was not recorded. The setting could not be determined during the wreckage examination. Knowledge of the setting can be useful, because the flap setting directly affects the stall speed and take-off performance. However, as the aeroplane took off and climbed away from about the usual point on the runway, it was very likely that the usual amount of flap had been selected. The amount of flap set would not have caused the excessive pitch-up at take-off. Therefore the lack of information on the flap setting did not materially affect the analysis or findings in the final report.

[21] Refer to paragraph 3.1.3.

8.3. Other evidential matters

Statistical analysis of the range of centre of gravity positions

8.3.1. The aeroplane's empty centre of gravity position was unusually rearward compared with similar aeroplanes. According to the statistical analysis conducted by Victoria University, the centre of gravity position estimated for the accident flight would not have been an extreme position when four tandem pairs of parachutists were on board.

8.3.2. Of the scenarios analysed, the most extreme centre of gravity position was 0.161 metre rear of the flight manual limit, compared with the 0.122 metre rear of the limit that was originally estimated for the accident flight.[22] The more thorough statistical analysis was at variance with the final report statement that "the centre of gravity position on the accident flight was possibly the most rearward centre of gravity of any of the … previous flights" (TAIC, 2012, paragraph 4.2.16).

8.3.3. The Victoria University analysis indicated that it was unlikely (a less than 33% chance) that the centre of gravity position on one of the earlier flights had been at or more rearward than the position estimated for the accident flight. However, under one realistic loading scenario, a more rearward centre of gravity position was more or less likely to have occurred on an earlier flight (refer to the probability expressions in Appendix 4).

8.3.4. Therefore, as control difficulties had not been reported on any of the earlier flights, the rearward centre of gravity position alone was very unlikely to have been the cause of the loss of control that preceded the accident.

Controllability of the aeroplane with a rearward centre of gravity

8.3.5. The results of the flight tests conducted at Gore led the expert conference to conclude that if the accident aeroplane had had stability characteristics similar to the test aeroplane's, as was suggested, it was virtually certain that, in the absence of other adverse factors, the pilot should have been able to control the aeroplane with the centre of gravity at the position estimated in the final report, and with take-off power set.

8.3.6. The experts heard various opinions about the controllability of the Walter Fletcher when the engine power was rapidly increased or exceeded the take-off limit. Agricultural pilots in particular sometimes exceeded the power limit on take-off, but they had not reported any problems with pitch control as a result. This is explainable by the fact that, although agricultural operations involve heavy aeroplanes, the centre of gravity is almost always forward of the flight manual rear limit. Therefore it is very likely that for agricultural operations the margin to the manoeuvre neutral point is greater than it is when used for parachuting operations.

8.3.7. Increased engine power is an adverse factor that could affect the controllability of an aeroplane. With increased engine power the manoeuvre neutral point moves forward, closer to the aeroplane's centre of gravity, and hence the control stick pitch forces would reduce. If the flight tests had used more power than the 'take-off' setting, the manoeuvre neutral point would have been less than 33.5 inches (0.851 metre) aft of datum (see Figure 3). Any movement of the manoeuvre neutral point forward would have contributed to a decrease in stick force. This could have made it difficult for the pilot to control the aeroplane pitch when raising the nose for take-off and during the subsequent climb.

8.3.8. The possibility that the excessive pitch-up immediately at take-off was intentional also cannot be excluded. Whether it was intentional or not, the extreme pitch attitude that occurred very likely caused the cabin occupants to slide rearward. Hence the centre of gravity would have moved further rearward, most likely by one inch (0.025 metre) or more, which would have decreased the distance from the centre of gravity to the manoeuvre neutral point and therefore have reduced the pitch control (stick) force.

8.3.9. The pilot might have reacted to the extreme pitch attitude, especially if it was unintended, by ensuring that he had the maximum possible engine power. Under most circumstances, and particularly when an aerodynamic stall is threatening, extra power helps a pilot to maintain or regain control. However, a very rearward centre of gravity with the maximum possible power

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[22] The position was recalculated during this review to have been 0.120 metre aft of the limit, a negligible change.

was an adverse combination that could have reduced controllability had the pilot been attempting to recover from an imminent stall.

8.4. Summary

8.4.1. The review considered carefully the technical factors suggested as possible causes of the loss of control by various parties after the publication of the final report. Some factors could be confidently excluded, and some could not.

8.4.2. The cause(s) of the excessive pitch-up and steep climb after take-off was not determined.

9. Findings

9.1. The addendum should be read in conjunction with the final report published on 9 May 2012, which still stands, along with the identified safety issues and its safety recommendations. The original findings (with the same paragraph numbering as used in the final report) are in Appendix 7.

9.2. As a result of the review the Commission made the following additional findings, which in some cases supersede or refine one or more of the original findings:

a. ZK-EUF was 110 kilograms over its maximum permissible weight on the accident flight, but was still 149 kilograms lighter than the maximum all-up weight for which it had been certified in its previous agricultural role. Therefore the excess weight alone would have been exceptionally unlikely to have caused the accident.

b. The aeroplane's centre of gravity is estimated to have been at least 0.120 metre rearward of the flight manual limit.

c. The aeroplane had been flown routinely without its pilots knowing the weight and balance for the flights. The centre of gravity position affects how controllable an aeroplane is. Therefore the risk associated with the parachuting flights was increased by the pilots not knowing accurately the centre of gravity position.

d. Flight tests indicated that the aeroplane should have been controllable at the take-off, in the absence of any adverse factor such as adverse elevator trim, and with the centre of gravity position estimated for the accident flight. Therefore, the centre of gravity position alone should not have caused the accident. However, in combination with any other adverse factor, a very rearward centre of gravity increased the risk of the pilot losing control of the aeroplane.

e. It was exceptionally unlikely that the pilot had attempted the take-off with the control stick locked.

f. The engine was delivering power throughout the short flight and at the time of impact. No relevant pre-existing technical defect with the aeroplane was identified, but the possibility of such a defect cannot be excluded.

g. The Commission considered various adverse factors that might have been present singly or in combination, but could not determine the cause of the excessive pitch up at take-off that preceded the steep climb and the subsequent stall.

9.3. The following table shows how the additional findings affect some of the findings in the final report.

Table 1: Effect of additional findings on original findings in final report

	Additional finding	Final report findings that are affected by this finding	How affected
a	ZK-EUF was 110 kilograms over its maximum permissible weight on the accident flight, but was still 149 kilograms lighter than the maximum all-up weight for which it had been certified in its previous agricultural role. Therefore the excess weight alone would have been exceptionally unlikely to have caused the accident.	*(Final report finding 5.8) ZK-EUF was 17 kg over its maximum permissible weight on the accident flight, but was still 242 kg lighter than the maximum all-up weight for which the aeroplane was certified in its previous agricultural role. Had the aeroplane not been out of balance it is considered the excess weight in itself would have been unlikely to cause the accident. Nevertheless, the pilots should have made a full weight and balance calculation before each flight.*	The additional finding increases the estimated take-off weight, but **reaffirms** final report finding 5.8, that the weight alone was almost certainly not a causal factor.
b	The aeroplane's centre of gravity is estimated to have been at least 0.120 metre rearward of the flight manual limit.	*(Final report finding 5.2) The aeroplane's centre of gravity was at least 0.122 m rear of the maximum permissible limit, which created a tendency for the nose to pitch up. The most likely reason for the crash was the aeroplane being excessively out of balance. In addition, the aeroplane probably became airborne early and at too low an airspeed to prevent uncontrollable nose-up pitch.* *(Final report finding 5.7) The weight and balance of the aeroplane, with its centre of gravity at least 0.122 m outside the maximum aft limit, would have caused serious handling issues for the pilot and was the most significant factor contributing to the accident.*	The additional finding makes a minor adjustment (two millimetres) to the estimated centre of gravity position.
c	The aeroplane had been flown routinely without its pilots knowing the weight and balance for the flights. The centre of gravity position affects how controllable an aeroplane is. Therefore the risk associated with the parachuting flights was increased by the pilots not knowing accurately the centre of gravity position.	*(Final report finding 5.8) ZK-EUF was 17 kg over its maximum permissible weight on the accident flight, but was still 242 kg lighter than the maximum all-up weight for which the aeroplane was certified in its previous agricultural role. Had the aeroplane not been out of balance it is considered the excess weight in itself would have been unlikely to cause the accident. Nevertheless, the pilots should have made a full weight and balance calculation before each flight.*	The additional finding **complements** final report findings 5.8 and 5.9, by emphasising the increased risk when pilots do not know the weight and balance of their aircraft.

		(Final report finding 5.9) The aeroplane owner and their pilots did not comply with civil aviation rules and did not follow good, sound aviation practice by failing to conduct weight and balance calculations on the aeroplane. This resulted in the aeroplane being routinely flown overweight and outside the aft centre of gravity allowable limit whenever it carried 8 parachutists.	
d	Flight tests indicated that the aeroplane should have been controllable at the take-off, in the absence of any adverse factor such as adverse elevator trim, and with the centre of gravity position estimated for the accident flight. Therefore the centre of gravity position alone should not have caused the accident. However, in combination with any other adverse factor, a very rearward centre of gravity increased the risk of the pilot losing control of the aeroplane.	*(Final report finding 5.2) The aeroplane's centre of gravity was at least 0.122 m rear of the maximum permissible limit, which created a tendency for the nose to pitch up. The most likely reason for the crash was the aeroplane being excessively out of balance. In addition, the aeroplane probably became airborne early and at too low an airspeed to prevent uncontrollable nose-up pitch.* *(Final report finding 5.7) The weight and balance of the aeroplane, with its centre of gravity at least 0.122 m outside the maximum aft limit, would have caused serious handling issues for the pilot and was the most significant factor contributing to the accident.*	This additional finding (together with additional finding 'g') **refines** final report finding 5.2 and **replaces** final report finding 5.7. The review: 1. was unable to determine that the aeroplane became airborne early or at too low an airspeed 2. determined that the aeroplane should have been controllable even with the estimated centre of gravity being so far aft of the allowable limit, and therefore 3. was unable to conclude that the position of the centre of gravity "was the most significant factor contributing to the accident".
e	It was exceptionally unlikely that the pilot had attempted the take-off with the control stick locked.	None.	A new finding.
f	The engine was delivering power throughout the short flight and at the time of impact. No relevant pre-existing technical defect with the aeroplane was identified, but the possibility of such a defect cannot be excluded.	*(Final report finding 5.1) There were no technical defects identified that may have contributed to the accident and the aeroplane was considered controllable during the take-off roll, with the engine able to deliver power during the short flight.*	The additional finding **refines** final report finding 5.1.

g	The Commission considered various adverse factors that might have been present, singly or in combination, but could not determine the cause of the excessive pitch-up at take-off that preceded the steep climb and the subsequent stall.	*(Final report finding 5.2) The aeroplane's centre of gravity was at least 0.122 m rear of the maximum permissible limit, which created a tendency for the nose to pitch up. The most likely reason for the crash was the aeroplane being excessively out of balance. In addition, the aeroplane probably became airborne early and at too low an airspeed to prevent uncontrollable nose-up pitch.*	This additional finding, together with additional finding 'd', **refines** final report finding 5.2.

10. Safety actions

10.1. This section lists the pertinent safety actions taken since the accident.

Safety actions in response to a recommendation issued by the Commission

10.2. On 13 September 2010 the Commission made the following urgent safety recommendation:

> The Commission recommends that the Director of Civil Aviation as a matter of urgency alerts all pilots and operators using the Fletcher FU24-954 aircraft for parachuting operations that when loaded with 6 or more passengers it is possible for the aircraft CG [centre of gravity] to be aft of the allowable limit, and that this could result in control difficulties, and that parachutists should be seated in the forward cabin area, preferably restrained to prevent them inadvertently moving rearward. (037/10)

10.3. On 20 September 2010 the General Manager of the General Aviation Group of the CAA replied in part:

> As we have already advised the Commission, the CAA issued Emergency Airworthiness Directive (AD) DCA/FU24/179 on 11 September 2010, to address the safety issues that you identify in your letter. The AD was sent immediately to all operators of Fletcher series aircraft conducting parachute operations. We accept that this is based on information gained early in the investigation and the issue of the AD should be considered to be immediate interim action pending completion of your investigation.
>
> **AD DCA/FU24/179 Parachuting Operations – Limitation and C of C Determination,** which requires;
>
> 1. Amendment of the Aircraft Flight Manual (AFM) to restrict maximum occupancy of the cabin aft of F.S 118.84 to six persons. This may be accomplished by inserting a copy of the AD into the AFM adjacent to the applicable supplement for parachuting operations.
>
> 2. No parachuting operation is to be conducted with any number of occupants, unless for each individual flight:
>
>   a. A weight and balance calculation is performed to establish that the aircraft Centre of Gravity will remain within AFM limits for the duration of the flight, and
>
>   b. The calculation uses actual weights for all occupants and their equipment, and
>
>   c. The calculation accounts for the positions of all occupants. The occupants' positions shall be taken as the most aft positions that result from the rearmost members of the group sitting against the aft cabin wall and subsequent occupants located immediately forward of them, unless a means of restraint is provided to prevent the occupants moving rearwards from their normal position, and
>
>   d. A record of the Centre of Gravity determination is kept for each parachuting operation.
>
> The effective date of the AD is 11 September 2010 and compliance with 1 and 2 above is required before further parachute-drop operations and before every parachute-drop operation, respectively.

10.4. On 25 October 2012 the CAA replaced AD DCA/FU24/179 with the following:

DCA/FU24/182 Standard Category Aircraft – Parachuting Operations

Applicability: All turbine powered FU24 series aircraft with a Standard Category Airworthiness Certificate and used for parachuting operations.

Note 1: DCA/FU24/182 supersedes the requirements in DCA/FU24/179.

Requirement: To prevent operation outside of the C of G envelope which can result in loss of aircraft control, accomplish the following:

1. For every parachuting flight accomplish the following:

a. A weight and balance calculation is performed to establish that the aircraft C of G will remain within AFM limits for the duration of the flight, and

b. The calculation uses actual weights for all occupants and their equipment, and

c. A record of the C of G determination is kept for each parachuting operation.

2. Add fuselage station markings in the cabin of the aircraft to aid in determining weight and balance positions in accordance with acceptable technical data. Insert a Flight Manual Supplement specifically approved for parachuting operations for the aircraft, which must contain detailed information for determining the weight and balance of the aircraft. The operator must ensure that aircraft crew are aware of the AFM Supplement.

Note 2: CAA approved AFM supplement AIR 2672-FMS-P1 for the FU24 series aircraft with STC 98/21E/15 embodied and CAA approved AFM supplement AIR 2817-FMS-P1 for FU24 series aircraft with STC 3/21E/1 embodied are an acceptable means to comply with requirement 2 of this AD.

Note 3: Copies of the CAA approved AFM supplements can be obtained from flight.manuals@caa.govt.nz

Note 4: Requirement 1 of this AD may be accomplished by adding the weight and balance calculation requirement for every parachuting flight to the tech log.
(NZ Occurrence 10/3403 refers)

Compliance: 1. From 11 September 2012 (the effective date of DCA/FU24/179).
2. By 25 November 2012.

Effective Date: 25 October 2012.

10.5. On 13 September 2010 the Commission also made the following urgent safety recommendation:

> The Commission recommends that the Director of Civil Aviation as a matter of urgency reviews the approvals granted for the FU24-954 aircraft with a view to amending the Flight Manual to allow more accurate determinations of aircraft centre of gravity. This review should also extend to other conversions of Fletcher and Cresco aircraft. (038/10)

10.6. On 20 September 2010 the General Manager of the General Aviation Group of the CAA replied in part:

> The CAA intends to issue a further Emergency Airworthiness Directive (DCA/FU24/180 Parachuting – Flight Manual Supplement Approval) to be applicable to all FU24 series aircraft modified to conduct parachute operations. It will address the issue that it may be possible in some parachute configurations to exceed the aircraft's aft Centre of Gravity limit. In doing so, CAA will review all AFM parachute operation supplements, including those approved by delegation holders or foreign authorities to ensure that they provide adequate determination of the Centre of Gravity position.
>
> In addition to the ADs, CAA has commenced a broader safety review of parachuting operations, to establish if there are other safety issues arising. The review includes existing parachuting flight manual supplements, pilot training and type ratings for FU24 series aircraft, the provision of operational information to pilots, clarification of aircraft loading limitations and a review of the necessity of seating and/or restraint systems for parachutists. (See paragraph 10.12.)

10.7. On 22 March 2012 the Commission made the following recommendations to the Director of Civil Aviation:

> The modification of ZK-EUF by the engineering company was not in keeping with required engineering practices and the supporting documentation was both incomplete and inaccurate. The Commission recommends the Director takes the necessary action that ensures that high engineering standards are maintained by this and other aircraft maintenance organisations. (005/12)
>
> The operator's fuel management policy, control of the flight manual and failure to ensure the aeroplane was being operated within its centre of gravity limits may be an indication of wider non-compliance issues. The Commission recommends that the Director takes the necessary action that ensures all parachuting operators are conforming to Civil Aviation Rules and operating safely. (006/12)
>
> In approving the change in airworthiness category, the CAA did not review all the required documentation and so missed the opportunity to ensure the aeroplane was fit for the purpose. The Commission recommends that the Director takes the necessary action that ensures there is a thorough and coordinated oversight when accepting aircraft modifications and approving changes in category, especially for specialised operations like parachuting. (007/12)
>
> The wearing of appropriate seat restraints can reduce injury and save lives. The Commission recommends that the Director monitor the outcome of the joint FAA/USPA [Federal Aviation Administration/United States Parachute Association] study and determine if any findings are applicable for the New Zealand parachuting industry. (008/12)
>
> The owner's introduction into service of ZK-EUF was not in accordance with Civil Aviation rules and there was no assistance or oversight provided by the CAA to ensure it was safely completed. The Commission recommends that the Director ensure there is a coordinated and proactive approach by relevant departments within the CAA to ensure safety efforts are best directed to promote the coordinated safe management of flying activities. (009/12)
>
> Parachute-drop pilots can fly for many years without external validation of their parachuting related skills. The Commission recommends that the Director initiate a regular checking requirement to help ensure drop pilots remain skilled and current, similar to other commercial operators. (010/12)

10.8. On 13 April 2012 the General Manager of the Safety Information Group of the CAA replied:

> (005/12) Accepted. Newly introduced risk based surveillance processes will improve the effectiveness of the CAA's audits, through better targeting and focus on 'risk issues'.
>
> (006/12) Accepted. Following the accident, the CAA carried out a series of spot checks on commercial parachuting operations, paying particular attention to flight manual data and the application of weight and balance limitations. In addition to this activity, the implementation of Civil Aviation Rule Part 115 (Adventure Aviation) will require tandem parachute operators to be certificated, and enable closer oversight of such operations.
>
> (007/12) See Comment. This recommendation addresses 2 separate issues. First, with respect the review of documentation required for a change from 'restricted' to 'standard' category, the Director will consider whether physical aeroplane inspections are warranted when an aircraft changes category. However, the resources and other implications of such inspections will need to be identified and evaluated before the Director accepts the recommendation in full. Second, with respect to aircraft modifications, the CAA has amended the conditions of all design delegation holders, which has the effect of the CAA being able to exercise closer oversight of any major design changes. These changes took effect on 24 August 2010.
>
> (008/12) Accepted. The Director will monitor the outcome of the joint FAA/USPA study, and consider their applicability/relevance to the New Zealand aviation environment.
>
> (009/12) See comment. The CAA is currently undergoing a major change programme to ensure that it is able to target its resources more effectively, and conduct its activities more consistently. To this end, the thrust of the recommendation is accepted. The CAA also notes that the introduction of Civil

Aviation Rule Part 115 will enable the CAA to exercise closer oversight of organisations conducting commercial parachute operations, which in part address elements of the recommendation.

(010/12) See comment. The Director will consider the recommendation in light of the changes that are being brought about by the introduction of Civil Aviation Rule Part 115.

10.9. On 22 March 2012 the Commission made the following recommendation to the Secretary for Transport:

> The use of performance impairing substances is known to have a detrimental effect on the ability of people to safely operate in critical transport environments. The Commission recommends that the Secretary for Transport promotes the introduction of a drug and alcohol detection and deterrence regime for persons employed in safety critical transport roles. (011/12)

10.10. On 3 May 2012 the General Manager Aviation and Maritime, Ministry of Transport, replied in part:

> I accept the specific recommendation 011/12 directed to the Secretary for Transport.
>
> I also urge the Commission to note the existing health and safety in employment regulatory regime, where drugs and alcohol are specifically mentioned in the definition of "hazard". This regime already places obligations on both employers and employees.
>
> Since the Fox Glacier accident the Minister of Transport has approved a new Rule Part 115 that entered into force in November 2011. The Rule requires adventure aviation operations to be certified by 1 May 2012. Adventure aviation organisations, including commercial parachuting, now face the risk that their safety certification can be suspended and removed for safety violations. This gives such operators a stronger incentive to ensure they address alcohol and drug taking safety risks in their organisations.
>
> Over the next two years the Government will be considering rule amendments that would require aviation organisations to introduce safety management systems [SMSs]. This would require certificated operators to assess and mitigate all safety risks relevant to their operation. This risk of intoxication of personnel by drugs and alcohol would clearly be a safety risk that we would expect both operators and the Civil Aviation Authority (when certifying and auditing aviation organisations) to be actively addressing under an SMS regime. Decisions will also be made in the near future to ensure that the Civil Aviation Authority is resourced to transition to the ICAO [International Civil Aviation Organization]-endorsed SMS approach which has widespread industry support.
>
> Whilst recognising that where the illegal use of drugs is involved, changing individual behaviour will be challenging, the Ministry will encourage the Civil Aviation Authority to step up its effort to alert the aviation community through education of the risks that drugs pose to the safety operation of aviation undertakings. This will require an ongoing effort.
>
> As you are aware, the Ministry has developed a Transport Regulatory Policy Statement that specific rule changes may not always be the best interventions to achieve desired safety outcomes. Non-regulatory interventions can often be more appropriate. In this regard we appreciate the Commission's recommendation to promote a drug and alcohol detection and deterrence regime, rather than to implement a regime.
>
> The Ministry of Transport has in the past sponsored an inter-agency Substance Impairment Group. This looked at whether or not compulsory random drug and alcohol testing, and specific breath alcohol limits, should be required by regulation in the aviation, marine and rail transport modes. In part because of a lack of data, we were not convinced at that time that the costs would outweigh the benefits. We will, however, monitor international experience in this regard and, in particular, the recent relevant changes in the Australian aviation regime.

10.11. On 10 March 2015 the Ministry of Transport released a discussion paper on options to reduce the risks of alcohol- and drug-related impairment in the aviation, maritime and rail transport sectors. The consultation followed the Commission's final report on its investigation of a hot-air balloon crash near Carterton in 2012. In its report the Commission recommended regulatory changes to strengthen the management of alcohol and drugs in the aviation, maritime and rail sectors. Submissions on the document closed with the Ministry on 8 May 2015.

10.12. On 18 June 2015 the Commission asked the Director of Civil Aviation for an update on the status of the "broader safety review of parachuting operations", which the CAA had said in a letter of 20 September 2010 had commenced (see paragraph 10.6).

10.13. On 24 July 2015 the CAA replied that no specific document had mapped out the areas the CAA had considered, but specialist staff had been tasked in 2010 with reviewing the issues stated in the Commission's final report concerning adventure and agricultural aviation. The CAA noted that "the advent of Rule Part 115 addressed the majority of the issues".

10.14. The CAA's response also stated that it had worked with the parachuting industry regarding the issue of safety restraints. Although some in the industry were convinced that a requirement to wear restraints would provide a hazard equal to or greater than not wearing them, some operators had voluntarily introduced restraints. The CAA was continuing with an operational review and risk assessment of the requirement.

Safety actions that were not in response to a recommendation of the Commission

10.15. On 11 October 2011 the Minister of Transport signed the new Civil Aviation Rule Part 115 Adventure Aviation (Certification and Operations). Part 115 (initial issue) entered into force on 10 November 2011. Transitional arrangements in Part 115 required commercial tandem parachute and parachute-drop aircraft operators conducting operations immediately before 10 November 2011 to comply with Part 115 by 1 May 2012. CAA resources were increased as a result.

10.16. On 26 July 2012 the CAA issued the following airworthiness directive for Fletcher aeroplanes:

DCA/FU24/181 Horizontal Stabiliser Electric Trim System – Installation

Applicability: All turbine powered FU24 series aircraft with a Standard Category Airworthiness Certificate.

Requirement: Because of the wide trim range required during aircraft operation, an approved electric trim system must be installed. Accomplish the following:

1. Install an approved electrically operated pitch trim system.

2. If the electric trim system becomes inoperative, the aircraft may continue to be operated for a maximum of 3 days while it is repaired. The manual trim system must be serviceable and extra care must be taken to ensure correct trim is set before take-off. Install a warning placard on the instrument panel while the electric trim is inoperative in clear view of the pilot with the following text:

> **Electric Trim Inoperative**
>
> **CAUTION:**
>
> **Before take-off ensure the trim is in the TAKE-OFF POSITION.**

(NZ occurrence 10/3403 refers).

Compliance: 1. By 26 August 2012 unless already accomplished.
2. From 26 August 2012.
Effective Date: 26 July 2012.

10.17. On 29 May 2014 the CAA issued the following airworthiness directive for Fletcher aeroplanes:

DCA/FU24/183 Control Column – Inspection

Applicability: All FU24 and FU24A series aircraft fitted with control column P/N 08-45031/32.

Note: This AD requires an inspection of the control column for mechanical damage, deformation and cracks per Pacific Aerospace Limited (PAL) Mandatory Service Bulletin (MSB) No. PACSB/FU/095 issue 2 dated 28 May 2014.[23]

Requirement: To prevent failure of the control column due to possible mechanical damage or deformation which could result in cracks, inspect the control column per Pacific Aerospace Limited (PAL) Mandatory Service Bulletin (MSB) No. PACSB/FU/095 issue 2 dated 28 May 2014.

If no mechanical damage or deformation is found, no further action is required. If any cracks are found, replace the control column per PACSB/FU/095 before further flight.

If any mechanical damage or deformation is found, accomplish the NDT [non-destructive testing] inspection of the control column per PACSB/FU/095. If any cracks are found, replace the control column per PACSB/FU/095 before further flight. If no cracks are found accomplish a NDT inspection at intervals not to exceed 50 hours TIS [time in service] until replacement. Replace the control column at the next maintenance inspection or within the next 150 hours TIS, whichever is the later.

(Occurrence No 12/1784 refers)

Compliance: Within the next 50 hours TIS.
Effective Date: 29 May 2014.

[23] Pacific Aerospace Limited Mandatory Service Bulletin No. PACSB/FU/095 was first issued on 10 July 2012.

11. Citations

TAIC, 2012. Report 10-009, Walter Fletcher FU24, ZK-EUF, loss of control on take-off and impact with terrain, Fox Glacier Aerodrome, South Westland, 4 September 2010. Transport Accident Investigation Commission; Wellington.

Appendix 1: Participants in the review

Wreckage review

Tom McCready	licensed aircraft maintenance engineer and trained air accident investigator
Bruce Robertson	licensed aircraft maintenance engineer and trained air accident investigator
Peter Williams	Commission air accident investigator
Sam Stephenson	Commission air accident investigator and licensed aircraft maintenance engineer

Independent examination of control stick

Stephen Rowbotham, BEng, CEng, MIMMM	Quest Integrity NZL Limited, Gracefield, Lower Hutt

Expert conferences

Experts in regard to operating the Fletcher or other aeroplanes (and role at time)

Stuart Bean, Walter Fletcher parachuting pilot (Abel Tasman Skydive Limited)
Steve Moore, graduate Empire Test Pilot School (General Manager General Aviation, CAA)
Kevin Young, agricultural pilot and Fletcher test pilot (Super Air)
Mark Houston, Fletcher test pilot, air accident investigator (Flight Operations Inspector, CAA)[24]
Roger Shepherd, Fletcher test pilot (Investigating Officer – aviation concerns, CAA)

Experts in regard to aeronautical engineering or maintenance

Murray McGregor, aeronautical design engineer (Flight Structures Limited)
Bruce Robertson, licensed aircraft maintenance engineer and trained air accident investigator (Avtek Limited)

Commission personnel

Tim Burfoot, Chief Investigator of Accidents
Peter Williams, air accident investigator
Sam Stephenson, air accident investigator, licensed aircraft maintenance engineer
Cathryn Bridge, General Manager Legal and Business Services

Measurement of Walter Fletcher seating positions

Sam Stephenson — Commission air accident investigator
Staff of Skydive Wanaka
Staff of Performance Aviation Limited, Wanaka

Statistical analysis of centre of gravity positions

Dalice Sim, PhD	Statistical Consultant, Victoria University of Wellington
Lloyd Pledger, MSc	Statistical Assistant, Victoria University of Wellington

Flight tests at Gore aerodrome

Murray McGregor	aeronautical design engineer, Flight Structures Limited
Bill O'Connor	Walter Fletcher pilot, Phoenix Aviation Limited

[24] Mr Houston attended the first conference only.

EMAIL

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Reference: 106168.01rev1

Attention: Peter Williams

Organisation: Transport Accident Investigation Commission

E-Mail Address: p.williams@taic.org.nz

From: David Firth and Stephen Rowbotham

Checked by: Ohgeon Kwon

Date: 14th May 2014

Subject: Visual examination of failed control column from aircraft ZK-EUF

1. Introduction and Background Information

Quest Integrity NZL Limited (Quest Integrity) was contracted by Transport Accident Investigation Commission (TAIC) to examine the failed control stick from ZK-EUF.

The following background was supplied by TAIC:

1. On 9 May 2012 the Commission released its report into the causes of the accident involving Walter Fletcher aeroplane ZK-EUF at Fox Glacier on 4 September 2010. The Commission identified 'weight and balance' as the prime cause of the crash. On 3 May 2013 the Coroner released his report on the accident. The Coroner found that weight and balance could be ruled out as the prime cause of the crash, and that some other factor, combined with weight and balance, caused the crash. The other factor could not be identified. The Coroner found that a fracture of the aeroplane's control column, while unlikely, could not be ruled out as a cause of the crash.

2. A number of parties were critical of the finding that weight and balance was the prime cause and that mechanical failure as a cause was ruled out. TV 3 aired a segment about the crash on its programme "3rd Degree" on 26 March 2014. Experts hired by the programme suggested that a 'control system failure' led to the crash. The programme

made reference to other instances of control stick failure that were raised at the Coroner's inquiry (but not during the Commission's inquiry). TV 3 dug up the buried wreckage including the control stick.

3. No party has made a formal request for the Commission to re-open its inquiry. However, given public concern, the Commission believes it is in the interests of justice to proactively review the case, including a re-examination and, if necessary, further testing of the wreckage.

4. The aeroplane was destroyed by impact forces and an intense fire that followed. The control stick was found separated from the elevator torque tube to which it should have been attached. The control stick was examined by the Commission's investigator at the accident site and subsequently, it was buried in sandy soil for over 27 months.

The Commission's primary interest is the lower fracture where the control column separated from the elevator torque tube, see schematic diagram shown in Figure 1.

2. Work Scope

Following discussions between TAIC and Quest Integrity the following work scope was agreed to be completed in the first instance:

- Examine the control stick from ZK-EUF by visual and a fractographic means to determine the nature of all fractures.
- Provide the Commission with a written report that describes the nature of the fracture, the direction in which the lower complete failure occurred, and the reasons for those conclusions.

This report covers this assessment. However, it does not cover additional issue such as if the control stick was manufactured to specification.

3. Visual examination

The control column as supplied is shown in Figure 2. The stick consisted of the following, probably steel, items welded together:

- Bottom straight tube fractured about 50mm long that was reported to have been attached to the elevator torque tube.
- Curved tube about 220mm long in straight line across the arc.
- Top straight tube about 70mm long.

In addition a section of probably aluminium tube was over the top tube and a copper braded damaged wire was inside the top tube.

Visual examination of the control column revealed significant damage to the column detailed as follows:

- A significant indentation in the curved tube that was about 30mm in length. A sharp step was present at the top of the indentation. The indentation is consistent with being formed by a single impact load that was directed from the front bottom of the stick as shown in Figures 2 and 3. This impact must have started to occur prior to the failure of the bottom tube otherwise the sample would have carried the load.
- The bottom tube had failed as shown in Figure 2, 3 and 4.

Fractographic examination (using an optical binocular microscope) revealed that:

- Failure occurred around the circumference and through the edge of the weld to the curved tube.
- The fracture surface was primarily at 45 degrees to the surface and typical of tensile overload. Where thin walled material fails in overload the fracture is predominantly at 45 degrees to the surface resulting in shear lip as shown in Figure 4. The observed failure is consistent with the impact which caused the dent in the curved pipe also caused the failure of the tube. The failure probably initiated at the stress raiser at the edge of the weld to the curved tube and the final fracture was diametrically opposite where a small step in the fracture was present.
- The presence of the 45 degree fracture indicates that the failure did not occur as a result of fatigue or any other pre-existing defect in the pipe.
- Due to the findings of the optical examination it was not deemed necessary to examine using a Scanning Electron Microscope as no further pertinent information regarding the failure mechanism would be gained.

4. Conclusion

The control stick failed as a result of overload and likely occurred at the same time as the significant indent in the curved tube as a result of a single significant impact loading. This is consistent with damage occurring as a result of the accident.

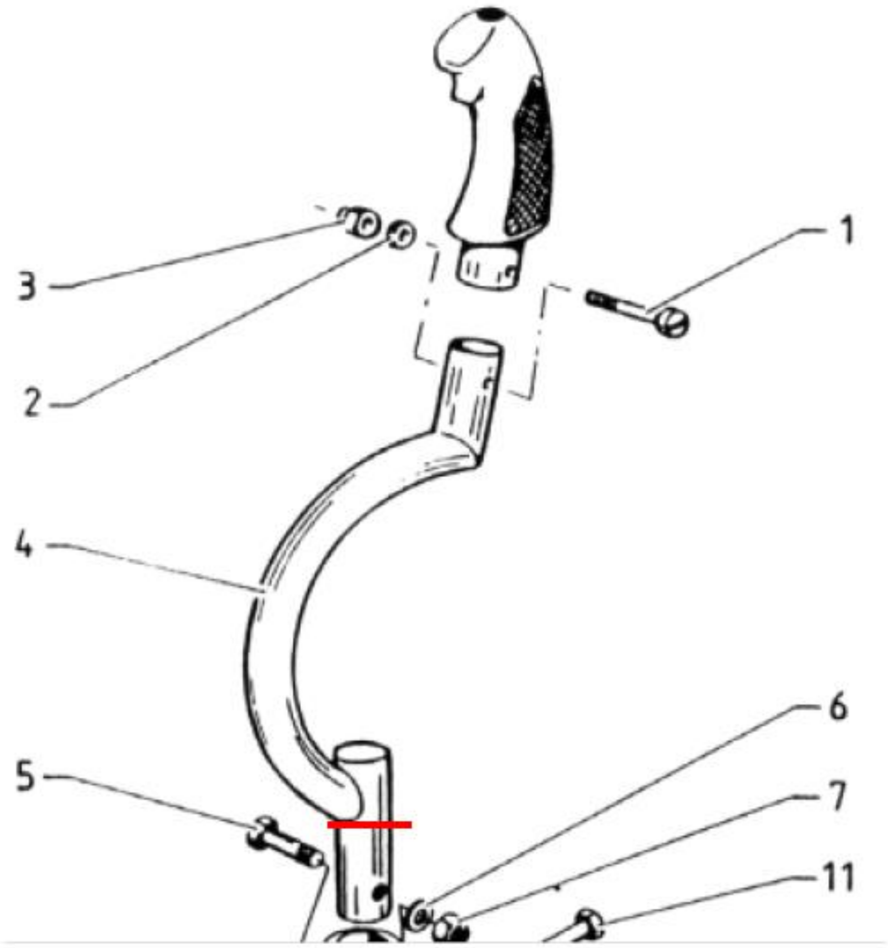


Figure 1: **Schematic diagram showing control column and fracture location (red line).**

Figure 2: **Control Column as supplied. Photomicrograph shows the fractured bottom tube that was welded to the curved tube. The side on the right of the picture was marked F (front). The black arrow shows the probable direction of the impact force which generated damaged found on the curved section of tubing.**

Figure 3: **Close up of the indentation / impact damage in the curved tube section. The arrows show the probable direction of the impact force.**

Figure 4: **Fracture Surface on bottom tubing, 45 degree shear lip / overload fracture clearly visible.**

Appendix 3: First expert conference, 16 June 2014

The conference participants[25] stated that, based on their expert knowledge and experience of aircraft piloting and engineering and after joint consideration of the relevant information presented by the Commission at the meeting, they had reached **agreement on the following points** in relation to their possible contributions to the accident:

	Topic	Probability[26]	Main evidence
1	Control stick fracture at take-off?	Exceptionally unlikely	Independent report by Quest Integrity concluded that stick broke at impact. Examination of control stick by participant with relevant expertise. Other control stick failures discounted as being different models or due to maintenance practice not seen here.
2	Pitch control jam?	Very unlikely	No evidence of a jam, although if there had been the jam was possibly destroyed or dislodged in the accident. The risk of jam considered very small given the panel covering the elevator bell-crank, design of the aeroplane and security of objects e.g. oxygen tanks being strapped down.
3	Pitch control cable failure at take-off?	Very unlikely	Cable recently replaced. Cable breaks consistent with overload or post-accident cutting. Same for rudder cable.
4	Prop to beta (reverse) mode during take-off?	Exceptionally unlikely	Beta actuation is not normally possible when there is sufficient power to allow the propeller to 'constant speed', i.e. the propeller governor is controlling propeller speed. If it did happen, aeroplane would be expected to pitch down, not up. Usual practice was to take off with beta mode selected OFF.
5	Engine mount failure during take-off?	Exceptionally unlikely	Re-examination of the wreckage found no evidence of pre-impact failure.
6	Incorrect (adverse) trim set for take-off?	Very unlikely	Impact damage to screw-jack corresponded to the expected near-full nose-down take-off trim. If the trim position from the previous landing had not been re-set for the take-off, the pilot would have recognised it almost straight away. Along with the centre of gravity being well aft, this would have caused a noticeable, but not alarming, rotate [take-off] angle with the potential for a tail strike. There was no evidence of a tail strike. If a mis-set trim was the only factor, it would not have caused the over-rotation and the pitch forces would have been manageable using one hand, allowing the pilot to re-set the trim. The pilot had rejected a take-off with incorrect trim setting previously, leading to operator adding a cockpit reminder to check trim.

[25] Mr Houston did not endorse the joint statement. However, comments he made on the initial draft of the statement were incorporated where applicable and were accepted by other participants.

[26] The probability terminology conforms with that recommended by the Australian Transport Safety Bureau, which is taken from that of the Intergovernmental Panel on Climate Change. See Appendix 3.

7	Flight control lock in place during take-off?	Exceptionally unlikely	Flight tests showed that aeroplane would 'wheelbarrow' on runway and not pitch up. Control lock bracket (judging from scene photograph) appeared to lack damage expected if control stick had been ripped out of bracket. Holes in bracket tabs were not in direction expected if stick had been ripped free. It is virtually certain that the bracket fell out when the tabs softened in the fire.
8	That agricultural ops have shown that the Walter Fletcher can operate with a greater rearward centre of gravity than the aeroplane supposedly had on the accident flight.	Exceptionally unlikely	In agricultural operations the centre of gravity could possibly be slightly aft of the limit, but as was demonstrated on spreadsheet model and confirmed by pilots, it was exceptionally unlikely to ever be further aft than that estimated for the aeroplane.
9	At some pitch attitude the unrestrained pax load would have shifted aft.	Very likely	Axiomatic that this must happen at some point. But a load shift did not initiate the initial pitch-up.
10	Could the rear bulkhead have collapsed?	Very unlikely	This position was dependent on confirmation (which was obtained after the meeting from Super Air) that the standard bulkhead was used. The standard bulkhead is very robust with a forward-opening section. There was no reason to access the rear fuselage outside of scheduled maintenance. The aeroplane battery, for example, was installed forward of the engine firewall.

The participants **could not agree positions on the following topics** for the reasons shown, and they recommended the actions indicated:

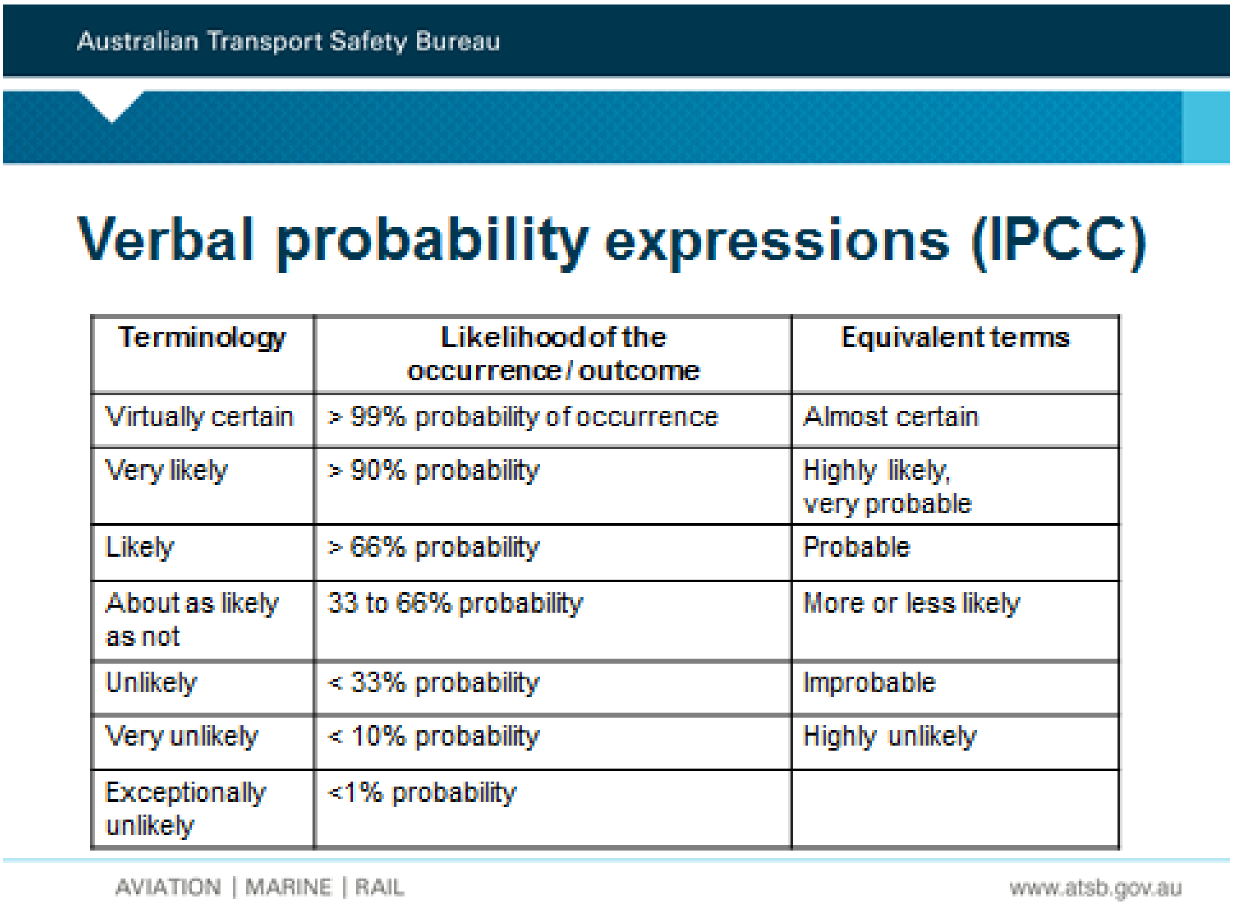
	Topic	Reason	Recommended action
11	Actual weight and balance at take-off.	The Commission weight estimate, corrected by Super Air to account for more fuel and the oxygen system, was a reasonable proxy for the accident flight, but the seating positions need confirmation.	1. Compare by loading another aeroplane.
12	Controllability of the aeroplane at estimated centre of gravity position.	Not proven. Neither of the flight test series (August 2012 and March 2000) explored a centre of gravity as far aft as that estimated for the accident flight. We don't know how far aft the centre of gravity can go before aeroplane is uncontrollable.	2. Further flight tests to measure control stick force/G and extrapolate to the estimated centre of gravity position at which point aeroplane would be dynamically unstable and uncontrollable.
13	Was there a commanded or uncommanded power increase?	Aeroplane would pitch up, and stability and controllability margins would be eroded. If it occurred when rotating for take-off, would happen quickly and could be difficult to control. Only one witness heard 'over-speeding', but where and when in the flight path was not determined.	3. An uncommanded power increase was considered a very unlikely event. The question might be resolved by tear-down of fuel control unit. 4. Normal take-off power is 550 horsepower. A commanded power increase to an output of 620 horsepower (or a little beyond) can be readily achieved. 5. Review witness reports to better describe flight path from rotation [that is, from raising the nose for take-off].

14	Pilot's reach.	His height (~5'7"?) and the type of parachute used might not have allowed him to apply full nose-down elevator.	6. Review. Subsequently it was advised that the pilot probably always used the seat back cushion, and that even though he wore a seat-bottom parachute he had not reported any difficulty in achieving full range of control stick movement.

Appendix 4: Second expert conference, 28 January 2015

The participants reached agreement on the following points:

	Topic	Probability	Main evidence
1	That the range of weight and balance at take-off has been established.	Very likely	Based on reasonable variations of seating positions and known weights.
2	Was the aeroplane controllable within estimated centre of gravity range?	Virtually certain	Test flights at Gore indicated that, in the absence of any other adverse factors, the aeroplane would have been controllable. (It was very likely that the manoeuvre neutral point of the aeroplane that was tested was as far forward as could be expected for the Walter Fletcher fleet.)
3	Was there an uncommanded power increase?	Exceptionally unlikely	Advice from manufacturer of the engine and fuel control unit (GE Czech) and maintenance experience.
4	Was there a commanded power increase?	Cannot be excluded	Test flights at Gore confirmed that stability and controllability margins would be eroded by an increase above nominal take-off power.



Verbal probability expressions (IPCC)

Terminology	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	

Appendix 5: Flight testing to assess manoeuvre neutral point

Flight Structures Ltd

PO Box 6041 Urlich Hamilton 3245

8th September 2015 Ref: FSLR 3030 rev 1

Transport Accident Investigation Commission
PO Box 10323
Wellington 6143

Attention: Peter Williams

FU24-950 with STC 98/21E/15: Flight Testing to Assess Manoeuvre Neutral Point – Take-off Configuration

Dear Peter,

This document is reissued at revision 1.
Basic subject matter remains as a documentation of flight testing performed at Gore on November 3rd and 4th 2014.

The introduction to the initial issue (revision 0) of this document commented on the low static stability margins exhibited by the test aircraft and the possible relationship of these margins to the Fox Glacier accident aircraft.
Those comments remain applicable.

The principal change at revision 1 is the addition of a confidence assessment applicable to the investigation.

We view this as a working document and so please feel free to contact us if there are aspects that may require additional clarification.

Yours sincerely,

Murray McGregor
Flight Structures

1. INTRODUCTION.

The aircraft type involved in the September 2010 parachuting operation accident at Fox Glacier was FU24-954 s/n 281 with STC 98/21E/15 (Walter M601D engine installation) embodied.
In support of the investigation of the Fox Glacier accident, flight testing has been performed to enable an assessment to be made of the aircraft centre of gravity position associated with the aircraft manoeuvre neutral point to be made. The flight phase investigated was the low speed, high power take-off configuration.
Flight testing was performed at Gore on November 3rd and 4th 2014 on an FU24-950 aircraft with STC 98/21E/15 embodied.
Flight test pilot was Bill O'Conner and flight test engineer was Murray McGregor. Refer to section 12 of this document for CAA test pilot approval.

2. TEST AIRCRAFT.

Testing was conducted using FU24-950 s/n 210 (ZK-JSW) in agricultural high volume solids dispersal configuration. Refer to section 13 of this document for the aircraft experimental airworthiness certificate.
The following is noted:

- In terms of overall aircraft aerodynamics FU24-950 and FU24-954 aircraft embodying STC 98/21E/15 may be considered as equivalent.
- The high volume solids gate-box fitted to s/n 210 has a frontal area of less than 5% of the aircraft total frontal area and the horizontal tail surfaces are shielded for any slipstream disturbance that might be caused by the gate box. Thus the gate-box installation would not be expected to have a significant effect on aircraft stability or manoeuvring characteristics. This assessment reflects previous flight experience.
- Parachuting configuration aircraft have a deflector fitted ahead of the cabin door. This deflector has the potential to adversely affect airflow over the horizontal tail surfaces when the aircraft angle of attack is low. However for the low speed high angle of attack flight phases investigated by these tests the HTS will be below any slipstream effects caused by the deflector. Thus over the speed range of interest the deflector would not be expected to have a significant effect on aircraft stability and manoeuvring characteristics.

Prior to commencing testing the "break-out" forces on the pitch control circuit were found to be acceptable being measured as less than 0.5lb by the stick force gauge .

3. TEST EQUIPMENT

A stick force indicator was installed on the control column in the manner shown in Figure 1. As installed on s/n 210 the effective arm of the knob on top of the stick gauge was 15% larger than the arm at the centre of the hand grip.
The gauge makes use of a conventional analogue dial test indicator. A calibration chart correlating the dial test indicator reading with applied force showed a linear force to indicator reading characteristic. The gauge may effectively be read to within 0.1 lb.

An artificial horizon and aircraft G meter were also installed in the aircraft.

Figure 1 – Stick Force Gauge Installation

4. SUMMARY OF ESSENTIAL THEORY

The manoeuvre neutral point is defined as that CG position where the pitch control force variation with respect to aircraft normal acceleration ("Stick force per G" or "Manoeuvre stick force gradient") has fallen to zero. In standard aeronautical nomenclature this is expressed as $dFs/_{dn} = 0$.

For aircraft of conventional configuration theory predicts that manoeuvre stick force gradient linearly decreases as the aircraft centre of gravity moves aft. On that basis an estimate of the manoeuvre neutral centre of gravity position may be made by a linear extrapolation of a plot of manoeuvre stick force measured at centre of gravity positions ahead of the neutral point.

There are two terms that contribute to the magnitude of the manoeuvre stick force gradient.

The first term is a function of the variation of stick force with airspeed in un-accelerated ("1G") flight and may be considered as the contribution of what is known as "aircraft longitudinal static stability" to the manoeuvre stick force gradient.
Longitudinal static stability margins are measured in flight and vary with aircraft centre of gravity position, power setting and airspeed.
This first term is thus a function of an aircraft flight characteristic.

The second term is a function of parameters such as tail surface position, tail surface lift characteristics, tail surface hinge-moment characteristic and also air density. There is not a primary variance with centre of gravity position, airspeed or power. This second term may be considered as a "damping" contribution arising from the curved flight path that applies to all manoeuvring flight.

For a given air density the magnitude of this second term is fixed for level flight "pull up" manoeuvres.
For turning flight manoeuvres, as well as air density, the second term is influenced by the magnitude of normal acceleration ("G") associated with the manoeuvre.
Manoeuvre stick force gradient is higher in turning flight than in level pull up manoeuvres.
For a given "G" and air density the difference between turning and pull up gradients tends towards constancy and is not critically dependant on the flight phase.

5. FLIGHT TESTING GOALS AND PROCEDURES

The primary goal of the flight testing was to the determine manoeuvre stick force gradients at four CG positions within the existing certified weight and balance envelope.

The flight phase of interest for the primary goal was take-off configuration at low airspeed.
Aircraft configuration for the tests was:

- Standard category weight of 4860 lb
- Most forward CG position tested: 16.8" aft of datum (nominal)
- Most aft CG position tested: 25.4" aft of datum (nominal)
- 20° wing flap setting
- Power settings of maximum continuous (MCP) and take-off (TO) power.
- 70 KIAS airspeed.

Determination of manoeuvre stick force gradients is most readily made in turning flight and this technique was adopted. Turning flight test were conducted at a 45° bank angle. This gives a "G" level of 1.4.

A single flight to assess the difference between turning and pull up stick force gradients at 1.4 G was made.
Aircraft configuration for this test was:

- Standard category weight of 4860 lb
- CG position: 16.8" aft of datum (nominal)
- 0° wing flap setting
- Power setting of 43% torque and 1900 rpm propeller speed.
- 100 KIAS airspeed.

Detail Test procedures were:

"Pull-up" Tests

- Trim to 100 KIAS
- Increase climb angle until airspeed has decreased to 80 KIAS.
- "Push over" and re-approach trim speed.
- As aircraft approaches trim speed apply up elevator to establish a pitch rate that will place aircraft back on trim airspeed ± 3KIAS at 1.4G load factor
- Record stick force and G-meter reading.

Turning flight Tests:

Trim to 100 KIAS
Roll aircraft to 45° bank and lower nose to maintain trim airspeed.
Record stick force and G-meter reading while maintaining bank angle and trim airspeed.

All measurements were taken between 3000 and 4000 ft pressure altitude.

A secondary goal of the flight testing was to the determine aircraft longitudinal static stability margins. Aircraft configuration for these tests is identical to the configurations proposed for the determination of manoeuvre stick force gradients.

6. TEST RESULTS: ASSESSMENT OF THE DIFFERENCE BETWEEN TURNING AND PULL UP STICK FORCE AT 1.4G

These tests were carried out on flight 1. Refer section 12 for aircraft weight and balance data.
The exercise was performed three times and, for the 0.4G load factor increment, “pull-up” stick forces were determined to be consistently 1.0 lb less than turning flight stick forces.
Note: This increment is the difference in Stick Gauge Force (SGF). The force at the control column hand grip would be 15 % higher.

7. TEST RESULTS: TURNING FLIGHT MANOEUVRE STICK FORCES

Stick Gauge Forces (SGF) for 1.4G turning flight measured in flights 2 to 5 are tabulated below. With reference to detail weight and balance data contained in section 12 the CG positions stated are the average of take-off and landing positions.

Flight	CG	SGF, 69% T_Q	SGF, 89% T_Q
	(in AOD)	(lb)	(lb)
2	16.87	14.4	13.4
3	20.2	12.2	11.3
4	22.84	10.0	9.3
5	24.86	8.2	7.6

8. TEST RESULTS: LONGITUDINAL STATIC STABILITY.

At the forward most CG position tested and for the configuration applicable to manoeuvre stick force gradient determination the aircraft exhibited essentially neutral static stability characteristics, i.e. there was no perceptible variation of stick force with respect to airspeed over a range of ± 10%.
Given that static margins become increasingly less positive as the aircraft CG is moved aft, further measurements of longitudinal stability were not made.

9. PRESENTATION OF RESULTS

Figure 2 is a graphical representation of the following turning flight test data sets:

- A fitted linear regression through SGF versus CG position flight test points for 69% engine torque (MCP).
- A fitted linear regression through SGF versus CG position flight test points for 89% engine torque (TO).

Also shown is the “turning flight” to "pull up” SFG increment of -1 lb applied to the 89% turning flight fitted line. This line intersects the graph horizontal axis at a CG position of 33.5” aft of datum.

FU24-950 with STC 98/21E/15: Manoeuvre Neutral Point Assessment – Take-off configuration

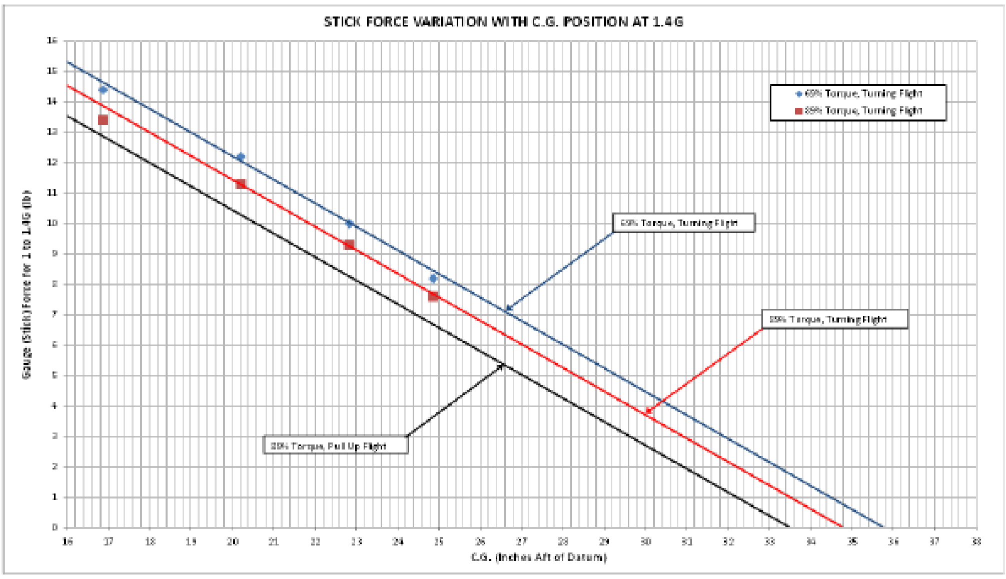


Figure 2

10. CONFIDENCE ASSESSMENT

<u>"Pull-up" manoeuvre force measurement.</u>
Stick forces measured in symmetrical pull up manoeuvres are sensitive to flight test technique and require precise execution to ensure accuracy.
Techniques used to perform the tests were in accordance with best practice.
However, the test aircraft did not have equipment installed that provided recorded time histories of the pull-up manoeuvres and so data to review the manoeuvres is not available.
Some uncertainty on the absolute applicability of stick forces measured in "pull-up" therefore exists.

<u>"Turning Flight" manoeuvre force measurement</u>.
It is considered that a good level of confidence may be ascribed to force measurements made in turning flight manoeuvres.

<u>Overall Assessment</u>.
It follows from the above discussion that the most significant uncertainty is related to the magnitude of the "turning flight to pull-up flight" offset.
In Figure 2 this offset is shown as being equivalent to a 1.3" shift in CG.
An upper limit of uncertainty of ± 30% is considered to be a reasonable assessment.
On that basis the uncertainty in neutral point CG potion would be ± 0.4".

11. DISCUSSION OF RESULTS.

Figure 2 predicts that for low speed pull up manoeuvres in take-off configuration the manoeuvre neutral point for the test aircraft is 33.5 inches aft of datum. This assessment is, strictly speaking, only applicable to the test altitude range of 3000 to 4000 ft.
At sea level, the damping term (refer section 4) is greater and there will be a small aft-ward shift in the manoeuvre neutral point. This variation can be reasonably considered to be contained within the accuracy limits of the test programme.

The test aircraft static stability margins are below what would normally be expected. In making that statement it is acknowledged that certification requirements do not require a demonstration of positive longitudinal stability for the flight regime being investigated. Nevertheless it was expected, particularly at forward CG positions, that for the flight regime being investigated, a positive longitudinal stability margin would exist.

The test pilot also uses the test aircraft in normal agricultural flight operations and was able to confirm that, compared to other aircraft of the same type, the test aircraft (s/n 210) is markedly less "trim intensive" in agricultural operations.
A minimised requirement to trim is indicative of low static stability margins and so it is probable that the test aircraft has lower than usual static stability margins.

It is thus likely that the prediction of 33.5 inches aft of datum for the manoeuvre neutral point represents a likely forward limit for the aircraft type. Aircraft with higher static stability margins would be expected to have a manoeuvre neutral point further aft.

12. DETAIL WEIGHT AND BALANCE DATA

Basic aircraft weight was determined by weighing on October 1st 2014.

Flights 1 and 2

Item	W(lb)	arm (in)	M (lb-in)	Item	W(lb)	arm (in)	M (lb-in)
Aircraft	3150	15.63	49234	Aircraft	3150	15.63	49234
Crew	360	-2.2	-792	Crew	360	-2.2	-792
Fuel	680	9.8	6664	Fuel	530	9.8	5194
Hopper	680	39	26520	Hopper	680	39	26520
Cargo Bay	0	103	0	Cargo Bay	0	103	0
Take-off	4870	16.76	81626	Landing	4720	16.98	80156

Flight 3

Aircraft	3150	15.63	49234	Aircraft	3150	15.63	49234
Crew	360	-2.2	-792	Crew	360	-2.2	-792
Fuel	520	9.8	5096	Fuel	427	9.8	4185
Hopper	680	39	26520	Hopper	680	39	26520
Cargo Bay	176	103	18128	Cargo Bay	176	103	18128
Take-off	4886	20.10	98186	Landing	4793	20.30	97275

Flight 4

Aircraft	3150	15.63	49234	Aircraft	3150	15.63	49234
Crew	360	-2.2	-792	Crew	360	-2.2	-792
Fuel	380	9.8	3724	Fuel	313	9.8	3067
Hopper	680	39	26520	Hopper	680	39	26520
Cargo Bay	315	103	32445	Cargo Bay	315	103	32445
Take-off	4885	22.75	111131	Landing	4818	22.93	110474

Flight 5

Aircraft	3150	15.63	49234	Aircraft	3150	15.63	49234
Crew	350	-2.2	-770	Crew	350	-2.2	-770
Fuel	299	9.8	2930	Fuel	193	9.8	1891
Hopper	500	39	19500	Hopper	500	39	19500
Cargo Bay	450	103	46350	Cargo Bay	450	103	46350
Take-off	4749	24.69	117244	Take-off	4643	25.03	116205

13. TEST PILOT APPROVAL

CIVIL AVIATION AUTHORITY OF NEW ZEALAND

TEST PILOT APPROVAL

(Category Three)

PURSUANT TO Civil Aviation Rule 19.405,

I, David George Gill, Team Leader Airworthiness,

HEREBY APPROVE

William Anthony O'Connor,

to act as a test pilot (Category Three), as defined in Advisory Circular AC19-1, for the purpose of carrying out experimental flying in aircraft, namely;

Fletcher FU24-950 Series, including turbine conversions

PROVIDED THAT:

a) Commercial Pilot Licence (Aeroplane) Nr 41816 held by William Anthony O'Connor remains current and Medical Certificate valid; and

b) All test flying is carried out in an aircraft issued with a Special Category-Experimental airworthiness certificate issued for the purposes of research and development, or showing compliance with the rules; and

c) All flying is carried out in accordance with a Flight Test Schedule authorised in advance by a Part 146 Design Organisation or the CAA.

This approval shall remain valid until 10 October 2016, unless revoked by the Director of Civil Aviation by notice in writing to William Anthony O'Connor.

SIGNED at WELLINGTON)
This 10th day of October 2014)
By David George Gill)

14. SPECIAL CATEGORY EXPERIMENTAL AIRWORTHINESS CERTIFICATE.

NEW ZEALAND

AIRWORTHINESS CERTIFICATE

CAA CIVIL AVIATION AUTHORITY OF NEW ZEALAND

Nationality and Registration Marks	Manufacturer and Manufacturer's Designation of Aircraft	Aircraft Serial Number
ZK-JSW	**New Zealand Aerospace Industries Limited** FU24-950	**210**

Categories:

SPECIAL CATEGORY - Experimental

Flight Manual Ref:	Period of Validity
AIR 2672	**Until 10 January 2015**

Conditions:

Subject to compliance with the Limitations and Conditions prescribed overleaf, the aircraft designated above is hereby authorised to operate for the purpose of Flight Testing for research and development.

This Airworthiness Certificate is issued pursuant to the Convention on International Civil Aviation dated 7 December 1944 and the New Zealand Civil Aviation Rules in respect of the above-mentioned aircraft which is considered to be airworthy when maintained and operated in accordance with the foregoing and pertinent operating limitations.

Date of issue: **10-Oct-2014**

Signature:
for Director of Civil Aviation

No entries or endorsements may be made on this Airworthiness Certificate and associated Flight Manual or other approved document except in the manner and by the persons authorised by the Director. If this Certificate is suspended or revoked as prescribed in the Civil Aviation Act 1990 or if the aircraft is deleted from the register for any cause this Certificate shall be returned to the Director.

Appendix 6: Cranfield University peer review of Flight Structures report

Cranfield UNIVERSITY

To: Peter Williams, Transport Accident Investigation Commission, New Zealand

From: Mudassir Lone and Alastair Cooke, Cranfield University, United Kingdom

Subject: Assessment of flight tests used in support of FU24-954 s/n 281 accident investigation

Date: September 15, 2015 : Version 2 (of original dated July 23, 2015)

This memo is in response to a request by the Transport Accident Investigation Commission (TAIC) of New Zealand to review a series of flight tests carried out by Flight Structures Ltd. in 2014[1] in the context of TAIC Aviation Enquiry 10-009[2].

Comments on flight test technique

A series of flight tests were conducted by Flight Structures Ltd. to determine the neutral point (NP) or manoeuvre neutral point (MNP) to investigate if the accident involving FU24-954 s/n 281 was due to the aircraft possessing low longitudinal manoeuvre stability.

The report[1] only covers tests for determining manoeuvre stability. However, static stability characteristics of the aircraft should have been determined first and then the testing phase should have moved on to examine manoeuvre stability. This is because there is some indication of the subject aircraft having marginal static stability at take-off[2].

An aircraft's MNP is typically obtained by carrying out either a series of (1) symmetric pull-ups or (2) wind-up turns. Both tests were carried out by Flight Structures Ltd. These tests require careful and precise execution and demand considerable pilot experience and skill. For example, symmetric pull-ups require the aircraft to be at zero pitch attitude at the exact instant of peak/desired g load.[3,4] Examples of the types of data are shown in Figure 1. In this case, the flight test data can be studied further if we have access to raw data (time histories) from the flight tests.

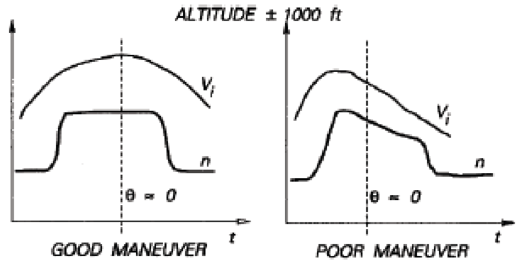


Figure 1: Examples of wings-level pull-up data. (Reproduced from Ref. [4])

1

The investigators have realised that the turning flight test predicts a MNP further aft than pull up. The tests have been carried out with the aircraft trimmed at 70 knots at two power settings. This brings the test points closer to the climb conditions of the accident.

Overall, the test methods and techniques are satisfactory and the investigators have highlighted the effects of experimental sensitivity and uncertainties due to lack of flight test data.

Comments on flight test data analysis

Figure 2 in Reference [1] (replicated and annotated in Figure 2) shows sufficient margin. Although the precision of the data points has been given, the tests are quite transient in nature, so a significant amount of uncertainty exists when taking the measurements.

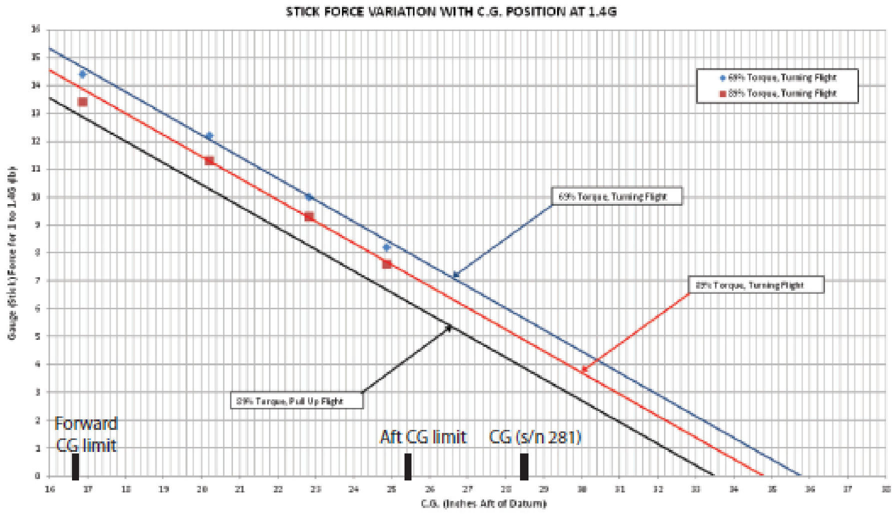


Figure 2: Determination of aircraft manoeuvre margin.(Reproduced from Ref. [1])

As acknowledged by the investigators, the data presented in the report effectively demonstrates a spot check has been carried out. Accurate calculation of the MNP requires the investigators to carry out a series of incremental g tests and conducting the corresponding analysis. This is illustrated in Figure 3 that shows the gradient of required elevator angle (η) to normal acceleration (g) at aft and forward centres of gravity are required to obtain MNP (h_m). A similar approach is recommended to obtain stick-free MNP, which will require the measurement of stick force instead of elevator angle.

At the forward centre of gravity limit the aircraft has been found to be neutrally stable. Therefore, it can concluded that for the actual accident, where the aircraft has an aft centre of gravity, the aircraft's static stability characteristics need further study.

The analysis also needs to consider that the differences between wind-up turns and symmetric pull-ups is not constant when carried out at the low normal accelerations, as shown in Figure 2.

2

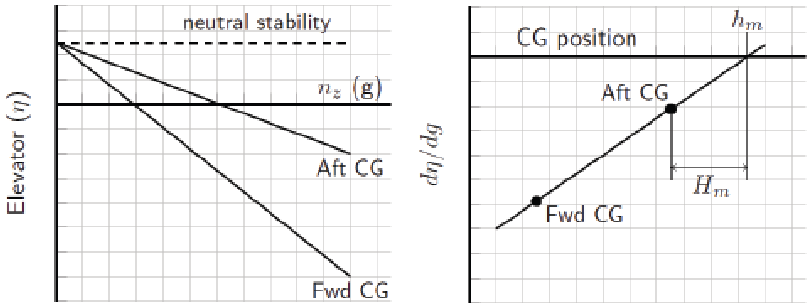


Figure 3: Typical approach to determine stick-fixed manoeuvre neutral point.(Reproduced from Ref. [5])

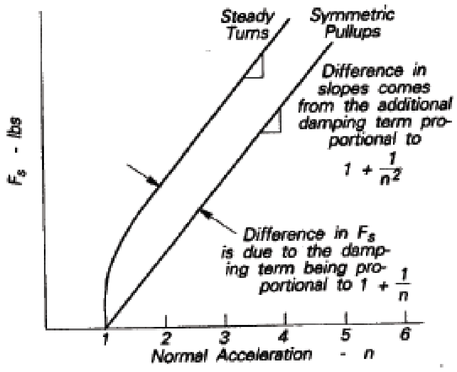


Figure 4: Difference between wind-up turns and symmetric pull-ups.(Reproduced from Ref. [4])

Conclusions and recommendations

In summary, the objectives of the flight tests are clear. References [1] and [2] suggest that the aircraft is angle-of-attack neutral (stick free) at forward centre of gravity. This implies that there is a need to study the aircraft's static stability characteristics and instrument the elevator to investigate stick-fixed MNP.

We are in overall agreement with the assessment. However, there has been no investigation of stick-fixed neutral point. If this was known, stick-fixed MNP could be estimated theoretically for verification.[4,5] It is assumed that no stick-fixed tests were conducted because the elevator was not instrumented.

References

[1] Flight testing to determine manoeuvre neutral point - take-off configuration, Ref. FSLR 3030 rev 0, Flight Structures Ltd., 14 November 2014.

[2] Aviation enquiry 10-009, Transport Accident Investigation Commission, April 2012.

[3] DEF-STAN-00-970 Part1 Section 2 - Issue 10, Design and airworthiness requirements for service aircraft, July 2013.

[4] Introduction to flight test engineering, D.T. Ward and T.W. Stragnac, Kendall Hunt Publishing, 1996.

[5] Flight dynamics principles, M.V. Cook, Elsevier Publishing Ltd., 2014.

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Appendix 7: Original findings from final report

5.1. There were no technical defects identified that may have contributed to the accident and the aeroplane was considered controllable during the take-off roll, with the engine able to deliver power during the short flight.

5.2. The aeroplane's centre of gravity was at least 0.122 m rear of the maximum permissible limit, which created a tendency for the nose to pitch up. The most likely reason for the crash was the aeroplane being excessively out of balance. In addition, the aeroplane probably became airborne early and at too low an airspeed to prevent uncontrollable nose-up pitch.

5.3. The aeroplane reached a pitch angle that would have made it highly improbable for the unrestrained parachutists to prevent themselves sliding back towards the tail. Any shift in weight rearward would have made the aeroplane more unstable.

5.4. The engineering company that modified ZK-EUF for parachuting operations did not follow proper processes required by civil aviation rules and guidance. Two of the modifications had been approved for a different aircraft type, one modification belonged to another design holder and a fourth was not referred to in the aircraft maintenance logbook.

5.5. The flight manual for ZK-EUF had not been updated to reflect the new role of the aeroplane and was limited in its usefulness to the aeroplane owner for calculating weight and balance.

5.6. Regardless of the procedural issues with the project to modify ZK-EUF, the engineering work conducted on ZK-EUF to convert it from agricultural to parachuting operations in the standard category was by all accounts appropriately carried out.

5.7. The weight and balance of the aeroplane, with its centre of gravity at least 0.122 m outside the maximum aft limit, would have caused serious handling issues for the pilot and was the most significant factor contributing to the accident.

5.8. ZK-EUF was 17 kg over its maximum permissible weight on the accident flight, but was still 242 kg lighter than the maximum all-up weight for which the aeroplane was certified in its previous agricultural role. Had the aeroplane not been out of balance it is considered the excess weight in itself would have been unlikely to cause the accident. Nevertheless, the pilots should have made a full weight and balance calculation before each flight.

5.9. The aeroplane owner and their pilots did not comply with civil aviation rules and did not follow good, sound aviation practice by failing to conduct weight and balance calculations on the aeroplane. This resulted in the aeroplane being routinely flown overweight and outside the aft centre of gravity allowable limit whenever it carried 8 parachutists.

5.10. The empty weight and balance for ZK-EUF was properly recorded in the flight manual, but the stability information in that manual had not been appropriately amended to reflect its new role of a parachute aeroplane. Nevertheless, it was still possible for the aeroplane operator to initially have calculated the weight and balance of the aeroplane for the predicted operational loads before entering the aeroplane into service.

5.11. The aeroplane owner did not comply with civil aviation rules and did not follow good, sound aviation practice when they: used the incorrect amount of fuel reserves; removed the flight manual from the aeroplane; and did not formulate their own standard operating procedures before using the aeroplane for commercial parachuting operations.

5.12. The Director of Civil Aviation delegated the task of assessing and overseeing major modifications to Rule Part 146 design organisations and individual holders of "inspection authorisations". The delegations did not absolve the Director of his responsibility to monitor compliance with civil aviation rules and guidance.

5.13. The delegations increased the risk that unless properly managed the CAA could lose control of 2 safety-critical functions: design and inspection. The Director had not appropriately managed that risk with the current oversight programme.

5.14. The CAA had adhered strictly to its normal practice and was acting in accordance with civil aviation rules when approving the change in airworthiness category from special to standard. However, knowing the scope, size and complexity of the modifications required to change ZK-EUF from an agricultural to a parachuting aeroplane, it should have had greater participation in the process to help ensure there were no safety implications.

5.15. There was a flaw in the regulatory system that allowed an engineering company undertaking major modification work on an aircraft to have little or no CAA involvement by using an internal or contracted design delegation holder and a person with the inspection authorisation to oversee and sign off the work.

5.16. The level of parachuting activity in New Zealand warranted a stronger level of regulatory oversight than had been applied in recent years.

5.17. The CAA's oversight and surveillance of commercial parachuting were not adequate to ensure that operators were functioning in a safe manner.

5.18. The CAA had mechanisms through the Director's powers under the Civil Aviation Act and his designated powers under the [Health and Safety in Employment Act 1992] to effectively regulate the parachuting industry pending the introduction of Rule Part 115.

5.19. An alcohol and drug testing regime needs to be initiated for persons performing activities critical to flight safety, to detect and deter the use of performance-impairing substances.

5.20. In this case the impact was not survivable and the passengers wearing safety restraints would not have prevented their deaths, but in other circumstances the wearing of safety restraints might reduce injuries and save lives.

5.21. Safety harnesses or restraints would help to prevent passengers sliding rearward and altering the centre of gravity of the aircraft. It could not be established if this was a factor in this accident.

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11-001	Bell Helicopter Textron 206L-3, ZK-ISF, Ditching after engine power decrease, Bream Bay, Northland, 20 January 2011
11-002	Bombardier DHC-8-311, ZK-NEQ, Landing without nose landing gear extended Woodbourne (Blenheim) Aerodrome, 9 February 2011
10-010	Bombardier DHC-8-311, ZK-NEB, landing without nose landing gear extended, Woodbourne (Blenheim) Aerodrome, 30 September 2010
12-001	Interim Factual: Cameron Balloons A210 registration ZK-XXF, collision with power line and in-flight fire, 7 January 2012

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