AIRCRAFT ACCIDENT REPORT

No. 92-007

Pterodactyl Ascender II + 2

ZK-FKF

Manukau Harbour

8 March 1992

Transport Accident Investigation Commission
Wellington - New Zealand

Price $14.40 (including G.S.T.)

ISSN 0112-6962

AIRCRAFT:	Pterodactyl Ascender II+2	**OPERATOR:**	Mr Ashley Paul NORTH
REGISTRATION:	ZK-FKF	**PILOT:**	Mr Ashley Paul NORTH
PLACE OF ACCIDENT:	Manukau Harbour	**OTHER CREW:**	Nil
DATE AND TIME:	8 March 1992, 0940 hours	**PASSENGERS:**	Nil

ABSTRACT:
See Pg 4

1.1 HISTORY OF THE FLIGHT:
See Pg 5

1.2 INJURIES TO PERSONS:
Pilot: 1 Fatal
Pax: Nil

1.3 DAMAGE TO AIRCRAFT:
Destroyed

1.4 OTHER DAMAGE:
Nil

1.5 PERSONNEL INFORMATION:
Age 45. Novice certificate issued by MAANZ.

Flight Times

	Last 90 days	Total
All Types	Nil	39
On Type	Nil	3

1.6 AIRCRAFT INFORMATION:
MAANZ Serial Number 290. Permit to Fly valid until 20 December 1992. Cuyuna 430 R engine indirectly driving a 3 blade propeller. See Pg 7

1.7 METEOROLOGICAL INFORMATION:
See Pg 9

1.8 AIDS TO NAVIGATION:
N/A

1.9 COMMUNICATIONS:
N/A

1.10 AERODROME:
N/A

1.11 FLIGHT RECORDERS:
N/A

1.12 WRECKAGE AND IMPACT INFORMATION:
See Pg 10

1.13 MEDICAL AND PATHOLOGICAL INFORMATION:
There were no medical factors that would have affected the pilot's ability to control the aircraft

1.14 FIRE:
None

1.15 SURVIVAL ASPECTS:
See Pg 11

1.16 TESTS AND RESEARCH:
Structural items tested complied with the manufacturer's specifications

1.17 ADDITIONAL INFORMATION
See Pg 11

1.18 USEFUL OR EFFECTIVE INVESTIGATION TECHNIQUES
N/A

2. ANALYSIS:
See Pg 15

3. FINDINGS:
See Pg 21

4. SAFETY RECOMMENDATIONS:
It was recommended to the Civil Aviation Authority that the Permit to Fly for Pterodactyl Ascender II+2 Microlight aircraft be withdrawn. It was recommended to the Microlight Aircraft Association of New Zealand that operations of single-seat Pterodactyl Ascenders be restricted. See Pg 22

5. APPENDICES:
NIL

* All times in this report are NZDT (UTC + 13 hours)

The units used in this report are those in the documents available to the pilot.

ABSTRACT

ZK-FKF was the second in a loose formation of three microlight aircraft which had taken off from Pikes Point Aerodrome, to fly to Raglan. While the formation was flying over the Manukau Harbour, parallel to the north shore, the aircraft was seen to dutch roll, then pitch nose-down. The right wing folded at about one-third span, and the aircraft fell into the sea, killing the pilot.

Similarities between the structural damage to ZK-FKF and other Pterodactyl Ascender microlights involved in mid-air breakups suggested design deficiencies. Video recordings of two such accidents demonstrated that the wings fluttered following an uncontrollable pitch down, the flutter forces resulting in the subsequent breakup.

Analysis indicated an insufficient reserve of pitch stability when the aircraft was flown at the upper end of its speed range, together with other control and structural design shortcomings.

It was recommended that the type's Permit to Fly be withdrawn.

1. FACTUAL INFORMATION

1.1 History of the flight

1.1.1 The Microlight Aircraft Association of New Zealand was holding a competition at Raglan Aerodrome. Two experienced members of the Auckland Microlight Club had planned to fly to it from their base at Pikes Point, on the north shore of the Manukau Harbour. Their aircraft were a Thruster, of conventional layout, and a Pterodactyl Ascender which was a canard (tail-first) design. They estimated the local wind was northerly at 10 to 15 knots, but did not obtain an official weather forecast.

1.1.2 While the two pilots were preparing their aircraft for the trip, they were joined by Mr North, who said he would like to accompany them. Mr North was less experienced, so the other pilots briefed him and helped him to prepare. It was intended that the three aircraft should fly in loose formation, in line astern, led by one of the experienced pilots in his Pterodactyl, then Mr North (whose aircraft was also a Pterodactyl) with the Thruster bringing up the rear. The spacing was to be about 100 m, and the altitude 500 feet to Cornwallis, then climbing to 1200 feet to cross the harbour.

1.1.3 The aircraft took off in this sequence, each turning individually to fly offshore parallel to the Manukau Harbour coastline, from Pikes Point to Shag Point and thence to Cornwallis (see diagram 1). This route had been chosen for a number of reasons:

(a) It avoided overflying built-up areas.

(b) It kept the aircraft clear of controlled airspace, below 1500 feet.

(c) It kept the aircraft within gliding range of land, until the point where the harbour mouth narrowed and the water crossing could be made safely.

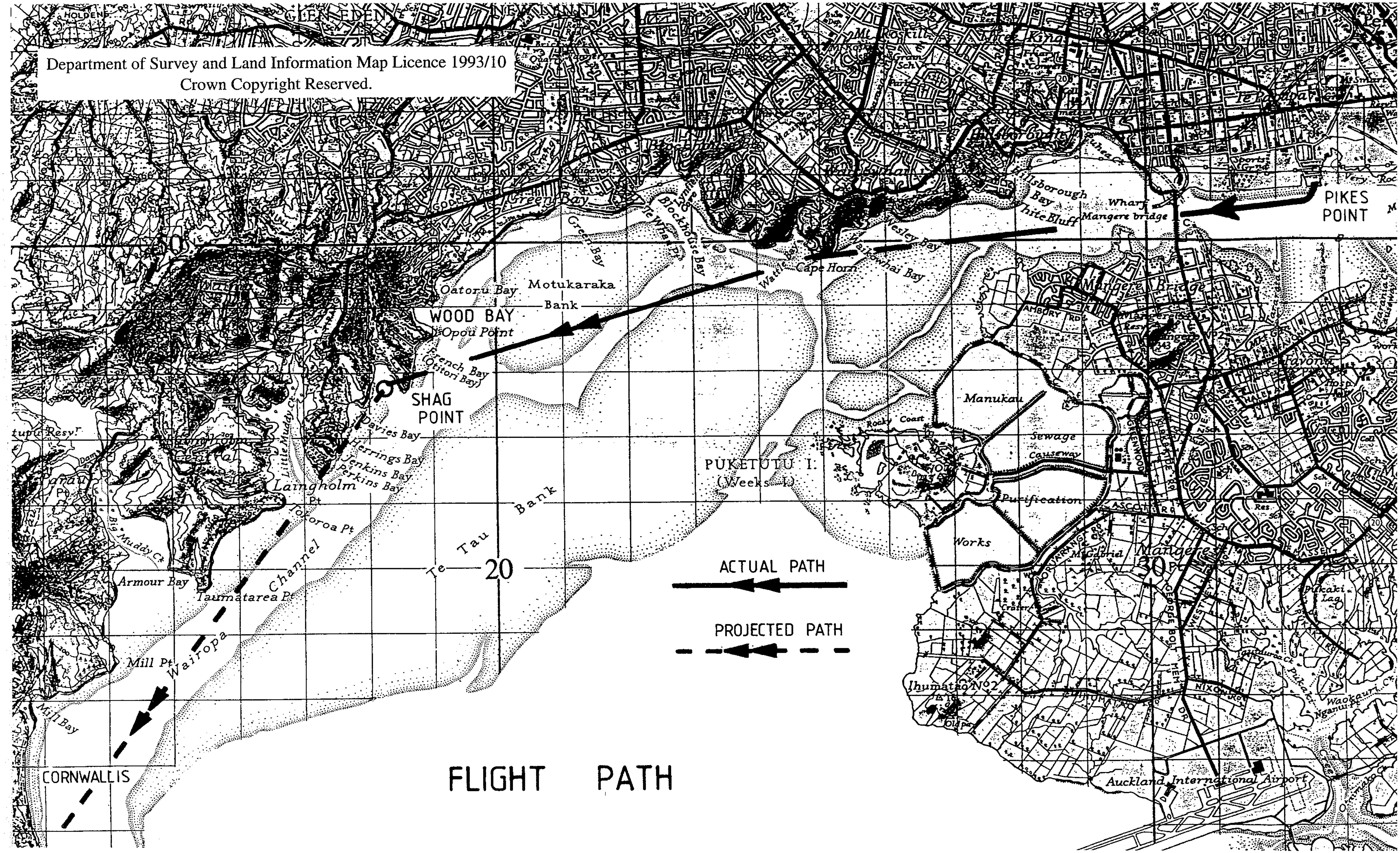
However in a northerly wind it had the disadvantage that it placed the aircraft in the lee of significant bluffs, and so had the potential to expose them to considerable turbulence, by microlight standards.

1.1.4 The lead Pterodactyl was being flown at about 50 mph, which the pilot considered a comfortable speed in the conditions. The turbulence in the lee of the bluffs was not severe enough to cause him concern.

1.1.5 At about this time the second Pterodactyl was some distance behind the lead aircraft, and was followed closely by the Thruster. The Thruster pilot felt that the Pterodactyl's speed was somewhat high, and checked his airspeed indicator which was a conventional ASI fed from a pitot head. It showed 50 knots (58 mph) which he considered excessive for a Pterodactyl in the conditions.

1.1.6 On reaching Shag Point, the pilot of the lead aircraft reduced his speed to 45 mph, as there was then a tailwind component. He looked behind and saw the second Pterodactyl. The aircraft were still at 500 feet and the separation appeared unchanged.

1.1.7 The pilot of the Thruster saw the second Pterodactyl diving: its wings "looked like they were back together". The aircraft went straight down, not spinning, into the water. The wreckage was 400 to 500 m from the beach.



PIKES POINT
WOOD BAY
SHAG POINT
CORNWALLIS
PUKETUTU I.
(Weeks I.)
Manukau Sewage Purification Works
Auckland International Airport
Mangere Bridge
Mangere
Green Bay
Blockhouse Bay
Cape Horn
Wesley Bay
Hillsborough Bay
White Bluff
Motukaraka Bank
Oatoru Bay
Opou Point
French Bay (Otitori Bay)
Davies Bay
Herrings Bay
Jenkins Bay
Perkins Bay
Laingholm
Tokoroa Pt
Taumatarea Pt
Armour Bay
Mill Pt
Mill Bay
Wairopa Channel
Te Tau Bank
20
30
GLEN EDEN
Ihumatao No2
ACTUAL PATH
PROJECTED PATH

FLIGHT PATH

The Thruster pilot landed his aircraft on the beach, gave his mobile telephone to a bystander to call for assistance, and then waded and swam to the wreckage. He arrived at the same time as a boat.

1.1.8 When the pilot of the lead aircraft checked next, he saw that the second aircraft was missing and the Thruster was landing on the beach. The lead pilot could see the wheels of the second aircraft sticking out of the water, and flew low over it, but could see no movement. There were no boats in the bay, so he landed at Wood Bay alongside the Coastguard buildings, to raise the alarm.

1.1.9 The three aircraft had been seen by a number of witnesses, who remarked that the second aircraft seemed more affected by the wind than the other two, in that it was "wobbling about". One witness, who saw it from behind, described a dutch roll motion (combined cyclic yaw and pitch). Two witnesses saw the aircraft break up: one thought it had pitched nose up, the other nose down. Both stated that the right wing had folded upwards from about a quarter of the wingspan out from the root – "like an arm bending at the elbow", as one put it.

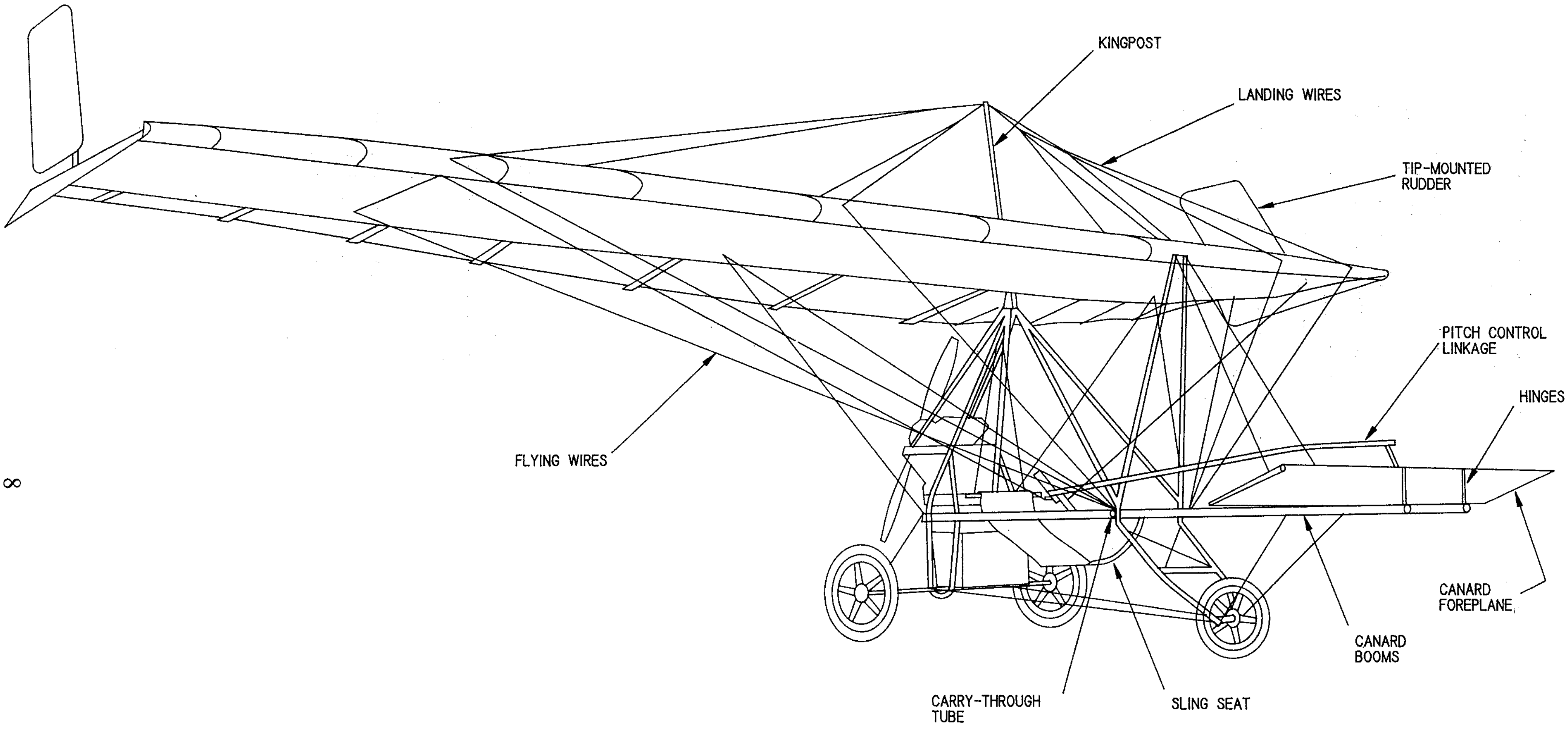
1.1.10 The accident happened in daylight at 0940 hours NZDT, in Paturoa Bay, Manukau Harbour, National Grid Reference 583 705 NZMS 260, Sheet R11 "Auckland".

1.6 Aircraft information

1.6.1 The Pterodactyl Ascender II+2 was the latest in a series of designs that started with a tailless hang glider to which an engine was added. Subsequently a canard (foreplane) was added so that pitch attitude could be controlled by a control column, rather than by weight shift. The II+2 variant incorporated a second seat alongside the pilot. (See Diagram 2).

1.6.2 The wings of the Ascender were swept back at 20° and braced externally by landing and flying wires. Internally each wing had two compression struts and diagonal drag wires (diagram 3). The double surface wing had a flat undersurface between the tubular spars, the upper surface being held in shape by pre-formed battens. These extended somewhat beyond the rear spar to the leech of the upper surface fabric. The wing section was similar to a "Clark Y" profile, with a fixed area-extending trailing edge flap. A uniform washout of 2.5° was incorporated, and the flap section of the outer six bays was somewhat reflexed so that it was parallel to the mean chord line of the basic aerofoil. These measures, necessary for stability on the tailless aircraft, had been retained as the design was developed.

1.6.3 The canard was mounted on two booms, which extended forward from what had originally been the hang-cage on the hang glider. The longitudinal members were extended beyond the cross-bar/carry-through tube at the front of the frame as stubs, and extending beyond them were sleeves within which the canard tubes were located. The canard was, in effect, cantilevered about the carry-through tube: although it was braced against landing loads by wires to the wing leading edge, the corresponding wires which appeared to provide lift bracing were in reality part of the nosewheel suspension, and were "bungy-sprung".



PTERODACTYL ASCENDER II+ - GENERAL ARRANGEMENT DIAGRAM 2

(SINGLE SEAT VARIANT)

1.6.4 The carry-through tube, which took most of the flight loads from the entire wing, had an outside diameter of one and one eighth inches. The hang-cage longitudinals, which had an outside diameter of one and three quarter inches, were drilled through to accommodate it. Bolt holes of 1/4 inch diameter were then drilled through vertically for bolts to locate the assembly; the holes eliminated much of the remaining tube wall. Each longitudinal member was prevented from crushing by a wood insert (which had the potential to retain moisture and accelerate corrosion). On ZK-FKF the remaining cross section of metal was 0.055 square inches, at the top and bottom of each tube.

1.6.5 The canard was hinged at its leading edge, and the control horn was also mounted on the leading edge spar. The foreplane was essentially of flat-plate section with a rounded leading edge. It was characteristic of that section that the centre of pressure position was virtually constant, at the quarter-chord point.

1.6.6 Ascender pilots advised that ordinarily, the loads on the canard were very light: it was essentially a trim-tab, since the configuration had been designed to be stable without it. The geometry of the foreplane control linkage to the control column (which was mounted on the righthand longitudinal frame of the hang cage) was such that there was little mechanical advantage.

1.6.7 One Ascender pilot who had experienced a pitch-down and recovered from it said that it took a very strong pull force on the control column to raise the nose. He encountered the pitch-down while flying at the published rough-air speed, (40 mph) in turbulent conditions, and closed the throttle to prevent the speed building excessively during the ensuing dive.

1.6.8 The standard seat shown in diagram 2 was a canvas sling, in which the pilot sat in a semi-reclining position, between the horizontal tubes of the hang cage. The harness was secured to the horizontal tubes, and provided restraint against vertical motion, but little restraint to fore-and-aft motion. Rearward motion was checked by the crossbar to which the back of the sling was fastened. The pilot's feet rested on the two tubular footrests mounted on the canard booms, but these could pivot forward and were held upright by friction. On ZK-FKF, in common with other recently built Ascenders, the seat was a fibreglass moulding suspended from the framework by a number of wires; the harness remained unchanged.

1.6.9 The never-exceed speed, V_{ne}, published by the manufacturer was 60 mph. A "cruising speed" of roughly 40 to 50 mph was quoted, and the manoeuvring speed (the optimum speed in rough air conditions) was 40 mph. The stalling speed, at the maximum all-up weight of 700 pounds, was 32 mph. The payload was nominally 450 pounds.

1.6.10 The original designer did not respond to inquiries from the Commission, but MAANZ had been advised by him that he had set limits of 45 mph V_{ne}, and 34 mph in rough air. Subsequent increases in weight, power and speed were outside the design concept of the aircraft.

1.7 Meteorological information

1.7.1 At the time of the accident a deep depression, about 225 nm west of Auckland, was moving quickly south-east. A strong north-westerly airflow covered the northern part of New Zealand, the wind being nearly aligned with the Northland Peninsula. The ascent from Kaitaia about one and a half hours after the accident showed a shear of five knots per thousand feet up to 5000 feet. This was likely to cause mechanical turbulence. Added to that, the aircraft was flying (at 500 feet) just downwind of bluffs which were 300 to 600 feet high.

1.7.2 The surface wind at Auckland International Airport was north-easterly, which was the usual direction in north-westerly flows. Thus there would have been a shear caused by the wind direction changing with height to the north-west. It was probable that the wind at Titirangi Beach was more easterly than at the Airport.

1.7.3 The New Zealand Meteorological Service stated:

> "Although it is not possible to state the amount of turbulence, it is probable that the microlight encountered turbulence which was at least moderate and possibly severe for the type of aircraft".

1.7.4 Visibility was good, with a cloud base of 1800 to 2000 feet except for some patches of stratus at 1000 feet.

1.7.5 The actual weather reported at Auckland International Airport at 0900 hours was:

Wind:	040° at 14 knots
Visibility:	1/8 stratus at 1400 feet, 6/8 cumulus at 2000 feet, temporarily 5/8 stratus at 900 feet
Temperature:	23°C, Dewpoint 19°
QNH:	1007 hPa

1.12 Wreckage and impact information

1.12.1 The wreckage had fallen in shallow water, with the mainwheels showing above the surface. It was towed ashore, hosed down, and carted to a secure area for examination.

1.12.2 The right wing had broken upwards at the inboard compression strut; the left wing was essentially intact. The canard booms had fractured at the forward carry-through (see diagram 2) and the canard itself was broken in a number of places.

1.12.3 The rigging wires were intact apart from the right centering wire which had been cut by the propeller. However, the forward outboard landing wire on the right wing showed evidence of extreme overload. The inboard right drag wire also showed signs of high loading.

1.12.4 The fabric was in good condition and the only damage related to the break-up and impact.

1.12.5 The propeller was essentially intact; the engine turned over freely and had good compression.

1.12.6 It was established that each of the control connections was intact at impact.

1.12.7 Some damage to the wingtip-mounted rudders may have occurred during retrieval, but strike marks on the stops were consistent with flutter.

1.12.8 Damage to the hang cage and throttle lever were consistent with motion to the right at impact.

1.12.9 The fabric was stripped from the wings in order to investigate the damage to the spars. There were compression fractures in the leading edge, trailing edge and inboard compression strut of the right wing, and when the spars were aligned in their original positions they were found to have an "S" shaped set.

1.12.10 The midsection of the right rear spar was fractured half-way along its length. This was a bending failure, at a point where the spar had previously been struck, from ahead and below, by a hard object with sharp facets. The only external indication of this damage would have been a minor fabric cut, visible from beneath the wing. The area in which the aircraft had been picketed was searched and a number of large stones were found. The grass around the aircraft had recently been cut with a powerful rotary slasher, and the adjacent metal hangar wall had dents similar in size and character to that in the spar.

1.12.11 The hang cage and canard booms were reassembled and found to be intact apart from the fractures in the booms. The booms had failed vertically upwards.

1.12.12 The aircraft was carrying a suitable amount of ballast for solo operation.

1.15 Survival aspects

1.15.1 Injuries suffered by the pilot were consistent with an impact of the order of 50 g, which was beyond human tolerance.

1.15.2 The pilot was wearing a full-face motorcycle helmet. Notwithstanding the severity of the impact, the helmet had protected his head and face from injury.

1.17 Additional Information

1.17.1 There had been a number of accidents involving Pterodactyl Ascender microlight aircraft. Those that were reported in sufficient depth for further analysis were:

ZK-FCB	Report No 83-041	Midair breakup, serious injury
ZK-FJK	Report No 84-109	Midair breakup, fatal injury to two
ZK-EWR	Report No 85-024	Midair breakup, fatal injury
ZK-FIY	Report No 88-025	Midair breakup, fatal injury

1.17.2 A search of the literature was made with the assistance of the Department of Scientific and Industrial Research, using a computerised library search system. In the period 1982-84 there had been 26 fatal accidents in the United States.

1.17.3 One accident in the United States was recorded by a professional video team. A high-grade copy of the tape was obtained and analysed in detail at the video tape laboratory of the Royal New Zealand Police College.

1.17.4 The accident to ZK-FCB was recorded by an amateur photographer. The tape was enhanced at the video laboratory, and it was possible to see the individual events.

1.17.5 The wing failures in the New Zealand accidents are shown at Diagram 3. The similarity in the break-up patterns is evident, with breaks in the vicinity of the inboard compression struts, and compression damage to one or both struts. While the exact nature of all the failures was not documented, leading edge compression failures were identified in the cases of ZK-FJK and ZK-FKF. The leading edge broke in the vicinity of the inboard compression strut in every case; so did the trailing edge, and in each case there was an additional break in the trailing edge. Although each accident had a different cause factor attributed to it, it appeared that these might be triggering elements with a similar underlying cause. The video recordings were therefore examined in detail.

1.17.6 The United States video showed that the flight was made in calm conditions. The aircraft was fitted with a harness but the pilot did not use it. After a number of low hops the pilot (who had previous flying experience) took off normally, and turned to overfly the aerodrome. The aircraft was seen to oscillate in pitch, at about one cycle per second. During this oscillation the attitude became progressively more nose down, finally stabilising at an attitude perhaps 30° nose down. From there the aircraft was abruptly recovered to a nose high attitude, whence it finally settled to the original attitude.

1.17.7 Some time later there was a second oscillation in pitch, at the same rate as before. It was possible to see that, as the nose started to rise after each pitch down, the wingtip twisted nose-up at a greater rate. This twist was accompanied by "S" shaped bending of the leading edge spar. Again, the aircraft resumed level flight. The aircraft yawed to the left during each pitch-up.

1.17.8 Some eight seconds later there was a violent yaw to the left, accompanied by cyclic torsion of the wingtips at about 1 Hz. Compressive S-bend cycling of the spars was visible at 2 Hz. The left tip rudder could be seen flailing. The pilot's feet came off the foot rests and he was catapulted forwards into a kneeling attitude. Contemporaneously the aircraft pitched to a nose-down attitude steeper than that achieved hitherto; this attitude was achieved in 0.2 seconds. After two complete cycles of compressive oscillation, the right wing failed at about one-third span. The right wing folded back to meet the left wing as the aircraft fell to the ground.

1.17.9 The accident to ZK-FCB occurred in turbulent conditions, as the aircraft was approaching to land after a cross-country flight. The video showed that, with the aircraft apparently in normal descent, the right wingtip twisted nose-down. One torsional cycle, and two compressive oscillation cycles, occurred in the space of a second. Four seconds later the aircraft pitched somewhat nose-down; two seconds later the aircraft pitched steeply nose-down, this second pitch-down being completed in 0.12 seconds. The tip rudders were fluttering. The aircraft was recovered to approximately level flight.

ASCENDER WING FAILURES

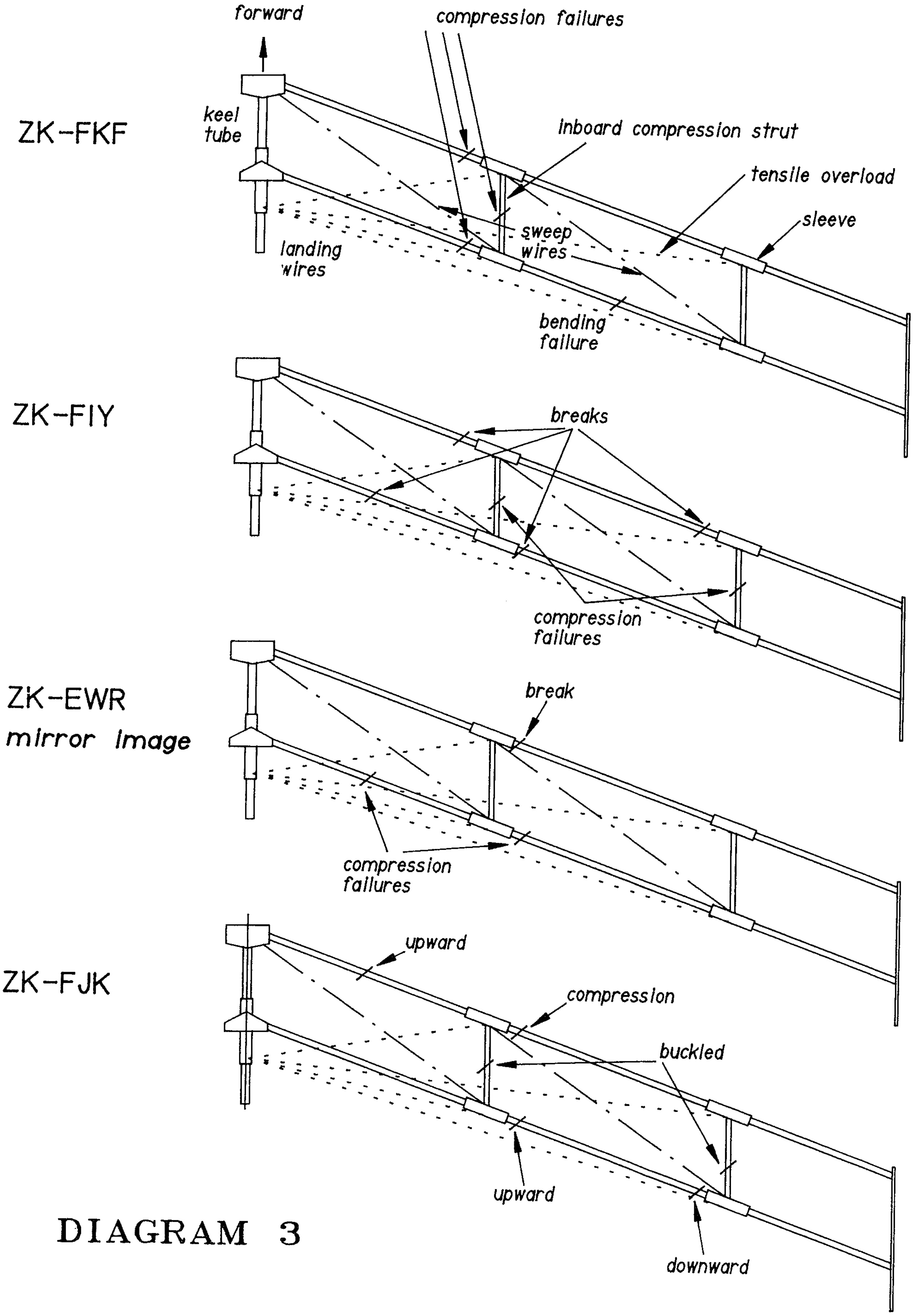


DIAGRAM 3

1.17.10 After a further three seconds further torsional and compressive oscillation occurred then, after two seconds the aircraft pitched down, recovered, and pitched down again, over a period of two seconds. During both descent phases torsion and compression was again apparent; during the second the left wing failed in compression at about one third span. By this time the aircraft was only a few feet off the ground: the pilot, although injured, survived.

1.17.11 The torsional oscillation frequency was about 1 Hz, and the compressive oscillations were at about 2 Hz, on each occasion.

1.17.12 The minimum response time expected of the pilot, for a purely reflex action was about 0.25 seconds. The pitch downs in the videos were generally completed in 0.5 seconds, and in one case in as little as 0.12 seconds, ie. less than the time in which the pilot could have started to take action to counter the pitch-down.

1.17.13 An experienced Ascender pilot decided to explore the performance of his aircraft at higher speeds, in calm evening conditions at a date prior to this accident. Speed was progressively increased to 55 mph, at which point the pilot "became uneasy" (but could not say why) and discontinued the experiment. No defect was observed when examining the aircraft before subsequent flights, but when the fabric covering was removed from the wings it was found that there was a compression buckle of the leading edge tube just inboard of the inboard compression strut of the right wing, and that the leading edge tube had taken on an "S" shaped set.

1.17.14 An unreported accident occurred when an Ascender pilot's feet slipped off the footrests while the aircraft was flying at low level, and the aircraft pitched into the ground. The pilot believed that the weightshift from his body moving forward, in response to the lack of foot support, might have been the cause of the pitch-down.

1.17.15 For the issue of a Permit to Fly, when the aircraft concerned was the first of its type in New Zealand, the following criteria had to be met:

(a) Six aircraft of that type must have flown

(b) 150 hours total time must have been logged

(c) At least one of the aircraft must have flown for more than 50 hours

(d) The type must have had a "satisfactory airworthiness history"

While criteria (a), (b) and (c) were a matter of documentation, criterion (d) had been considered satisfied by a response from the designer/manufacturer.

1.17.16 The two-seat variant of the Pterodactyl microlight, the Ascender II+2, appeared in New Zealand in 1984. The first of type (ZK-FFH) went through the above process because, as a two-seater, it required a Permit to Fly. The earlier single seat variants did not. (The rationale for the distinction was that microlight aircraft were low-energy devices and so posed little risk to the public, but that where a member of the public was potentially at risk as a passenger, somewhat greater scrutiny of the aircraft was called for).

1.17.17 The first-of-type certification for the Pterodactyl Ascender II+2 was issued in 1984.

2. ANALYSIS

2.1 The damage to ZK-FKF – Steady state conditions

2.1.1 The in-flight damage to ZK-FKF comprised compression failures of the leading and trailing edge spars of the right wing, and compression failure of the right inboard compression strut. There had been heavy tensile loading of the right outboard leading landing wire. The front and rear spars of both wings had taken a permanent "S"-shaped set, which was consistent with loading in compression.

2.1.2 Compressive loads in the trailing edge spars could arise due to an increase in the sweep angle on the wing: such an increase could be caused by drag loads at high speed. The tendency to increased sweep would be resisted primarily by the sweep wires, but also by the combination of the rear flying and landing wires. The outboard landing wires were at a relatively shallow angle to the spar, and a tendency to increased sweep could result in high compressive stresses in the rear spar.

2.1.3 However, this mechanism could not account for compressive stresses in the leading edge spar. Rearward movement of this spar would result in the flying and landing wires being off-loaded. Rearward movement would be resisted by the compression struts, but the load could not be such as to cause them to collapse.

2.1.4 To apply a compressive load to the leading edge, it would be necessary to induce tension in the forward flying or landing wires, as would occur if an upward or downward load was applied near the tip. The flying wires, intended to carry in-flight loads, were at a reasonable angle, whereas the landing wires were at a relatively shallow angle. Excessive compression loads were more likely to be induced by a download which tensioned the landing wire. That a heavy download happened was borne out by the tensile distress exhibited by the right outboard leading landing wire.

2.1.5 A tensile load in the landing wires would also tend to move the leading edge back, this movement being resisted by the sweep wires in tension, the compression struts in compression, and the trailing edge in bending and compression.

2.1.6 Failure of the inboard compression strut would remove a point of support for the leading edge spar, which might then buckle and fail under compression, close to the point where the support was removed. However, failure of the compression strut would also off-load the trailing edge to some extent, since the strut would no longer be able to transmit the forces from the leading edge. Conversely if the trailing edge failed before the strut, the strut could not then have failed in compression. For all three tubes to fail in compression implied that they must have failed virtually simultaneously. The videos of other Ascender accidents showed this happening – certainly within 1/25 second.

2.1.7 Washout at the wingtip could result in a download on the outboard part of the wing at high speed. However, calculations indicated that the force which could be generated, at the speeds at which an Ascender flew, were insufficient to produce a destructive download. The possibility of the washout giving rise to centre-of-pressure shift sufficient to cause a heavy download on the leading edge was also examined and discarded. Since it appeared that steady-flight conditions would not give rise to the damage observed, the possibility of gust loading was examined.

2.2 Gust loading

2.2.1 The speed at which the pilot was estimated to be flying shortly before the accident was in the vicinity of the V_{ne}. The V_{ne} should have been approached cautiously, and only in smooth air. The hazards of exceeding V_{ne} in turbulence included the possibility that loads induced by gusts, or by control inputs from the pilot, might exceed the design strength of the aircraft, or that flutter might occur.

2.2.2 An aircraft with a Certificate of Airworthiness has to be tested to 1.1 V_{ne} to provide a safety margin. It was not possible to determine whether this had been done in the case of the Ascender II+2, nor on what basis the published V_{ne} was established, but the original designer considered it excessive.

2.2.3 The manoeuvring speed, V_a, was normally the speed at or below which the wing would unload in response to a gust, by stalling. It was prudent to reduce to this speed if turbulence which was more than moderate was encountered or expected.

2.2.4 While meteorological analysis suggested that considerable turbulence was to be expected, the evidence of the two experienced microlight pilots who were in the vicinity at the time was that the turbulence there was not severe enough to cause concern.

2.2.5 Eyewitnesses agreed that ZK-FKF appeared to be affected more by the turbulence than were the other two aircraft.

The possibility that the right rear spar, crippled by stone damage, yielded under gust load, was considered. The result would have been to warp the wing, resulting in a tendency to roll, and the pilot's attempts to counter this could have resulted in the dutch rolling motion described by one witness. However, since the bend occurred between the two braced points it would have required a sharp gust to cause it; and as Ascender pilots advised that dutch rolling was a possible response to gusts if the pilot overcontrolled, it was unnecessary to postulate such an occurrence. (See also para 2.3.9 - cross-coupling).

2.2.6 The video of the accident sequence in which ZK-FCB broke up showed that the wing was able to absorb large direct loads without breaking. Irrespective of whether or not ZK-FKF was flying too fast for the conditions, simple gust-induced overload failure was not a likely explanation.

2.3 Pitch-down

2.3.1 One of the witnesses who saw the break-up of ZK-FKF believed that it pitched up immediately before the wing folded up; the other was sure it had pitched down. The sequences in the two videos were consistent with both statements, in that an initial pitch-down was followed by a pitch-up as the pilot attempted to regain control, and in both cases this sequence was repeated within a very short interval. Depending on the witnesses' exact perspectives of the incident, and on what caught their attention, either perception would have been possible. In essential details, either video could have been of the incident described by the witnesses. Damage consistent with rudder flailing on ZK-FKF, and rudder flailing seen in both videos, was a further point of similarity.

2.3.2 The forces generated by flutter could be very large (see, for example, Aircraft Accident Report No. 91-012, ZK-DAG). Forces sufficient to produce compressive failures, as the bracing wires attempted to resist the vertical motion of the spars during each cycle of torsional flutter, could be envisaged readily.

2.3.3 Given that the manner in which the wings broke in both videos was the same as the failures of the wing of ZK-FKF, that the depiction on the videos was consistent with the eyewitness descriptions of the accident to ZK-FKF, and that flutter-induced forces were consistent with the mode of failure whereas static or gust loads were not, it was concluded that all three accidents were, in essence, identical. The excessive speed which caused the final destructive flutter arose, in each case, from an uncontrolled pitch-down.

2.3.4 The source of the pitch-down was next examined. It was an unusual characteristic of aerofoils similar to the Clark Y profile that there was little movement of the centre of pressure with change of angle of attack, within the range of angles encountered in normal flight. This characteristic resulted in pleasant aircraft handling, with small trim changes required as speed varied. However, if the angle of attack was reduced below about 4°, the centre of pressure moved aft rapidly, possibly as far as the trailing edge of the wing. This shift could be due to the stagnation point moving to the upper surface of the leading edge, resulting in reduced pressure below it - an effect likely to be exacerbated by camber change where the underside of the wing was merely unsupported fabric.

2.3.5 No quantitative reference could be found as to the effect of an area-increasing flap on a Clark Y aerofoil, but in general such a flap was likely to exacerbate centre of pressure shifts.

2.3.6 It was a known characteristic of aircraft with aerofoils of the Clark Y pattern that they might "tuck under" at high speed. In an aircraft of a conventional layout the tailplane might have had insufficient authority to prevent the increased nose-down pitch force, resulting from aft movement of the centre of pressure as the angle of attack was reduced, from forcing the nose of the aircraft down yet further. To ensure against this happening, the tailplane volume coefficient (a measure of the tailplane's authority) had to be sufficient: a figure of 0.45 was considered a minimum for aircraft the wings of which had moderately cambered aerofoils, while for heavier undercamber 0.55 was considered necessary. The trailing-edge flap probably brought the Ascender into the latter category. The Ascender's foreplane volume coefficient was 0.36. It was not surprising, therefore, that at low angles of attack the foreplane might have had insufficient authority to prevent a further pitchdown. The rapid centre of pressure movement to be expected at high speeds would have resulted in the pilot receiving little warning that a dangerous situation was developing.

2.3.7 The 2.5 degrees of uniform washout built into the wing was required for stability of the original flying wing design. When the wing approached the pitch-down condition, the outer portion would be the first to be affected. Since the wing was swept at 20 degrees, the tip was behind the geometric centre of the wing. Aft movement of the centre of pressure at the tips would result in a "down elevator" effect on the aircraft as a whole, exacerbating the nose down tendency.

2.3.8 If the Pterodactyl under the given flight conditions was assumed to have a plain Clark Y aerofoil, it was calculated that "tuck under" would occur at a speed somewhat in excess of V_{ne} in smooth air. However, a gust vector tending to reduce the angle of attack could precipitate the effect at a lower speed, possibly below V_{ne}. The addition of the trailing edge flap would reduce the speed of onset further. The phenomenon had been encountered by one surviving pilot at a speed in the vicinity of the published manoeuvring speed, in turbulent conditions.

2.3.9 The foreplane of the Ascender was essentially a trim tab, and in normal flight the control forces were light. However, the geometry of the control linkage was such that, if the foreplane was required to carry a load for any reason, the pilot would experience a force on the control column of about 2/3 of the load on the foreplane. If the aircraft had pitched nose-down for any reason, the pilot would need to have applied a pull force to the control column to raise the nose, and it was estimated that this pull force could have been as high as 50 pounds. The experience of the pilot who recovered from a nose-down pitch tended to confirm these calculations.

2.3.10 Such a control force would be difficult to apply with the side-mounted control column, especially from a semi-reclining position. There would probably be an element of cross-coupling in pitch and roll, as observed in the United States video and there would have been a tendency to "submarine" under the harness (the primary function of which was to hold the pilot down rather than to prevent forward motion). This tendency would have been exacerbated by a steep nose-down attitude. In such conditions the pilot's feet might have tended to slip off the footrests, which in any case could fold forward. In the United States video this was seen to happen, and it seemed reasonable that in the New Zealand low-level pitch-down accident the slippage of the pilot's feet may have been a consequence rather than a cause.

2.4 Flutter

2.4.1 A sudden pitch-down, where the aircraft was already flying close to its V_{ne}, would be likely to have caused the aircraft to exceed its V_{ne}, and flutter would then have been a probable consequence. The rudders fluttered, and it was not surprising that they did so. They were pulled in one direction by a cable attached to the control column, and pulled the other way by a return spring. Springy control systems were likely to result in flutter, and the floppy hinge arrangement would have made matters worse. However, the rudder flutter observed on the videos occurred after wing flutter had started, and so was not a cause of it.

2.4.2 Flutter was not confined to the pitch-down case. In the New Zealand video, flutter was observable in apparently steady descent, presumably gust-induced. Also, damage to an aircraft consistent with flutter had been found after a flight in smooth air, in which the pilot was approaching the published V_{ne} but was some five mph below it according to his ASI. He discontinued the experiment because he "felt uncomfortable". Incipient flutter might have been the cause of him feeling uncomfortable; the static loadings at V_{ne} were unlikely to have caused the damage (compression buckling and a permanent bow in the leading edge) which was found.

2.4.3 Swept-wing aircraft were prone to aeroelastic effects, where the wing twisted under load so that the incidence at the tip varied. This effect was visible on the United States' video. It was possible that the aeroelastic effect may have given rise to elevator effects, thus accounting for the pitch oscillations at the same rate as the torsional oscillations. A case of violent pitch oscillation had been reported in New Zealand. When aeroelastic torsion occurred, it could provide the trigger for torsional flutter, if appropriate conditions were present.

2.4.4 Torsional oscillation of the wing was reacted to by the flying and landing wires in turn. As a spar tended to move up or down a flying or landing wire came under tension, and in turn produced a compressive load on the spar. As each cycle of torsional oscillation produced both up and down movement of each spar this resulted in compressive cycling at twice the torsional oscillation rate, as observed.

2.5 The canard tubes

2.5.1 In the various accidents the canard tubes were presumed to have been bent or fractured on impact. However, in the United States video there was at least the possibility that they failed during the break-up sequence, and on ZK-FKF this possibility also existed.

2.5.2 The method by which the canards were attached was a design afterthought, sleeves being added to existing stubs on the original glider hang frame. The longitudinals on the hang frame were drilled out to allow the passage of the carry-through tube: there was no reason to be concerned about the static strength of the longitudinals. However, with the canard booms being cantilevered from these stubs, their strength was vital. On ZK-FKF, 0.055 square inch of material remained to support the canard loads. In attempting to recover from a pitch-down, large loads could have been applied. It was calculated that full up deflection of the canard would cause the booms to fail at a speed 12 knots above V_{ne}. This was based on new, unmarked longitudinal tubes, and would be less if there was fatigue, corrosion, or any stress raiser present.

2.5.3 The area under the sleeve could not be inspected without completely dismantling the hang frame, so the pilot had no way of knowing whether any damage to the stub had occurred. Nodding loads during taxiing, in particular, had the potential to cause fatigue damage which could precipitate a failure at lower loads.

2.5.4 When one Ascender was dismantled for examination, it was found that the steel bolts through the longitudinals were heavily corroded where they passed through the wooden plugs. This suggested that the plugs were trapping moisture. In turn, this gave rise to the possibility of dissimilar metal corrosion in a critical area.

2.5.5 There was no evidence that failure of the canard tubes had caused an accident, or prevented one from being averted, but the potential for failure was there, especially as the tubes deteriorated in service.

2.6 *Similarities of Ascender accidents*

2.6.1 The break-up patterns of Ascenders the wings of which have failed in flight in New Zealand (except ZK-FCB, which was not documented) are shown in Diagram 3. The similarities, in terms of breaks in the vicinity of the inboard compression struts, are marked. Where the types of breaks were documented, there were compression failures including leading-edge compression failures. Although different triggering elements were considered likely in each case, in essence these were all the same accident. The only mechanism identified that could produce a leading-edge compression was flutter; in view of the similarity of the break-up patterns it was probable that they all experienced flutter.

2.6.2 It was unnecessary to postulate that all of the aircraft in these accidents also experienced pitch-down (though they may have) since the evidence of the pilot who became "uncomfortable" while approaching V_{ne} in smooth air shows that damage could occur in level flight. His aircraft had leading edge compression damage short of failure, and it seemed likely that he terminated the experiment just at the onset of flutter.

2.7 *Design deficiencies*

2.7.1 Before the Pterodactyl Ascender II+2 could be considered a safe aircraft, either for passenger flying or for instruction, a number of design deficiencies would have to be rectified. In addition to other possible considerations, the following action would be required:

(a) The foreplane volume coefficient would have to be increased so that pitch-down could not occur even if a gust were to be encountered at speed.

(b) The foreplane control hingeing and linkage would have to be changed so that control forces were manageable at all speeds, and were in the conventional sense (ie. if the nose was lowered, a push force was required to hold it there, at all speeds up to 1.1 V_{ne}).

(c) The canard boom mounting would have to be improved so that there could be no possibility of failure if full control deflection were required, and in such fashion that any deterioration could be observed by normal inspection.

(d) It would have to be demonstrated that the aircraft had no tendency to flutter, at speeds up to 1.1 V_{ne}.

2.7.2 The forces arising from flutter were such that no feasible amount of reinforcement would suffice to protect existing aircraft from such accidents as those discussed in this report. Accordingly, it was recommended to the Civil Aviation Authority that the Permit-to-Fly for the two-seat variant be withdrawn unless and until the necessary design changes were made, and demonstrated to be successful.

2.7.3 Since single-seat microlight aircraft did not require a Permit-to-Fly, existing single-seat variants could continue to fly without restriction. However, they would be subject to exactly the same perils as the two-seaters. They could continue to operate in reasonable safety provided that the speed range was restricted, and it could be assured that they would not encounter turbulence. This latter consideration virtually precluded cross-country flying, since it could not be assured in advance that turbulence would not be encountered. (Such an encounter was a factor in the accident to ZK-FCB). Because relatively minor mishandling could precipitate a crisis, the aircraft was unsuitable for flight by inexperienced pilots. Recommendations to this effect were made to the Microlight Aircraft Association of New Zealand.

2.8 Permit to Fly

2.8.1 Part of the investigation was a search of literature using a novel computer search developed by the DSIR. The search disclosed that in the United States there were at least 26 fatal accidents involving Pterodactyls in the period 1982-84.

2.8.2 Irrespective of the individual causes allocated to these failures, such a series of accidents could not be regarded as a "satisfactory airworthiness history".

2.8.3 Had this record been known at the time that the Permit to Fly was first sought, the permit may have been refused and consequently the subsequent accidents averted. What was missing at the time (and perhaps not readily available then) was a search of the literature. It was recommended to the Director of Civil Aviation that such a procedure be adopted in addition to other measures normally taken to safeguard the accuracy of information upon which the granting of a Permit to Fly was based.

3. FINDINGS

3.1 The pilot was appropriately certificated and experienced to make the flight.

3.2 The aircraft was serviceable before the flight, apart from impact damage to one wing spar.

3.3 The impact damage to the spar was not a factor in the accident.

3.4 The weather conditions at the time and place of the accident were moderately turbulent.

3.5 Direct gust loads were not a factor in the accident.

3.6 The pilot was flying the aircraft at a speed close to the published V_{ne}.

3.7 The published V_{ne} was higher than that approved by the original designer.

3.8 The aircraft pitched down uncontrollably.

3.9 The pitch-down was due to characteristics inherent in the aircraft's design.

3.10 The aircraft's wing fluttered.

3.11 The flutter generated compressive stresses in the wing spars, which failed.

3.12 The right wing folded upwards and the aircraft fell into the sea.

3.13 There had been four previous in-flight break-ups of Pterodactyl Ascenders in New Zealand.

3.14 All of the previous break-ups involved structural failures which were similar to those of ZK-FKF.

3.15 There have been other incidents of pitch-down and flutter with Pterodactyl Ascender aircraft in New Zealand.

3.16 In the period 1982 to 1984 there were 26 fatal accidents involving Pterodactyl Ascenders in the United States.

3.17 The accident record in the United States was not known to the Civil Aviation officials of the Ministry of Transport when the Permit to Fly was issued.

3.18 The accident was probably caused by an uncontrollable pitch-down, followed by flutter which caused the wing to break. A contributory factor was flight at a speed which may have been excessive in the circumstances.

4. SAFETY RECOMMENDATIONS

4.1 It was recommended to the Director of Civil Aviation that he:

Withdraw the Permit to Fly from Pterodactyl Ascender II+2 microlight aircraft (050/93), and

Require the owners of Pterodactyl Ascender II+2 aircraft to remove the second seat and associated structure (051/93).

4.2 It was also recommended to the Director of Civil Aviation that:

When a Permit to Fly is sought for an aircraft which will be the first of type in New Zealand, a more detailed search of the literature be made with a view to discovering the type's accident record (015/93).

The Acting Director of Civil Aviation responded as follows:

"I will revoke all Permits to Fly issued to the Pterodactyl Ascender II+2 Microlight Aircraft.

I will require all registered owners of Pterodactyl Ascender II+2 Microlight Aircraft to re-configure their aircraft by permanently removing the second seat and supporting structure.

I will reclassify the Pterodactyl Ascender II+2 Microlight Aircraft as a Class 1 Microlight Aircraft (CAR Part 103.3 refers)

CAA will review its procedures for acceptance of First of Type Class 2 Microlights to see if any better way of ascertaining the Type's accident history can be found before initial issue of a Flight Permit, Microlight.

CAA will inform MAANZ of its actions and seek their assistance in the implementation of the CAA recommendations."

4.3 It was recommended to the President of the Microlight Aircraft Association of New Zealand that he:

Require the owners of Pterodactyl Ascender II+2 aircraft to remove the second seat and associated structure (052/93), and

Make interim restrictions on all Pterodactyl Ascender aircraft permanent (053/93), and

Advise his members that these aircraft should be flown only by experienced pilots (054/93).

The Microlight Aircraft Association of New Zealand responded as follows:

> *"Regarding your Safety Recommendations recently promulgated in relation to the Pterodactyl make of microlight, we wish to advise that these recommendations had already been implemented by MAANZ, and that a copy of your recommendations has now been sent to each owner within New Zealand and the United States of America for action as they see fit."*

4.4 The interim restrictions referred to in Recommendation 053/93 above were:

V_{ne} limited to 45 mph
Flight in calm conditions only
Restricted to local flying.

23 September 1993

M F Dunphy
Chief Commissioner

GLOSSARY OF ABBREVIATIONS USED IN THIS REPORT

ASI	Air Speed Indicator
DSIR	Department of Scientific and Industrial Research
Hz	Hertz
m	Metres
MAANZ	Microlight Aircraft Association of New Zealand
mph	Miles per hour
nm	Nautical Miles
Permit to Fly	(as defined by the Civil Aviation Regulations 1953) means a certificate of authorisation granted by the Secretary for Transport sanctioning the private operation of an aircraft which cannot comply with the requirements for a Certificate of Airworthiness. In general, "Permit to Fly" aircraft are either microlight aircraft or amateur-built aircraft. Microlight aircraft are categorised as either: Class 1: equipped to carry one person only and have a maximum fuel capacity of 35 litres Class 2: microlight aeroplanes other than Class 1 microlight aeroplanes ZK-FKF was, under the rules in force at the time of the accident, a Class 2 microlight aeroplane. By removing the second seat and limiting the fuel capacity, the type can be made Class 1, thus not requiring a Permit to Fly.
V_a	Manoeuvring Speed
V_{ne}	Never Exceed Speed