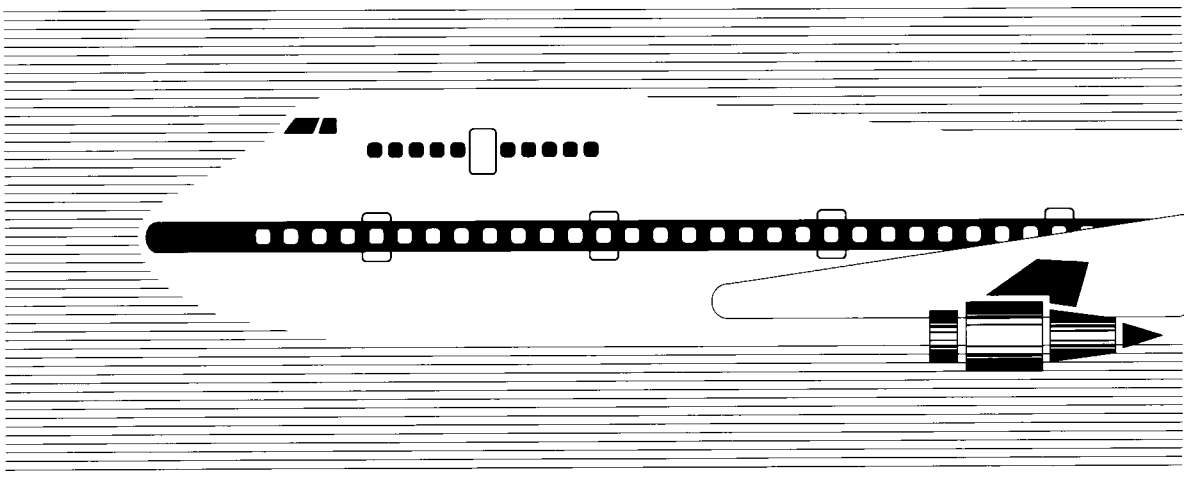
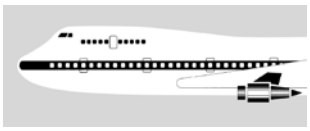
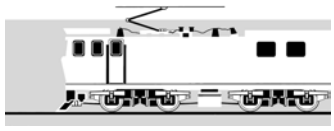


AVIATION OCCURRENCE REPORT

02-008 Piper PA31-310 Navajo ZK-NPR, landing gear failure to extend, Napier Aerodrome 24 June 2002


TRANSPORT ACCIDENT INVESTIGATION COMMISSION
NEW ZEALAND

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

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

Report 02-008

Piper PA31-310 Navajo
ZK-NPR

landing gear failure to extend

Napier Aerodrome

24 June 2002

Abstract

On Monday 24 June 2002, at about 0730, Air Napier PA31-310 Navajo ZK-NPR was on a freight flight from Palmerston North when the pilot had to make an emergency landing at Napier because the right undercarriage was unable to be extended. The landing was successful, with moderate damage to the aircraft and no injury to the pilot.

The right undercarriage had failed to extend because the uplock hook could not release the undercarriage leg. This resulted from a flat oleo strut becoming compressed, and was a previously unknown design deficiency.

A safety issue identified was the need for wide publicity, including foreign countries operating the PA31 type, about this deficiency.

Figure 1
ZK-NPR at Napier

Contents

Figures

Abbreviations

kg	kilogram
cm	centimetre
g	acceleration due to gravity

Data Summary

Aircraft registration:	ZK-NPR
Type and serial number:	Piper PA31-310 Navajo
Number and type of engines:	two Lycoming TIO-540-H2C
Year of manufacture:	1972
Operator:	Air Napier Limited
Date and time:	24 June 2002, about 0730[1]
Location:	Napier Aerodrome latitude: 39° 28′ south longitude: 176° 53′ east
Type of flight:	air charter (freight)
Persons on board:	crew: 1
Injuries:	nil
Nature of damage:	substantial; undercarriage, right engine and propeller, flaps
Pilot's licence:	commercial pilot licence (aeroplane)
Pilot's age:	55
Pilot's total flying experience:	4200 hours about 500 hours on PA31 type
Investigator-in-charge:	J J Goddard

[1] All times in this report are New Zealand Standard Time (Co-ordinated universal time + 12 hours)

1 Factual Information

1.1 History of the flight

1.1.1 On Monday 24 June 2002, the pilot of ZK-NPR was conducting an early-morning freight flight from Palmerston North to Napier, the operator's home base. He had flown the aircraft to Palmerston North on the evening of Friday 21 June, where it had remained until this flight. He drove home to Napier on Saturday morning, then back to Palmerston North on Sunday afternoon, where he refuelled the aircraft, to give an endurance of 4 hours, in preparation for the flight on the following morning.

1.1.2 The pilot started duty at 0430 on the Monday morning, completing a pre-flight inspection of the aircraft, and loading 167 kg of freight for the flight to Napier. He found nothing abnormal about the aircraft, subsequently reporting that the undercarriage strut extensions were all normal, at about 10 cm.

1.1.3 ZK-NPR departed from Palmerston North aerodrome just after 0500, and after a normal take-off was flown to Napier at 8 000 feet, with the pilot reporting appreciable turbulence crossing the mountain range. The aircraft arrived over Napier at about 0530, where the pilot elected to make a visual approach for runway 34. Napier Aerodrome was unattended by air traffic control or fire services at that time. After turning onto final approach he selected the undercarriage down. The undercarriage indicator illuminated 2 green lights only, instead of the normal 3 green lights; with the red "gear unsafe" light remaining on.

1.1.4 The pilot continued the approach to the runway, where he made a touch-and-go landing, to check the undercarriage in contact with the tarmac. He discovered that his right wing dropped further than normal, so he climbed the aircraft away, retracting the undercarriage normally.

1.1.5 The pilot then contacted a second company pilot by radio, and asked him to inspect the undercarriage from the ground while ZK-NPR was flown low over the runway. After this was done, the second pilot reported to him that the right undercarriage door was down, but the undercarriage itself was not extended.

1.1.6 Shortly after this, the Napier Airport fire service came on watch, so the same exercise was repeated, with better ground illumination. This confirmed the previous report, of no right undercarriage extension.

1.1.7 The pilot flew the aircraft out to hold to the east of Napier, to await daylight, and where he completed the abnormal undercarriage procedures from the aircraft flight manual, without success. He also contacted his maintenance engineer in Napier, who consulted the Piper Navajo service manual in order to advise how to rectify the problem. The engineer concluded that the uplock mechanism would be holding the undercarriage up, and suggested trying to lower the undercarriage during a "negative-g" manoeuvre. This was tried, again without success.

1.1.8 During the 90 minutes spent holding before daylight, the pilot tried cycling the undercarriage up and down, during "negative-g" and "positive-g" manoeuvres, and while rocking the aircraft wings. He also tried lowering the undercarriage with the hand pump. No attempt was successful in releasing the right undercarriage.

1.1.9 When Napier Tower (air traffic control) came on watch shortly before 0700, the pilot advised them of the undercarriage problem, and that he would wait until daylight before landing at Napier. Because the surface wind was 250° at 10 knots, he elected to land on the grass along the southern side of sealed runway 25. After an approach and low run over the selected area, he landed ZK-NPR with the left main and nose undercarriage extended. He was able to keep the aircraft straight, and the right wing held up, until at low speed on the landing roll. The right wing then dropped and the aircraft slewed right through almost 180° before stopping on the western part of runway 25, which had a grass surface.

1.1.10 The right engine had stopped when its propeller touched the ground, but the left engine continued to run. The pilot completed shutdown procedures, and then vacated the aircraft through the crew door.

1.1.11 The Napier Aerodrome rescue fire service was on standby for the landing, and attended the aircraft promptly after it came to rest. No fire intervention or rescue action was required.

1.1.12 The aircraft was subsequently jacked up, and the right undercarriage lowered manually before it was towed to the hangar.

1.2 Personnel information

1.2.1 The pilot of ZK-NPR held Commercial Pilot Licence (Aeroplane), number 14884, issued in January 1981. His associated Class 1 medical certificate was valid to 21 December 2002. He held an Instrument Rating and a "C" category Instructor Rating. His aircraft type ratings included the PA31 type. He had flown 4200 hours, of which about 500 hours were on the PA31 Navajo type.

1.2.2 The pilot was also the chief executive, operations manager and maintenance controller of Air Napier Limited.

1.3 Aircraft information

1.3.1 ZK-NPR was a Piper PA31-310 Navajo, serial number 31-777, twin-engine aeroplane, manufactured in the United States in 1972. It was imported into New Zealand in 1993, and registered as ZK-DOM. It was re-registered as ZK-NPR in February 2000. At the time of this accident it had flown 7878 hours.

1.3.2 The Piper PA31 type has a retractable tricycle undercarriage, which incorporates normal oleo (air/oil) suspension struts. The retraction and extension is operated by a hydraulic system which is pressurized by engine-driven pumps. The main undercarriage legs retract inboard into each wing, where they are enclosed by doors. When the legs are retracted, they are suspended in a horizontal position by mechanical uplock hooks. When the undercarriage is selected down, hydraulic pressure is first applied to the inboard doors to open them, and then pressure is applied to the undercarriage actuators. The first movement of the actuator rotates the uplock hook back to release the leg, which is then free to extend. Full actuator travel completes the extension, and locks the leg in the down position. Three green lights on the instrument panel indicate normal extension, while one red light indicates when any leg is not locked in an up or down position. No lights indicate when the undercarriage is retracted.

1.3.3 A review of the aircraft records indicated that all routine and normal maintenance had been completed in accordance with the Operator's Maintenance Manual. The only outstanding Airworthiness Directive was scheduled to be completed on the day of the accident. The last routine inspection, an Event 3, was completed on 8 June 2002.

1.3.4 The undercarriage of ZK-NPR had no history of operational problems, except for one inboard door, which had opened slowly when the aircraft was parked overnight. This was rectified by a repair to the lock mechanism in the door hydraulic ram. The oleo struts had not required additional servicing, for re-inflation or additional fluid, between routine maintenance. The pilot habitually wiped clean the exposed oleo strut pistons during his pre-flight inspections, and advised that no significant oil leakage was found.

1.3.5 ZK-NPR was carrying 167 kg of freight distributed between the nose locker and the rear cabin area. This gave a take-off weight of 2667 kg, and an approximate landing weight of 2450 kg, with the centre of gravity within prescribed limits. The maximum permitted landing weight was 2948 kg.

1.4 Aircraft examination

1.4.1 The aircraft was examined in the Napier maintenance hangar, to where it had been recovered after the accident. Minor damage was evident to the right propeller, inboard undercarriage door, wing tip, and flap. The right oleo strut was compressed flat when the aircraft was supported on its wheels; the left and nose oleo struts were normally extended. (see figures 2 and 3) When the aircraft was jacked up, the right wheel assembly could be lifted easily, indicating that no pressure remained in the oleo strut. No fluid leaks were evident around the right undercarriage, except for the inboard door ram, which had a broken hydraulic fitting consistent with the damage incurred by the door on landing.

Figure 2
Right undercarriage, showing flat oleo strut

Figure 3
Right undercarriage, oleo strut extended

1.4.2 Detailed examination of the right undercarriage components showed no obvious discrepancy. The uplock hook was free to move against its spring, and its hook surface was not worn out of shape, while the engaging roller on the lower leg was free to rotate. The hydraulic actuator and all associated moving parts appeared to be in good condition, free to rotate and without obvious wear.

1.4.3 Two frames within the wing wheel bay showed fresh marks and minor damage. Matching witness marks (see figures 4 and 5) were found on the upper scissor-link (connecting the upper and lower leg parts to allow strut suspension movement while preventing rotation), and on the lower leg casting. When the undercarriage was subsequently retracted, it was evident that these marked components came into contact while the undercarriage was supported by the uplock hook, and the oleo strut was compressed by 2-3 cm, the maximum movement allowed by the hook against its spring.

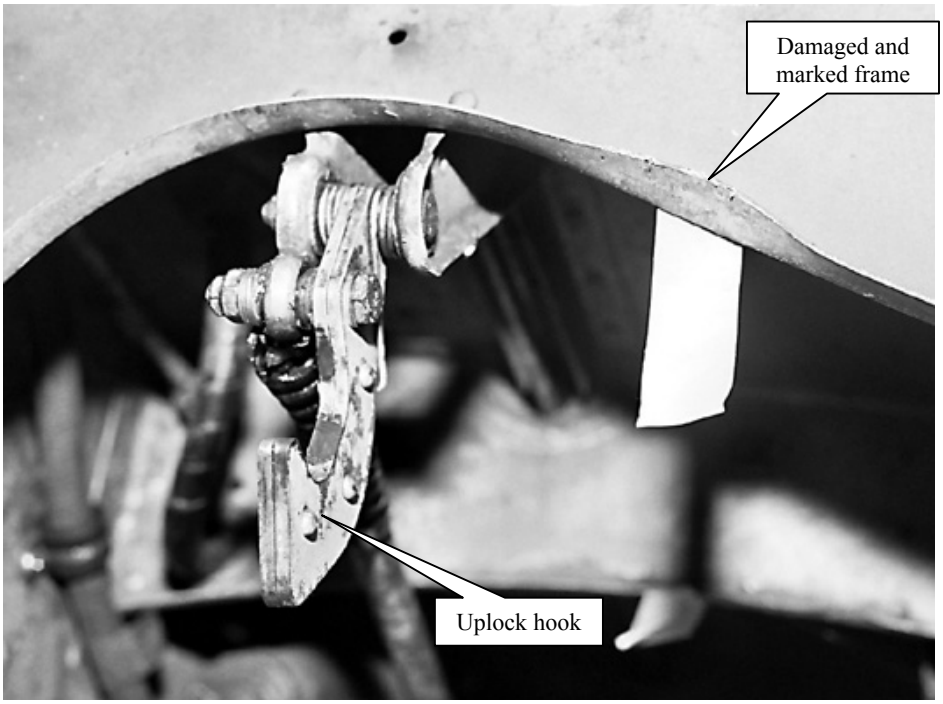


Figure 4
Right wheel bay, showing uplock hook, damaged frame and marks from lower leg

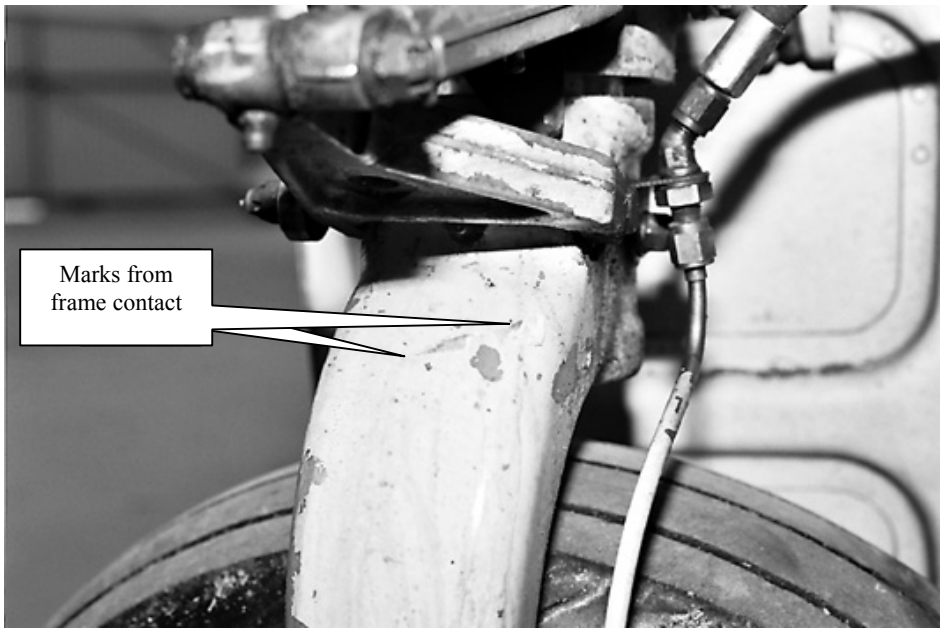


Figure 5
Right lower leg, showing matching marks from frame contact

1.4.4 After capping the damaged hydraulic fitting on the right inboard door, the undercarriage was retracted and extended. This occurred normally and without difficulty, with all normal indications on the instrument panel lights. The right undercarriage doors were disabled, so that the function of the mechanism could be observed. The right leg, with its depressurised oleo strut at full extension under gravity, engaged its roller normally with the uplock hook to achieve normal and complete retraction. Similarly, the uplock hook released the roller at the start of the extension cycle, to allow normal extension. All components moved freely and engaged correctly.

1.4.5 While the right undercarriage was retracted, and suspended on the uplock hook, the oleo strut was compressed by hand to the extent allowed by the movement of the hook against its spring. (see figures 6 and 7) This strut compression was easily accomplished, and brought the matching witness marks together within the wheel bay. With the strut so compressed, the undercarriage was selected down to no avail. The left and nose legs extended normally, but the right leg could not be released by the uplock hook, since all the hook travel had already been taken up by the compressed strut. When the oleo strut was decompressed by hand to its normal position, the right leg could again be extended normally.

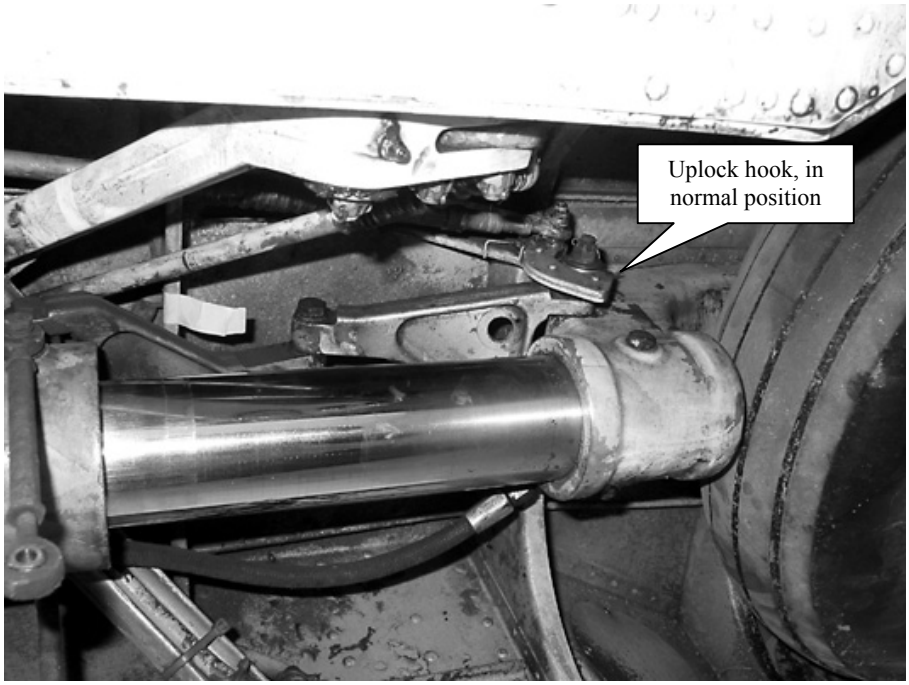


Figure 6
Right undercarriage retracted, on uplock hook – oleo strut normally extended

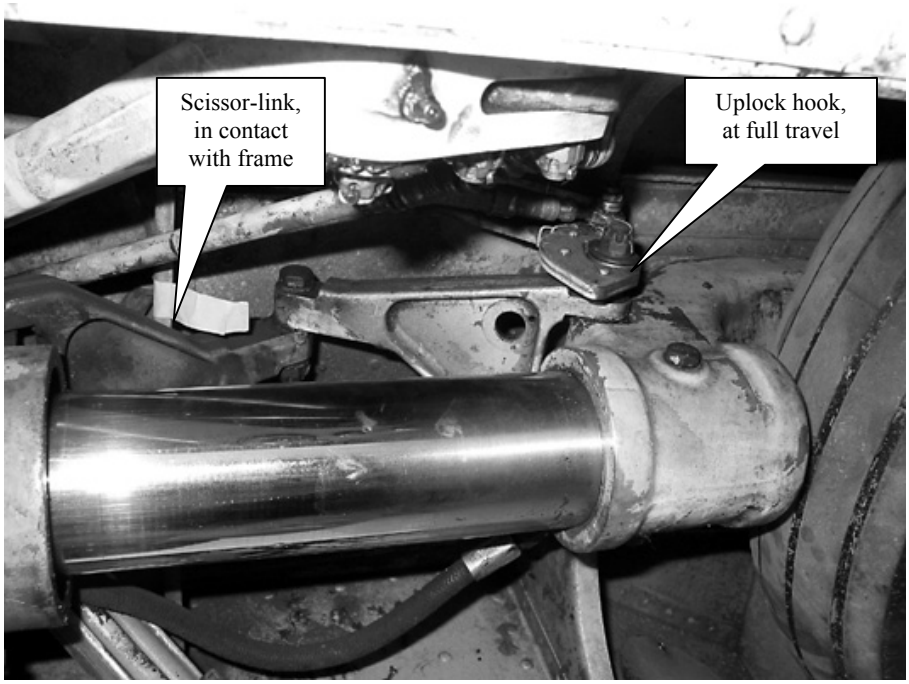


Figure 7
Right undercarriage retracted, on uplock hook – oleo strut compressed

1.4.6 The right undercarriage leg was removed for examination. It was first re-pressurised, and was found to hold pressure normally. Internal examination of the oleo strut generally showed components to be in good condition, but the O-ring seal in the lower bearing had rolled over within its groove, and was probably the cause of the loss of pressure of the strut. 820 millilitres of oil was drained from the strut, whereas subsequent refilling, on return to service, took 1.6 litres of oil.

1.4.7 The left and nose legs were also disassembled for inspection, before return to service. The left oleo strut was also found to have a rolled O-ring, but which had not caused any problem with deflation or leakage.

1.5 Other information

1.5.1 A search was made of accident and incident databases in the USA, the UK and New Zealand, for similar occurrences involving a PA31 undercarriage failing to extend. Although a number of such events had been reported with a variety of causes attributed, none had previously identified a flat oleo strut as a factor in the failure to extend.

1.5.2 The PA31 type first flew in 1962, and several thousand aircraft, including later variants, have since been in service worldwide, mostly in commuter airline or charter operations.

1.5.3 The PA31T and PA42 types, variants of the PA31, use a similar undercarriage design.

1.5.4 The New Piper Aircraft Incorporated, the present holder of the PA31 type certificate, advised that the flat strut case was not analysed or tested during the original certification of the landing gear retraction system.

1.5.5 The airworthiness standards specified in the present US Federal Aviation Regulations, and the previous Civil Air Regulations (in force when the PA31 was certificated), did not specifically require the flat strut case to be considered in the design or certification of landing gear retraction systems.

2 Analysis

2.1 The pilot's decision to land the aircraft on its left and nose undercarriage, rather than on its belly, appears to have directly minimised the damage incurred by the landing. In addition, his choice of an area which allowed a landing into wind, and the light weight of the aircraft, both enabled a landing at minimum ground speed. The alternative of landing on the sealed runway 25, rather than his choice of landing on the grass alongside, which was firm and dry, probably offered neither advantage nor disadvantage in the circumstances. A sealed runway surface would be preferable for an abnormal landing if the aircraft configuration were such that it might plough into the surface.

2.2 The first action taken by the pilot, after getting a "gear unsafe" indication on the first approach to land, was probably not best practice in the circumstances. He established that the right undercarriage was not extended by first doing a touch-and-go landing, which, especially with reduced visual cues at night, could have led to an unintended ground contact. However, he did achieve his object.

2.3 The pilot's following actions were reasonable. He next called for ground assistance to visually confirm the problem. Seeking advice from his maintenance engineer was prudent, since time was available to consider options and courses of action. The advice given was good, but in the circumstances, without the subsequent knowledge of the cause of the undercarriage failure to extend, there was probably nothing further he or the engineer could have done to resolve the problem. The decision to await daylight was made possible by the aircraft's fuel endurance, and

was prudent because it enabled the landing into wind; a night landing would have needed runway 34 which, unlike runway 25, was equipped with runway lights.

2.4 Subsequent examination of the aircraft showed nothing amiss with the right undercarriage, except that the oleo strut had lost its pressure. This had occurred at some stage during the flight, because the pilot had found it normally inflated during his pre-flight inspection. It was unlikely that he could have found out about the flat oleo strut because the take-off was normal, and the undercarriage retracted without incident. Even if he had known about the flat oleo strut, it would have been unlikely to alter subsequent events and actions taken, since a flat oleo strut was not known as a potential cause of an undercarriage malfunction.

2.5 The matching witness marks within the right wing wheel bay and on the right undercarriage leg clearly showed that the oleo strut, while supported by the uplock hook, had become compressed during the flight. Normally, the pressure in the oleo strut would hold it out at full length. The subsequent tests, which replicated the compressed strut condition, showed that this occurrence defeated the ability of the uplock hook to release the leg during the undercarriage extension cycle, unless the strut could be returned to its normal full length.

2.6 The mechanism which caused the deflated strut to become compressed was not discovered, but once it had lost its pressure, little force was required to compress the strut while it was suspended horizontally by the hook. Several possibilities could have contributed:

- The turbulence reported on the flight, especially if it caused the aircraft to adopt a yawing or rolling motion, might have produced an outboard force on the wheel and lower leg, tending to compress the strut.
- The action of the uplock hook, at the start of the extension cycle, is to move back in the direction of compressing the strut. The strut pressure normally reacts against this movement, allowing the hook to release the leg. With no internal pressure, the strut might have become compressed instead.
- Tests showed that the strut had resealed, and was able to hold pressure normally afterwards. If the strut had lost pressure during the flight at 8 000 feet, to reach the outside air pressure at that altitude, and had then resealed before or during the descent – perhaps as a result of internal fluid movement – it could have developed a small negative pressure at low altitude which would tend to compress the strut. Such a hypothetical pressure could develop a compression force of up to about 180 newtons (40 pounds).

2.7 This ability of a flat and partially compressed oleo strut on the PA31 to defeat the release of the uplock hook had evidently not been identified before, as shown by the reported occurrences of undercarriages failing to extend which were found in the databases searched. Although a number of failure-to-extend events had occurred, a variety of other causes had been attributed in each case. It may be that a flat strut has not previously been implicated, but it is also clear that the idea of a flat strut having this effect has not been part of the conventional wisdom held by aircraft manufacturers, operators, maintainers, or certification authorities. A possible result of this lack of expectation about flat struts is that the cause of some previous mishaps could have been misidentified as some other mechanical defect.

2.8 Because of this lack of knowledge about the possible effect of flat struts on the PA31 undercarriage, it is considered that the topic should be given wide publicity, to achieve the following results:

- To alert operators and pilots to the possible result of flying a PA31 aircraft with a flat oleo strut, and if such action is necessary, to avoid retracting the undercarriage.
- To enable any future investigation of a PA31 undercarriage failure-to-extend occurrence to consider the flat-strut scenario. This may improve reporting, and establish whether it is a sufficiently common problem to require resolution by an aircraft modification.

2.9 While the airworthiness standards specified in US Federal Aviation Regulations did not specifically address the flat strut case in undercarriage design, the general desirability of considering such an event, as shown by this occurrence, is evident. This will probably be best accomplished by wide publicity of this topic reaching designers and airworthiness authorities.

2.10 After nearly 40 years in operation, involving several thousand PA31 aircraft, it appears that this occurrence is the first time that a flat oleo strut has been identified as a major factor in an undercarriage failure-to-extend occurrence. Because of the low risk which this one failure represents, it may not be appropriate at present to advocate the design of a modification to the aircraft type to prevent its recurrence. Any further similar event, however, would pose a strong argument for modification action. A simple modification might, for example, comprise a fixed stop mounted in the wheel well above the scissor-link, to prevent the upward articulation which would accompany any compression of the oleo strut. A more elegant modification might involve the redesign of the uplock hook, so that it either operated on the upper part of the leg which was not subject to compression, or alternatively operated in the opposite direction, against the compression of the strut.

2.11 Internal examination of the oleo strut involved showed that the probable cause of the pressure loss was the O-ring seal in the lower bearing rolling over within its groove. This was not uncommon, but was obviously undesirable. It was possible that the low oil level contributed to the O-ring rollover, by allowing it to become dry. However, the aircraft had received normal maintenance in accordance with prescribed procedures, and the undercarriage had not required additional servicing which might have prompted attention to the oil level. The left main oleo strut, which had not deflated, and was apparently serviceable to an external inspection, was also found to have a rolled O-ring.

2.12 While ZK-NPR had been normally maintained, it may be prudent for maintenance personnel to consider whether their particular operation of PA31 aircraft might warrant additional routine servicing of undercarriage oleo struts, to guard against the possible effects of low oil levels.

2.13 Further consideration of the hypothesis, whereby the oleo strut in this case could have developed a negative pressure by resealing itself at cruise altitude and then becoming compressed at low altitude, produces advice for a PA31 pilot trying to overcome a similar undercarriage hang-up problem. This is to climb the aircraft back to cruise altitude or higher, where any negative internal pressure in the oleo strut would be cancelled, before again attempting to lower the undercarriage.

3 Findings

3.1 The pilot was appropriately licensed and experienced for the flight.

3.2 The flight was being conducted in a normal and routine way.

3.3 After the right undercarriage failed to extend, the pilot's actions were successful in minimizing damage on landing.

3.4 The failure of the right undercarriage resulted from the oleo strut losing pressure and becoming compressed, defeating the release mechanism.

3.5 The aircraft had been properly maintained, and was serviceable before departure on this flight.

3.6 The aircraft design had not considered the particular circumstances leading to this undercarriage failure.

3.7 This deficiency in the PA31 undercarriage design had not previously been identified.

3.8 No other undercarriage failure had been attributed to this cause, over a large operational history of the PA31 type.

4 Safety Recommendations

4.1 On 31 January 2003 the Commission recommended to the Director of Civil Aviation that he:

4.1.1 Publish widely, including to foreign Civil Aviation Authorities where the PA31 type is operated, advisory material about the cause of this undercarriage failure-to-extend accident, to alert operators and pilots to a previously unknown deficiency, and to assist any future investigation of a similar occurrence. (058/02)

4.2 On 19 December 2002 the Civil Aviation Authority advised in response to the preliminary recommendation:

> The Director is likely to accept the recommendation as worded. An abstract of the TAIC report will be published in Vector. In addition, we feel the most practical means of distributing advisory material would be to forward copies of the final TAIC report to affected Regulatory Authorities.

Approved for publication 29 January 2003

Hon. W P Jeffries
Chief Commissioner

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95-008 Addendum to Report 95-008, Piper PA 28-161, ZK-MBI, missing after departing from Gisborne, 21 May 1995

01-007 P-68B Partenavia ZK-DMA, double engine power loss, North Shore Aerodrome, 20 July 2001

01-005 Bell UH-1H Iroquois ZK-HJH, tail rotor failure and in-flight break-up, Taumarunui, 4 June 2001

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