ACCIDENT

Aircraft Type and Registration:	Piper PA-34-200T Seneca II, G-BNEN
No & Type of Engines:	2 Teledyne Continental TSIO-360-EB piston engines
Category:	1.3
Year of Manufacture:	1980
Date & Time (UTC):	22 February 2003 at 1230 hrs
Location:	White Waltham Airfield, Berkshire
Type of Flight:	Public Transport (Passenger)
Persons on Board:	Crew - 1 Passengers - 1
Injuries:	Crew - None Passengers - None
Nature of Damage:	Nose landing gear collapsed, damage to underside of nose, nose gear doors and engine cowlings, all propeller blades bent and engines shock loaded
Commander's Licence:	Commercial Pilot's Licence
Commander's Age:	36 years
Commander's Flying Experience:	1,300 hours (of which 800 were on type) Last 90 days - 125 hours Last 28 days - 40 hours
Information Source:	AAIB Field Investigation

Synopsis

During takeoff, the nose landing gear collapsed and the pilot was unable to prevent the propellers and nose of the aircraft from striking the runway. Investigation showed that the upper eye end of the Sprung downlock link had failed and that there was considerable wear in the upper and centre pivots of the drag brace.

The geometric downlock mechanism had recently been adjusted to correct an inability of the nose landing gear to free fall. There was no procedure available in the aircraft maintenance manual for correcting an inability to lower the landing gear by free fall.

Two new safety recommendations are made and reference is made to three earlier recommendations.

Account of the accident

The aircraft was being used for a passenger flight from White Waltham to Cambridge. After start-up the aircraft was taxied to the holding point where the pilot completed the pre-takeoff vital checks and waited for another aircraft to land. After this aircraft had landed, G-BNEN was lined up on the grass runway and, when the landing aircraft had cleared the runway, the take-off run was initiated. The aircraft accelerated normally to

about 50 kt when the nose began to drop. The pilot was unable to stop the nose-down pitching with elevator and he realised that the nose landing gear had retracted. Although he then closed the throttles, both propellers had already struck the runway. The aircraft slid to a halt supported on the main landing gear and the undersides of the nose and the engine cowlings. The pilot remarked that he had heard no unusual noises during the take-off run before the nose had started to pitch down.

Recovery and examination of the aircraft

The aircraft was towed from the runway after lifting its nose, pulling the nose landing gear down and bracing its drag strut in the over-centre condition. Preliminary inspection, in the maintenance area, revealed that both blades of both propellers had suffered severe damage and that the forward undersides of both engine nacelles had been abraded by contact with the runway. The nose landing gear doors and the underside of the nose fairing back to the front bulkhead of the main cabin structure were also badly damaged and the forward cabin had been distorted, resulting in side and upper skin wrinkling forward of the windscreen. Initial inspection of the nose landing gear mechanism revealed that the threaded stem of the upper eye-end of the downlock link had bent and fractured.

After the aircraft had been placed on jacks and the downlock link removed, the nose landing gear was checked for freedom of movement. The drag link was found to articulate freely but it was also noted that considerable lateral play could be induced at the centre joint. The failure of the downlock link eye-end precluded any determination of the downlock adjustment before the accident. The drag link assembly was removed for more detailed examination. Inspection of the downlock link revealed that, in addition to the failure of the upper eye-end, the slot in the link had been crushed and distorted by the cross-pin at its upper end. This indicated that it had experienced a high compressive load. The crushing distortion was measured to be approximately 0.02 inch.

Inspection of the drag link after its removal from the aircraft showed that there was considerable wear in the upper and centre pivot joints ('A' & 'C'on Figure 1, next page) but the lower joint ('B' on Figure 1) of the lower link exhibited very little wear. Before dismantling the assembly, the 'over-centre' dimension of the drag link assembly was measured to be 0.310 inch which was greater than the specified minimum.

The upper joint, attaching the link to the landing gear leg, was the most severely worn. Measurement of the individual components showed that the bolt itself was unworn and dimensionally correct. The steel sleeve (Part No 9061-29) which runs in the upper link bush was found to have no significant wear on its outer suface. However, the bore of this sleeve, for which wear limits are given in the Aircraft Maintenance Manual (AMM), had been worn bell-mouthed at both ends. Although at its mid-point the bush bore was measured as 0.001 inch smaller than the lower limit given, resulting in a bolt clearance of only 0.003 inch on the measured bolt diameter, at the ends the clearance was 0.006 to 0.007 inch; the greatest wear being 0.001 inch above the maximum limit. The inside diameter of the bronze bush at the upper end of the upper drag link, within which the steel sleeve worked was also measured and also found to be bell-mouthed. There were no established wear limits for this bronze bush at the time of this accident. In the bore of this bush it was found that the wear was oval and more severe along the axis of the link. Similarly to the steel sleeve, the bore of the bronze bush also was very little worn near the middle of the bush and most worn on the left side which had been adjacent to the landing

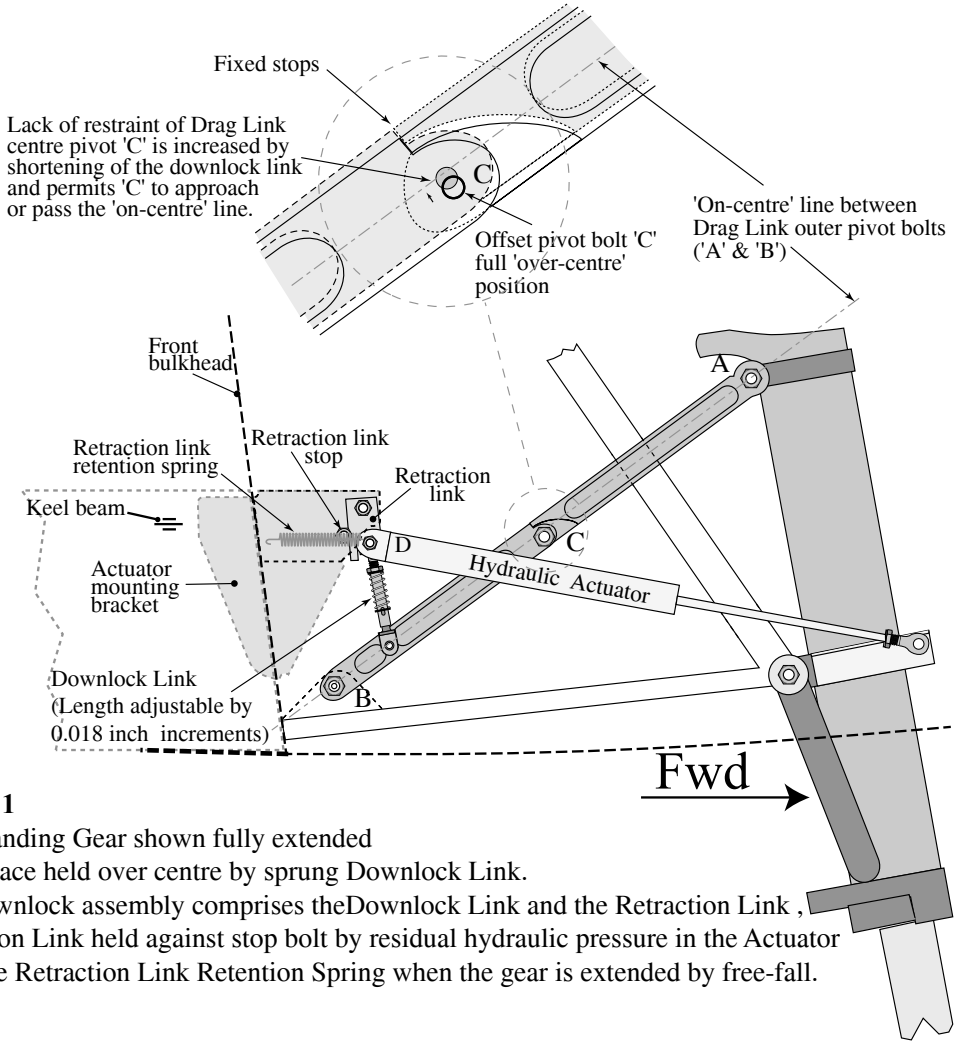

Figure 1
Nose Landing Gear shown fully extended
Drag Brace held over centre by sprung Downlock Link.
The Downlock assembly comprises theDownlock Link and the Retraction Link ,
Retraction Link held against stop bolt by residual hydraulic pressure in the Actuator or by the Retraction Link Retention Spring when the gear is extended by free-fall.

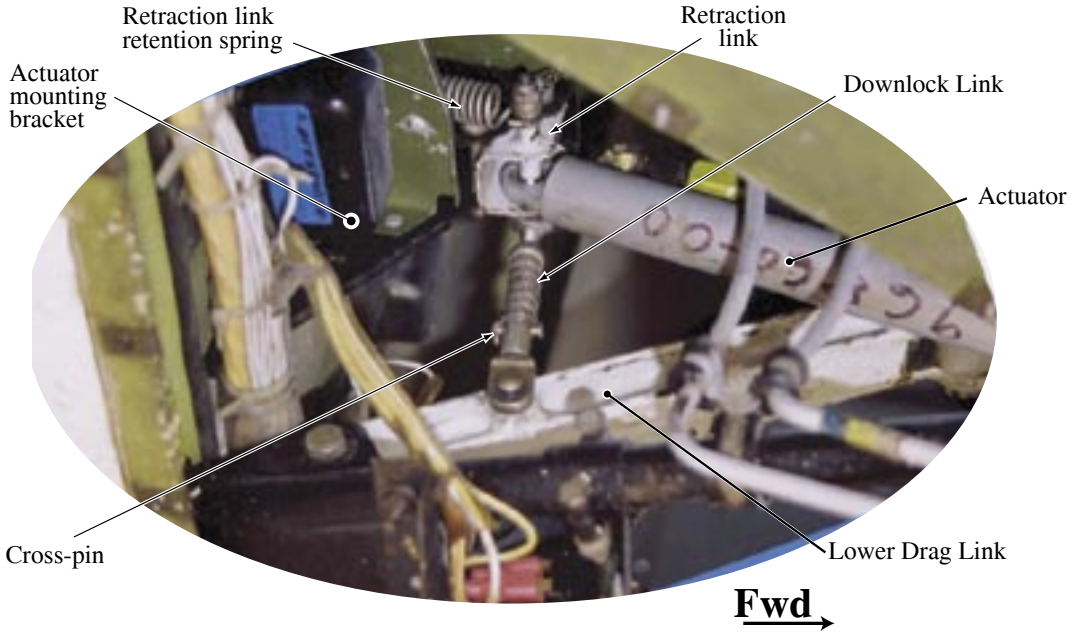

Figure 1a
PA-34 nose landing gear - view from below and right side showing lateral stagger of downlock linkage components.

gear leg when installed in the aircraft. If the minimum measured internal diameter of the bronze bush was taken as nominal, the maximum wear was 0.012 inch with an ovality of 0.008 inch. (See Figure 2, right, for typical bush wear shape.)

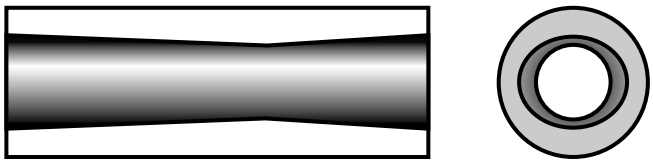

Figure 2

Section through bushes at 'A' and 'C' conical and oval wear

At the centre joint, the paired outer lugs of the lower drag link are not bushed because the pivot bolt should not turn relative to the lower link whilst the joint is articulating; neither lug was found to have measurable wear. However, the bronze bush of the single lug of the upper link element of this joint was moderately worn. The wear pattern on this bush was similar to that of the upper joint but in this case the wear was predominantly on the left side with the same tendency to be more severe in the link axial direction than across it. The bore on the right hand side of the bush was near circular and close to nominal size.

Recent aircraft utilisation and history of maintenance on its nose landing gear

The aircraft was in regular use for charter work and had a consistent utilisation of about 50 hours per month in the period running up to this accident. It had, on six occasions in the very recent past, landed and taken off using the grass runway of White Waltham Airfield without incident. All regular maintenance work had been conducted by the same company for some time and, consequently, they were familiar with this aircraft. At the time of this accident it had flown for a total of approximately 6,950 hours.

There is an FAA Airworthiness Directive (FAA AD 93-24-12) which requires the nose landing gear upper drag link forward pivot bolt to be renewed at 500 flight hour intervals. In October 2002, whilst carrying out a 50 hour check about 200 flight hours before the accident, the maintenance organisation complied with this Directive. Whilst doing so it was observed that there appeared to be some free play at the drag link centre stops. The assembly was removed, cleaned and the 'overcentre' measurement checked and found to be correct. It was then refitted and the downlock link extended slightly to correct its adjustment. Subsequent retraction and extension tests were satisfactory. Additionally, at the next 150 hour check, about two months later, both normal and emergency (free-fall) extension tests were performed satisfactorily.

On 12 February 2003, the operator's Chief Pilot, whilst familiarising a newly recruited pilot with the aircraft, observed that a 'down and locked' indication was not obtained for the nose gear when he demonstrated the emergency lowering of the landing gear, although both main gear indications were obtained. However, when he recycled the landing gear normally with the hydraulics, all three gears indicated 'down and locked'. This fault was reported verbally to the maintenance organisation and it was arranged that it would be addressed at the next 50 hour maintenance check which was due about a week later.

At the 50 hour check the fault in the emergency lowering of the nose landing gear was confirmed. It appeared that the downlock link was slightly too long to allow the retraction spring to pull the retraction link onto the downlock stop (see Figures 1 & 3). After lubrication of the downlock mechanism, the link was shortened by a small amount

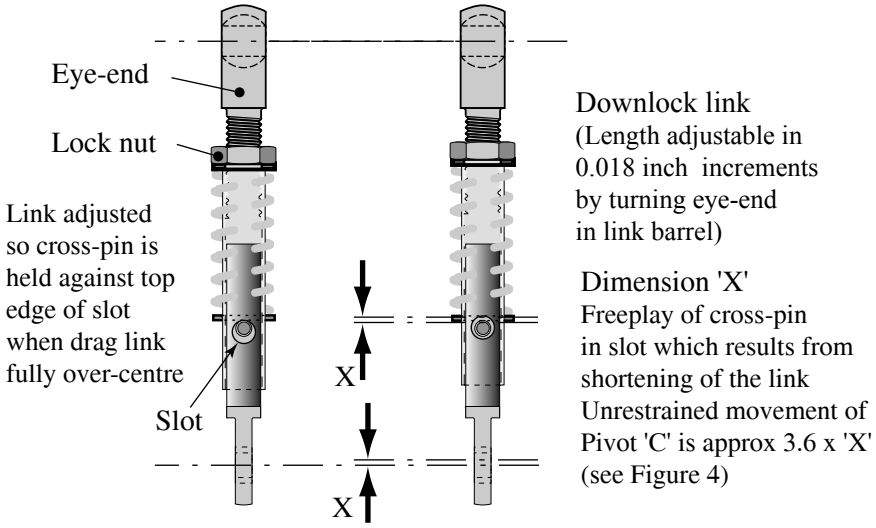

Figure 3

Downlock link, details
Relationship of cross-pin to slot and adjustment of eye-end

and the nose gear would then free-fall to the locked position. The free play at the drag link centre stops was not considered to be excessive after this adjustment and the general condition of the gear mechanism was assessed as normal. Following this maintenance the aircraft had taken off twice from a hard runway and landed once on the hard runway and the second time on grass. It was during the subsequent takeoff from the grass runway that the nose landing gear collapsed.

Analysis (refer to Figures 1, 3 and 4)

The instructions for rigging the downlock link state that after having set its length, initially, to hold the drag link at its maximum 'overcentre' position, the final step calls for it to be shortened by one half-turn of the eye end (0.018 inch). Consideration of the geometry of the lock and link mechanism indicates that every half-turn shortening adjustment of the length of the downlock link permits about 0.065 inch of unrestrained movement of the centre joint of the drag link towards the 'on centre' position by allowing movement of the pin in the downlock link slot (Dimension 'X'). Since it is only possible to adjust the link length by increments of half a turn, it is possible for the unrestrained movement to approach twice this value and for the lock to be correctly rigged in accordance with the setting-up procedure in the AMM. Any subsequent shortening (necessarily by half-turn steps) would relax the restrained 'overcentre' state of the drag link a further 0.065 inch.

The occurrence of the nose landing gear collapse so soon after an adjustment had been made to the length of the downlock link strongly suggests a connection between the two events. Whilst there is no doubt that shortening the downlock link would have made it easier for the retraction spring to draw the downlock linkage into the position required to hold the retraction link against its stop, it would reduce the distance by which the drag link was forced 'overcentre'. This solution to the problem of the failure of the gear to 'free-fall' into the locked position is not proposed in the AMM. Moreover, neither the normal adjustment instructions nor the 'Troubleshooting' table in the AMM appear to give any guidance on what to do in this eventuality.

Consideration of the way in which the lock mechanism works during 'free-fall' extensions indicates that the hydraulic actuator acts, to some extent, as a damper against violent deployment and that the downlock spring draws the retraction link fully up to its stop. When the nose landing gear is extended but the aircraft's weight is not on the wheel, the weight of the forward raked strut tends to pull the drag link straight (ie off its full overcentre stop), against the gravitational pull on the drag link assembly itself which is tending to drive it

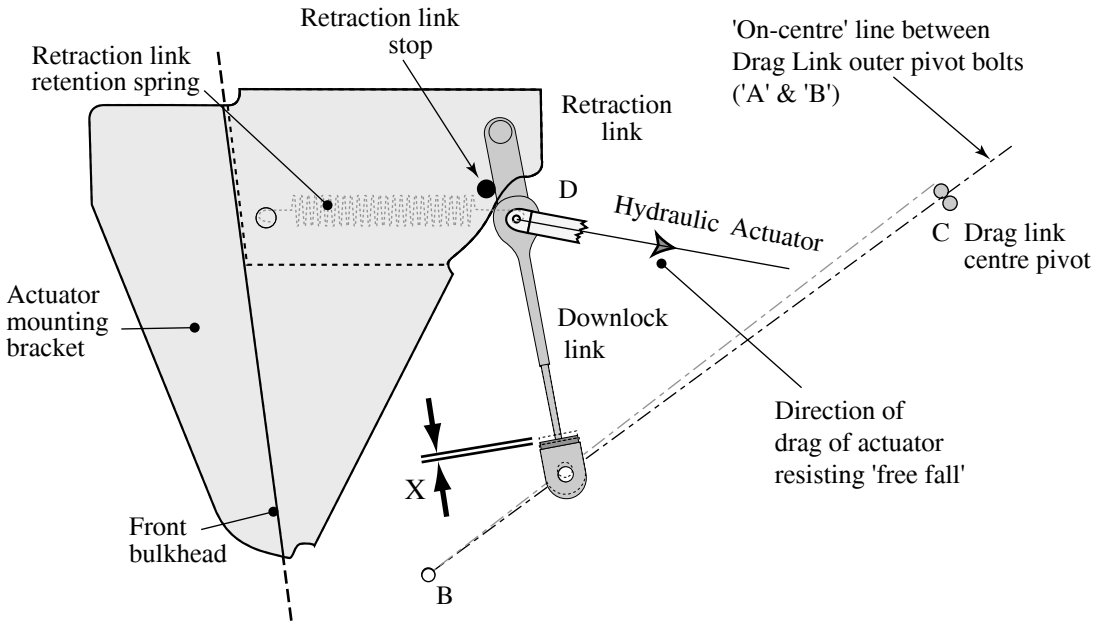

Figure 4

Schematic diagram of locking linkage
showing effect of free play in Downlock Link on restraint at pivot 'C'

to full 'overcentre'. Thus the action of the downlock spring, whilst pulling the retraction link onto its stop, has to overcome any resistance in the (unpowered) actuator, friction in the linkages and the force resulting from the weight of the strut, augmented by any aerodynamic drag loads on the extended gear. These latter two factors will be greater on drag link assemblies with larger 'over-centre' measurements.

From the above it would appear that the most likely prime reason for the failure of the nose landing gear to extend fully and lock, when extended by 'free-fall' in flight, was the insufficient strength of the retraction spring to overcome the combination of forces resisting it. No untensioned length, no minimum break-out force and no minimum force/extension relationship are specified for this spring. Judgement of its fitness to remain in service on strength grounds appears to be subjective.

Discussion

The AAIB has investigated a number of nose landing gear collapses on this aircraft type. Nearly all of these have involved the downlock link suffering either fracture or bending of the upper eye-end threaded portion and crushing/tearing damage to the link 'slot'. Those instances when the collapse has not resulted in the failure of the upper eye-end have characteristically involved damage to the actuator mount bracket and the structure surrounding its attachment to the fuselage front bulkhead and keel beam (as was the case in the preceding report in this Bulletin, concerning the collapse of the nose landing gear of G-BEJV). In all cases the damage has precluded accurate determination of the pre-failure adjustment of the downlock mechanism and, consequently, any quantifiable determination of maladjustment. Additionally, it is not possible to be certain that some crushing of the link 'slot' has not occurred as a result of 'hammering' in use; any such damage would result in increased freedom of the drag link centre joint.

Typically, all the damage has been of an overload nature with no evidence of progressive deterioration of strength. In all cases the loading which has led to the damage and subsequent collapse could only have arisen if the drag link had been in an 'under-centre' condition when weight came onto the nose wheel. A considerable proportion of the occurrences have happened soon after an adjustment or reassembly of the nose gear downlock mechanism. They have also occurred in mechanisms which have been in service for a considerable period without renewal of any of the drag link pivot bushes. None of those investigated by the AAIB has involved the failure or significant wear of the upper drag link pivot bolt which has to be changed, in accordance with an Airworthiness Directive, at 500 hour intervals.

In general, it would appear that several factors, either singly or in combination, can lead to reduced constraint of the free movement of the drag link centre pivot under dynamic loading, for it to be able to move to a vulnerable, 'undercentre' position. These are:

(a) Downlock link adjustment

If the link is adjusted too short, free movement of the crosspin in the slot will occur.

(b) Bush and pin wear

The resulting slack will allow increased movement in, and at right angles to, the plane of the mechanism.

(c) Structural flexibility

This may be exacerbated by degraded fastening of the actuator mounting bracket at the fuselage front bulkhead.

As a result, if weight comes onto the nose wheel when the landing gear mechanism is in this undercentre condition, the downlock link has to resist the forces tending to cause the landing gear to fold in the retracting sense, which it is insufficiently strong to do, unless there is any weakness in the attachment of the actuator mount bracket to the front bulkhead/keel beam structure, in which case the bracket and its mounting structure become severely disrupted.

Having occurred during the take-off run, this particular accident is of considerably greater concern than the more usual occurrence of nose landing gear collapse during the landing run. When on the ground, the PA-34 has a relatively small propeller tip clearance and the propellers are close to the longitudinal position of the nose wheel. Any collapse of the nose landing gear will most probably result in the propellers striking the runway.

In this instance, the collapse occurred at a speed when the pilot was not ready to take the aircraft into the air. If a collapse were to occur immediately before the pilot started to rotate, the danger would exist that a brief propeller strike on the runway might fracture a blade pitch control mechanism just as the aircraft became airborne, with unpredictable results. It should be noted that at take-off rpm, each propeller blade would strike the runway at a rate of 43 times per second, leading to a high potential for propeller disruption in a very short period of time.

Previous Recommendations

As a consequence of the investigations into several previous nose landing gear collapses on PA-34s, the AAIB has made three previous Safety Recommendations. These were:

Safety Recommendation 2000-45 (FAA 00-327). It is therefore recommended that the New Piper Aircraft Company should review and amplify the instructions for rigging the nose landing gear downlock mechanism contained in the Piper PA-34 Maintenance Manual.

Safety Recommendation 2000-46 (FAA 00-328). The FAA and the CAA, in conjunction with the New Piper Aircraft Company, should investigate the causes of reported cases of Piper Seneca nose landing gear collapse. Consideration should be given to design modification which should minimise movement of the drag brace resulting from loads applied to the nose landing gear, and to ensure sufficient force is applied to the drag brace to retain it in the locked condition.

Safety Recommendation 2004-07 (FAA 04-019). It is recommended that the Federal Aviation Administration, as the primary certificating authority for the Piper PA-34 Seneca aircraft series, should require the aircraft manufacturer to provide a clear and unambiguous description of the operation of the nose gear downlock spring link, its installation and its correct rigging by both narrative and pictorial means.

Safety action

In May 2003 the manufacturer produced a Service Bulletin (SB 1123) in response to a number of Accident Prevention Recommendations made by the US National Transportation Safety Board (NTSB), as well as the first two AAIB Recommendations mentioned above. This addressed the issues, in part, and was approved by the FAA.

In recognition of what were seen as deficiencies in SB1123, the Civil Aviation Authority, with the co-operation of AAIB, sent a letter in May 2004 to the manufacturers, which was copied to the FAA, detailing those parts of the Bulletin which were considered not to address the concerns sufficiently. In particular, with the exception of correcting the 'over-centre' dimension of the drag link for Seneca II aircraft, there was no clarification of the rigging procedure for the downlock mechanism.

Additionally, and as a result of the AAIB investigation of another PA-34 nose landing gear collapse, the AAIB made the third of the Recommendations mentioned above (2004-07). As a result, the aircraft manufacturer has issued Revision A of SB 1123, approved by the FAA in November 2004, which, in the main, addresses the concerns raised in AAIB Recommendations 2000-45 & 2004-07. It does not, however, fully address the concerns raised in the letter from the CAA to the manufacturer, nor does it fully meet the intent of Recommendation 2000-47.

These Service Bulletins had not been issued when the maintenance organisation last serviced and adjusted the nosegear downlock mechanism of G-BNEN.

Conclusions

A detailed description of the operation of the PA-34 nose landing gear can be found in the AAIB report on a previous incident (G-EXEC at Stapleford on 28 October 1999; see AAIB website). This description includes the susceptibility of the effectiveness of its downlock mechanism to misrigging, slack in the pivots and flexibility of the structure. Although SB 1123A specifies acceptable wear limits within the drag link pivot bushes, it does not indicate the likelihood that the internal wear of both the bushes and the steel sleeves will be conical, towards their axial centres, nor that it will probably be oval. These concerns, amongst others, were expressed in the letter from the CAA to the manufacturer.

This accident appears to have been triggered by the adjustment which was made in order to ensure that the nose landing gear would 'free-fall' to the locked down position. Although the mechanism appeared to operate satisfactorily in normal operation, its failure to extend by 'free-fall' had to be addressed. In the absence of any specific advice in the Maintenance Manual on how

to rectify this deficiency, or its most likely causes, the maintenance organisation made the only adjustment of the landing gear which was available to them, in accordance with the Manual. Although they considered that the condition and free play of the mechanism was 'normal' after this adjustment, in combination with the deflections induced in the local structure under dynamic loading was sufficient to allow the drag link to move to an 'under-centre' condition which the mechanism was not robust enough to resist.

Safety Recommendations

Since it is considered that the primary contributory factor to this accident was the lack of guidance in the Aircraft Maintenance Manual relating to ensuring correct 'free fall' extension of the nose landing gear it is recommended that:

Safety Recommendation 2005-106

The Federal Aviation Administration of the USA should ensure that the New Piper Aircraft Company includes, in the appropriate Maintenance Manuals, clear advice on the factors affecting 'free fall' extension of this landing gear and a more precise definition of an 'acceptable' nose landing gear 'Retraction Link Retention Spring'.

Although the Piper Service Bulletin 1123A improves the clarity of the instructions for rigging the nose landing gear, it is considered that some issues, which are identified in the CAA letter to Piper, and the issues of uneven wear in the bushes and sleeves, still need addressing. Furthermore, it is considered that the information contained in the Service Bulletin rightly belongs in the Maintenance Manual, thereby relieving maintenance engineers of the need to reconcile two documents. The intent to put the content of the Bulletin into the Manual at some future date is stated in the Bulletin. It is therefore recommended that:

Safety Recommendation 2005-107

The Federal Aviation Administration of the USA should ensure that the New Piper Aircraft Company reviews the content of Service Bulletin 1123A and expedites embodiment of the resulting instructions into the Maintenance Manual.