Air Accident Investigation Unit Ireland

SYNOPTIC REPORT

ACCIDENT
Piper PA-28R-180, G-FBWH
Sligo Airport

5 August 2018

An Roinn Iompair
Turasóireachta agus Spóirt
Department of Transport,
Tourism and Sport

Foreword

This safety investigation is exclusively of a technical nature and the Final Report reflects the determination of the AAIU regarding the circumstances of this occurrence and its probable and contributory causes.

In accordance with the provisions of Annex 13[1] to the Convention on International Civil Aviation, Regulation (EU) No 996/2010[2] and Statutory Instrument No. 460 of 2009[3], safety investigations are in no case concerned with apportioning blame or liability. They are independent of, separate from and without prejudice to any judicial or administrative proceedings to apportion blame or liability. The sole objective of this safety investigation and Final Report is the prevention of accidents and incidents.

Accordingly, it is inappropriate that AAIU Reports should be used to assign fault or blame or determine liability, since neither the safety investigation nor the reporting process has been undertaken for that purpose.

Extracts from this Report may be published providing that the source is acknowledged, the material is accurately reproduced and that it is not used in a derogatory or misleading context.

[1] **Annex 13**: International Civil Aviation Organization (ICAO), Annex 13, Aircraft Accident and Incident Investigation.
[2] **Regulation (EU) No 996/2010** of the European Parliament and of the Council of 20 October 2010 on the investigation and prevention of accidents and incidents in civil aviation.
[3] **Statutory Instrument (SI) No. 460 of 2009**: Air Navigation (Notification and Investigation of Accidents, Serious Incidents and Incidents) Regulations 2009.

AAIU Report No: 2020 - 007
State File No: IRL00918048
Report Format: Synoptic Report
Published: 5 May 2020

In accordance with Annex 13 to the Convention on International Civil Aviation, Regulation (EU) No 996/2010 and the provisions of SI No. 460 of 2009, the Chief Inspector of Air Accidents on 5 August 2018, appointed John Owens as the Investigator-in-Charge, assisted by Clive Byrne, Inspector of Air Accidents, to carry out an Investigation into this accident and prepare a Report.

Aircraft Type and Registration:	Piper, PA-28R-180, G-FBWH
No. and Type of Engines:	1 x Lycoming IO-360-B1E
Aircraft Serial Number:	28R-30368
Year of Manufacture:	1968
Date and Time (UTC)[4]:	5 August 2018 @ 12.18 hrs
Location:	Sligo Airport (EISG)
Type of Operation:	General Aviation
Persons on Board:	Crew - 1 Passengers - 1
Injuries:	Nil
Nature of Damage:	Minor
Commander's Licence:	Private Pilot Licence (PPL) Aeroplane (A), issued by the Irish Aviation Authority (IAA)
Commander's Age:	48 years
Commander's Flying Experience:	219 hours, of which 62 were on type
Notification Source:	Sligo Air Traffic Control (ATC)
Information Source:	AAIU Field Investigation AAIU Report Form submitted by the Pilot

[4] **UTC**: Co-ordinated Universal Time. All timings in this report are quoted in UTC; local time was UTC + 1 hour on the date of the accident.

SYNOPSIS

The Piper PA-28R-180 aircraft, with a Pilot and one passenger on board, landed on Runway (RWY) 29 at Sligo Airport (EISG). During the rollout, approximately 150 metres after touchdown, the aircraft experienced what the Pilot described as '*a strong bump*' which coincided with the right wing dropping slightly. The Pilot contacted air traffic control and was instructed to park the aircraft on the airport apron. It was subsequently discovered that the aircraft suffered a partial collapse of the right-hand main undercarriage. The occupants of the aircraft were uninjured. There was no fire.

NOTIFICATION

The AAIU was notified of this occurrence by the Sligo Air Traffic Control (ATC) Duty Officer.

1. FACTUAL INFORMATION

1.1 History of Flight

G-FBWH took off from Weston Airport (EIWT), Co. Dublin, on a cross-country flight to EISG. On departing EIWT, the Pilot (who was also the aircraft Owner) attempted to retract the landing gear, however, the '*gear in-transit*' light did not extinguish. The Pilot considered that it '*felt fully retracted*', but returned the aircraft to EIWT, lowered the landing gear, and completed a touch-and-go manoeuvre. Following this, the landing gear was retracted, all indications appeared normal and the flight proceeded to EISG.

The aircraft received clearance to land on RWY 29 in EISG, and as there was minimal traffic, the Pilot executed a long final approach and performed a normal landing. During rollout, approximately 150 metres (m) after touchdown, the aircraft experienced what the Pilot described as '*a strong bump*', which coincided with the right wing dropping slightly. The Pilot's initial belief was that the aircraft may have experienced a puncture; however, this was discounted as the aircraft was '*handling normally*'.

During the taxi to the airport apron, the Pilot observed a small hole in the right wing, which suggested that the '*bump*' experienced during the rollout was a partial collapse of the right-hand undercarriage. The Pilot contacted ATC, reported the issue and was advised by ATC to park the aircraft on the apron.

1.2 Aircraft Information

The aircraft, a Piper PA-28R-180 Cherokee Arrow was built in 1968 (**Photo No. 1**). It is an all metal, semi-monocoque structure, low-wing aircraft with four seats and is fitted with a 4-cylinder Lycoming IO-360-B1E engine. It has a retractable tricycle-type landing gear fitted, which is actuated via an electrically-powered reversible pump. Once airborne, the undercarriage, on command, retracts in approximately seven seconds into the left wing, right wing and nose section of the aircraft respectively.

At the time of the occurrence, the aircraft had accumulated a total flying time of 6,967.8 hours and was maintained using a self-declared maintenance programme by an IAA-approved EASA Maintenance Organisation[5]. The aircraft was operating under a Certificate of Airworthiness and its associated Airworthiness Review Certificate (ARC) was issued by an IAA-approved Continuing Airworthiness Management Organisation (CAMO) on 29 March 2018. The ARC was valid at the time of the occurrence.

Photo No. 1: G-FBWH. A Piper PA-28R 180 Cherokee Arrow (*Jeroen Stroes*)

1.3 Meteorological Information

The Pilot reported that weather conditions at EISG, at the time of the occurrence, were good. Visibility was over 10 km with an airfield temperature and dew point of 17°C and 11°C respectively. The wind was reported as 4 knots (kts) at 190 degrees magnetic.

1.4 Pilot Information

The Pilot held a valid PPL (A) issued by the IAA. At the time of the occurrence, the Pilot had 219 hours flying experience, of which 62 hours were on the occurrence type.

1.5 Airfield Information

EISG is located 5.5 nautical miles west of Sligo Town in the north-west of Ireland. It has one asphalt runway denoted 11-29 which is 1,200 m in length.

1.6 Damage to Aircraft

The right-hand main undercarriage assembly sustained considerable damage during the occurrence. The right-hand wing was punctured as a result of the top of the right-hand undercarriage shock strut coming through from beneath (**Photo No. 2**). The right-hand undercarriage door was damaged beyond repair and a significant amount of the associated undercarriage hardware was also damaged and required replacement.

[5] **EASA Maintenance Organisation**: To obtain European regulatory authority approval, an aircraft Maintenance/Repair Organisation, must be in compliance with the standards contained in Regulation (EU) No. 1321/2014 (as amended).

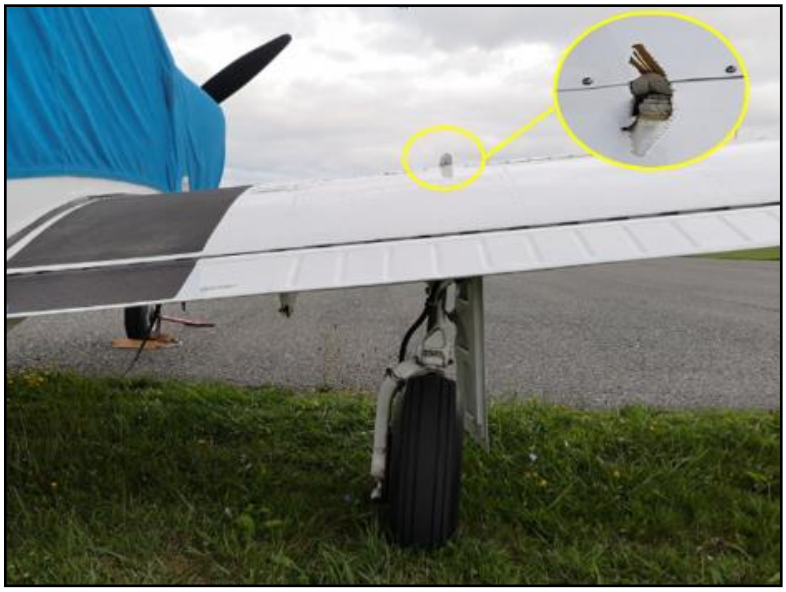

Photo No. 2: Top of undercarriage strut protruding through the wing surface

A photograph (**Photo No. 3**) taken at a local maintenance facility in EISG following the occurrence shows the underside of the aircraft looking outboard (OBD) and captures the undercarriage position post-incident. The aft undercarriage housing (ringed in yellow) was found to have detached from its aft support fitting.

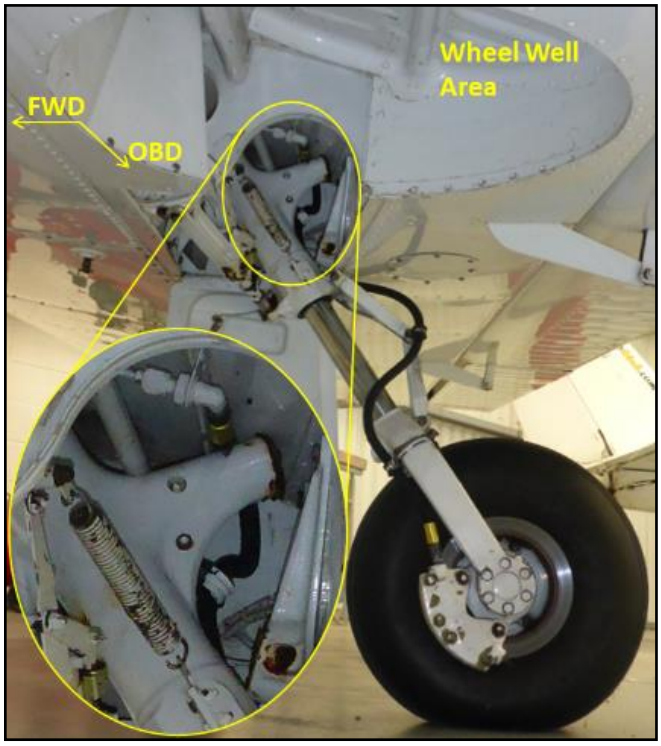

Photo No. 3: Right-hand undercarriage position post-occurrence

The forward support fitting, although significantly damaged (**Photo No. 4**) remained partially attached and prevented the total collapse of the right-hand undercarriage.

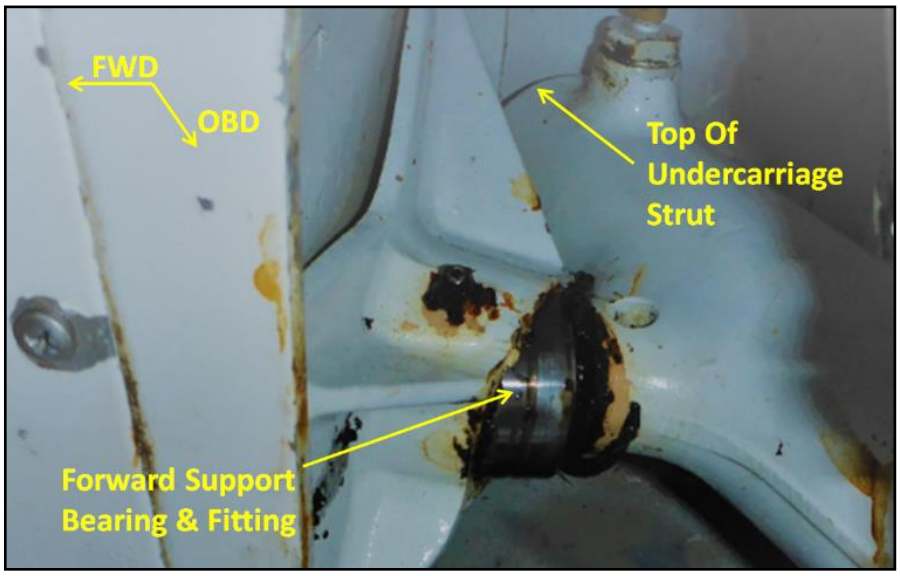

Photo No. 4: Forward support fitting damage

1.7 Undercarriage Arrangement

As illustrated in **Figure No. 1**, the right-hand undercarriage strut housing (13) is located in the wheel well area within the wing of the aircraft via two support fittings, and rotates about two main gear pivot points. At the aft support fitting (1), the undercarriage strut housing is fixed using a bearing (54) and retainer tube (4) arrangement. The retainer tube passes through the bearing and is secured to the inside of the undercarriage strut housing using an attachment bolt (48).

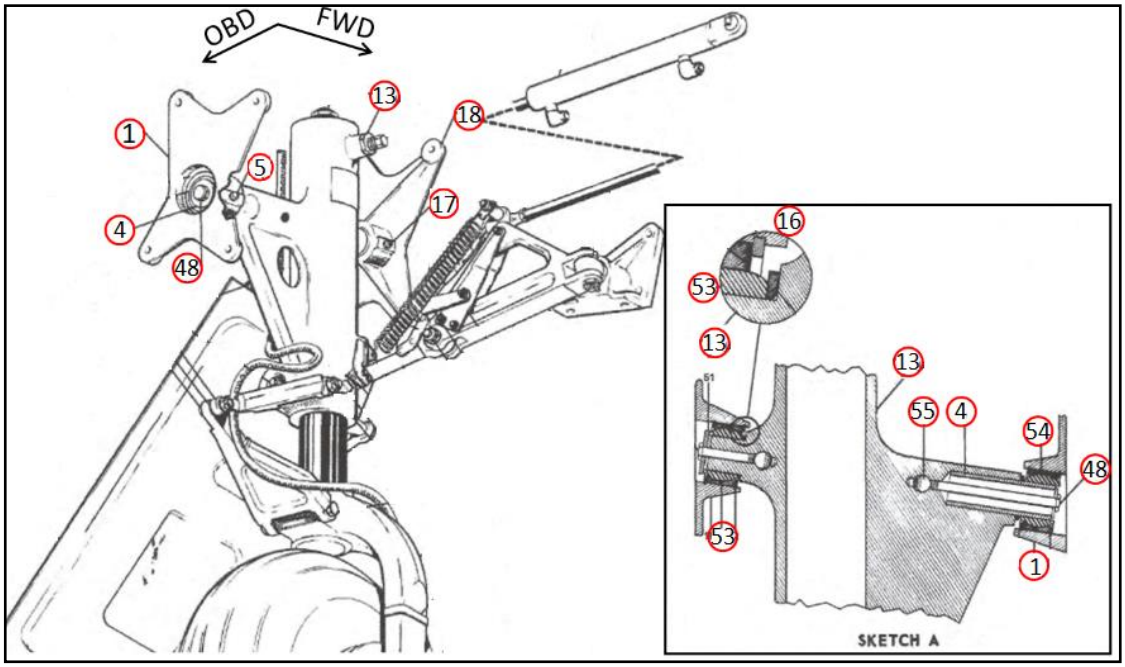

Figure No. 1: Main gear installation (Left-hand undercarriage shown, right-hand similar)
(Adapted from Piper Cherokee Service Manual, Jan 31, 2008)

This bolt is threaded into a barrel nut (55) which is positioned within the undercarriage strut housing. When secured within the forward and aft support fittings, the undercarriage will pivot about the forward and aft bearings (53 and 54) during retraction and extension.

The forward and aft bearings are serviced via grease nipples located at positions (17) and (5) respectively as shown in **Figure No. 1**.

1.8 Retainer Tube and Attachment Bolt

On inspection of the right-hand undercarriage installation, the retainer tube and its attachment bolt and washer, (**Photo No. 5**), were noted to be missing from their installed locations and were found loose within the right-hand wing space adjacent to the undercarriage attachment area. The bolt had evidence of old grease on the shank and threads. The surface of the retainer tube had a number of axial gouge marks about its circumference at the bearing end of the tube, which were found to be 9 mm in length. The end face of the retainer tube exhibited a distinct concave indentation damage signature.

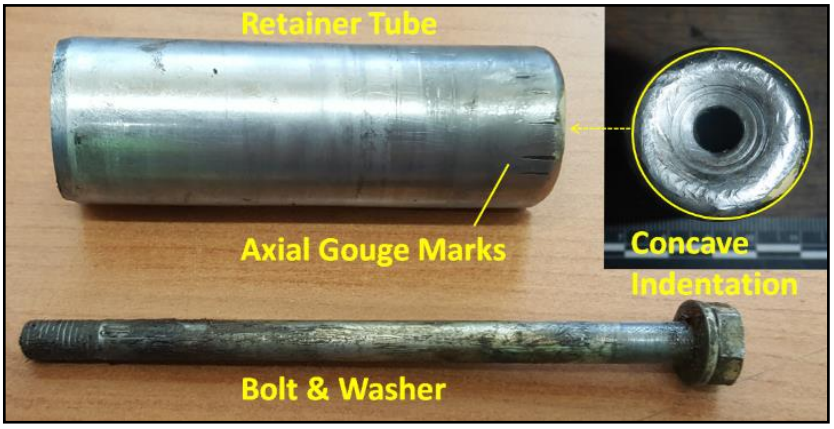

Photo No. 5: Retainer tube and attachment bolt & washer found in right-hand wing space

The retainer tube displayed two distinct wear patterns which indicate that the retainer tube had been fitted in two distinct positions over its operating lifetime. The spherical bearing has a nominal width of 1 inch / 25.4 mm and this wear pattern was clearly visible. An additional wear line was evident and located approximately 9 mm forward of the normal spherical bearing position. A close-up photo of the retainer tube showing these two wear marks is presented in **Photo No. 6**.

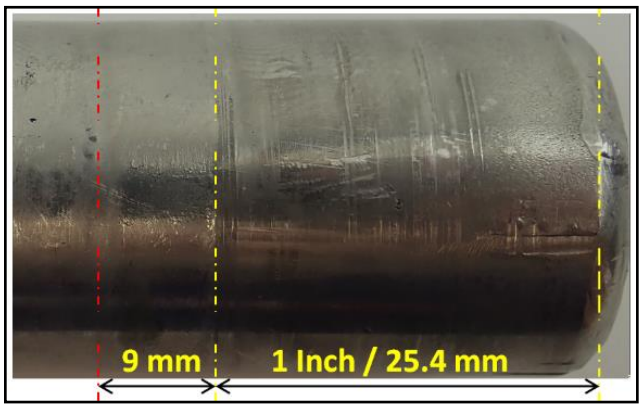

Photo No. 6: Retainer tube wear pattern

The retainer tube is fitted through an access hole in the underside of the wing. The Aircraft Service Manual[6] describes the installation (refer to **Figure No. 1**) as follows:

- *With the retainer tube (4) for the aft arm of the housing in hand, reach up through the access opening and insert the tube into the support fitting (1) through the hole in the web.*
- *Position the gear housing up in the wheel well and install the forward support fitting (16) bolts and washers.* […]
- *Push the retainer tube into the arm of the housing and secure with bolt.*
- *Check that the gear rotates freely in its support fittings and recheck thrust.*

The right-hand wing space is accessed by removing an access panel on the underside of the wing. This access opening is used for the installation, removal and inspection of the bolt and retainer tube during maintenance (**Photo No. 7**).

It is possible for servicing grease applied to the aft support bearing (**Photo No. 7** inset) to obscure the head of the bolt and end face of the retainer tube. Section II of the aircraft's Servicing Manual, *Handling and Servicing, paragraph 2-8b Torque Requirements, step d,* instructs the maintainer as follows:

> *'After the final torque, apply a slippage mark to the nut or bolt or screw head as applicable. NOTE: for more details on torqueing, refer to FAA AC 43.13-1, latest revision'.*

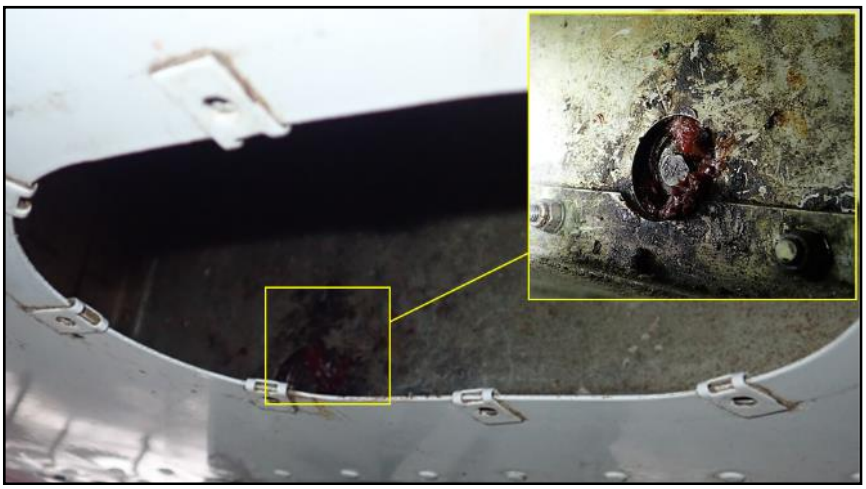

Photo No. 7: Under-wing access panel (L/H side shown)

Relative movement between the correct position and the subsequent position after the occurrence is illustrated in **Photo No. 8**. The dotted red line indicates the position of the undercarriage aft attachment fitting after the partial collapse. The dotted green line indicates the location of the attachment fitting and axis of rotation of the retainer tube as normally installed and secured to the undercarriage aft attachment fitting.

[6] **Piper Cherokee Service Manual:** Part Number 753-586, dated January 31, 2008, Removal and Installation of Main Landing Gear.

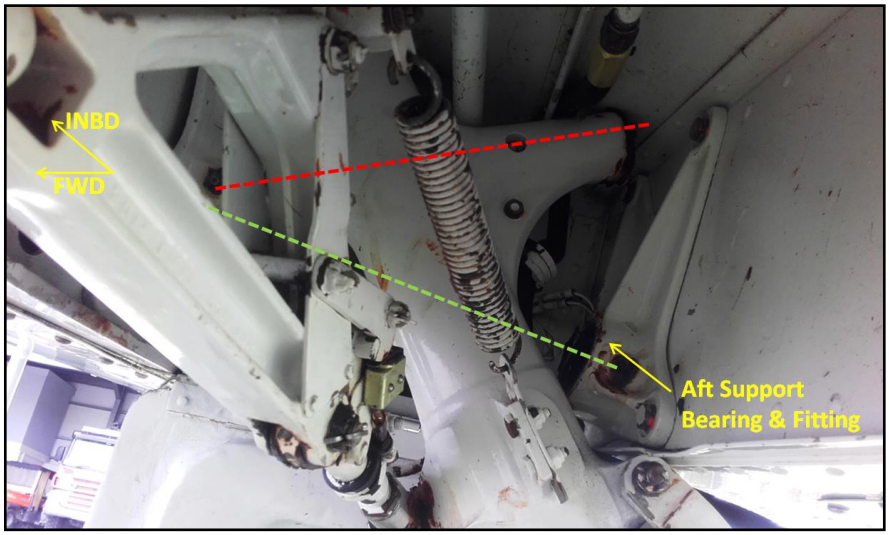

Photo No. 8: Relative movement during partial collapse

1.8.1 Attachment Bolt and Washer

The attachment bolt was accompanied by a washer as shown in **Photo No. 5**. The washer, 1.7 mm in thickness, displayed a concave distortion similar to that observed on the face of the retainer tube. The aircraft Service Manual does not show the inclusion of a washer between the retainer tube and the attachment bolt. The Aircraft Manufacturer informed the Investigation that it had:

> *'checked the engineering drawing and the parts catalog and […] do not see any requirement (or accommodation) for a washer being placed between the head of the bolt and the retainer tube'.*

The Investigation ascertained that the left-hand undercarriage also had a washer installed between the retainer tube and attachment bolt.

1.9 In-Service Inspection of Retainer Tube and Attachment Bolt

The Aircraft Service Manual, Section III – Inspection, page 3I11 states that routine inspection for the '*Landing Gear Group*' is carried out at a 100 hours interval. The removal and installation of the main landing gear in the Aircraft Service Manual does not describe how to check for the correct location of the retainer tube, nor does it state what the minimum number of threads through the barrel nut (Item 55**, Figure No. 1**) should be following installation.

The Aircraft Manufacturer informed the Investigation that the barrel nut has a '*nylon locking insert*'. When asked what the minimum number of threads should be visible to ensure that the landing gear attachment bolt has been secured correctly, the Manufacturer referred the Investigation to the following statement in FAA Advisory Circular (AC) 43.13-1B[7], Section 7, paragraph 7-37:

> *'All bolt installations which involve self-locking or plain nuts should have at least one thread of the bolt protruding through the nut.'*

[7] **FAA Advisory Circular 43.13-1B:** Acceptable Methods, Techniques, and Practices - Aircraft Inspection and Repair.

The Aircraft Manufacturer was asked if the retainer tube had a specific life attributed to it or was it satisfactory for the retainer tube to be reused. The Aircraft Manufacturer responded that there was '*no criteria for evaluating the condition of the retainer tube'* in the Aircraft Service Manual.

1.9.1 Nylon Locknuts

Requirements in relation to the use of nylon locknuts are referenced in FAA Advisory Circular 43.13-1B, Section 7, para 7-64, f, as follows:

> *'Fiber or nylon locknuts are constructed with an unthreaded fiber or nylon locking insert held securely in place. The fiber or nylon insert provides the locking action because it has a smaller diameter than the nut. Fiber or nylon self-locking nuts are not installed in areas where temperatures exceed 250 °F. After the nut has been tightened, make sure the bolt or stud has at least one thread showing past the nut. DO NOT reuse a fiber or nylon locknut, if the nut cannot meet the minimum prevailing torque values (See table 7-2.)'.*

The requirements for the use of self-locking fasteners on the aircraft type is outlined in the Aircraft's Service Manual in Section II – Handling and Servicing, on page 1C20, paragraph 2-8c.

> *'Fasteners incorporating self-locking devices must not be re-used if they can be run up using less than the required minimum torque values specified or as shown in Table II-IV. They may be reused, if hand tools are required to run them up, providing there is no obvious damage to the self-locking device prior to installation'.*

1.10 Maintenance History and Documentation

The aircraft had accumulated 12 flying hours since its last major inspection, which was a 100 hour / Annual Inspection and MIP[8] Bridging Inspection check, completed on 28 March 2018 and carried out at an IAA-approved EASA Maintenance Organisation. The aircraft had accumulated 201 flying hours since the last time the right hand undercarriage was removed during a '*port and starboard undercarriage refurbishment'* in May 2012 which was carried out at a UK CAA-approved EASA Part 145 maintenance organisation.

1.11 Recent Maintenance Work

1.11.1 100 Hour / Annual Inspection and MIP Bridging Inspection

A review of the most recent 100 hour inspection on the aircraft, started on 19 February 2018 and completed on 28 March 2018 at 6,955.6 total aircraft flying hours, indicated that, *inter alia*, scheduled and supplementary unscheduled main and nose landing gear tasks were completed.

[8] **MIP:** Minimum Inspection Programme. EASA (M.A.302(h)). Aircraft classified as European Light Aircraft (ELA1) and not used in Commercial Operations may be maintained to a Self-Declared Maintenance Programme. This may include the Aircraft Maintenance Program (AMP) template and the appropriate Minimum Inspection Programme.

1.11.1.1 Scheduled tasks

The tasks below were assigned as applicable and were signed off as having been completed:

- *General: General: 'Remove or open all necessary inspection plates, access doors, fairings, and cowlings. Clean the aircraft and aircraft engine as required'.*
- *Landing Gear: All Units: 'Inspect for poor condition and insecurity of attachment'.*
- *General: Lubrication/servicing: 'Lubricate and replenish fluids in accordance with the manufacturer's requirements'.*

The aircraft Service Manual lubrication chart[9], recommends lubrication of the main gear pivot points at a frequency of 100 hours. The lubrication chart for the pivot points also refers to special instructions 1 and 2. The special instructions are as follows:

1. *BEARINGS AND BUSHINGS - Clean exterior with a quick drying solvent before lubricating.*

2. *LUBRICATION POINTS - Wipe all lubrication points clean of old grease, oil, dirt, etc., before lubricating.*

1.11.1.2 Supplementary unscheduled landing gear tasks

The aircraft underwent nine supplementary unscheduled tasks on the landing gear during the 100 hour maintenance input. These tasks included six tasks on the nose landing gear and three tasks on the main landing gear. One of the main undercarriage tasks, Task 12, was directly requested by the Owner and was itemised in the 100 hour workpack[10] as follows:

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- *Task No. 12: 'At Owners request, carry out inspection MLG* [Main Landing Gear]'.
  - *Closing Action No. 12: 'MLG inspected iaw* [in accordance with] *section 7. Wear found in port side torque link. Otherwise SATIS* [Satisfactory]'.

At completion of these tasks there is a requirement to complete retraction checks of the landing gear assembly in order to verify proper operation. All checks were certified as having been complied with.

1.11.2 Nose Landing Gear Troubleshooting

The aircraft had accumulated two flying hours and two flights since it had undergone an unscheduled inspection regarding a nose landing gear down-lock circuit issue on 25 June 2018. Troubleshooting on the nose down-lock circuit was completed and the down-lock switch connections were '*found in poor condition*'. The connections were '*cleaned and sleeved in heat shrink*'. The aircraft then underwent undercarriage retraction checks and the aircraft was subsequently certified as serviceable and released to service on 27 June 2018. A release to service certificate for the work was inserted in the aircraft logbook.

[9] **Piper Cherokee Service Manual:** Part Number 753-586. Dated: January 31, 2008, Lubrication Chart (Landing Gear, Main) PA-28R-180 and -200.
[10] **G-FBWH Maintenance Workpack:** G-FBWH 100 Hour Scheduled Maintenance Workpack.

The aircraft Service Manual provides a '*Landing Gear Troubleshooting'* table[11]. Trouble shooting for a *'Yellow transit light on though gear has retracted'* issue is shown in **Table No. 1**. Possible causes include electrical microswitch inconsistencies and/or main gear not retracting enough causing microswitch issues.

TABLE VIIA-I. LANDING GEAR TROUBLESHOOTING		
Trouble	**Cause**	**Remedy**
Yellow transit light on though gear has retracted.	One or more up limit switches failed.	Isolate and replace switch.
	Nose gear up limit switch out of adjustment.	Check gear up adjustment and readjust up limit switch.
	Main gear not retracting far enough to actuate switch.	Check gear up adjustment.

Table No. 1: Landing gear troubleshooting matrix (Adapted from Piper Service Manual)

2. ANALYSIS

2.1 Damage to Aircraft

During the rollout from the landing at EISG, as the weight of the aircraft acted on the undercarriage, the lower part of the right-hand side main shock strut moved rearwards as it was unsecured in the longitudinal direction due to the absence of the retainer tube. Pivoting about the forward support fitting, the top of the undercarriage strut moved forward and up through the skin of the upper wing (refer to **Photo No. 3** and **Photo No. 8**).

2.2 Landing Gear Retraction Issue

During departure from EIWT on the occurrence flight, the gear in-transit light did not extinguish although the Pilot considered that the undercarriage '*felt fully retracted*'. As part of dynamic troubleshooting, the Pilot extended the landing gear and performed a touch-and-go manoeuvre at EIWT. The Pilot reported that the *'gear retracted and in-transit light went out'*.

It is probable that after take-off from EIWT and subsequent undercarriage retraction, the right-hand undercarriage was not aligning correctly when selected to do so. This was likely due to the retaining tube at the aft pivot point not being correctly secured. The action of the touch-and-go manoeuvre most likely served to temporarily realign the undercarriage in order to extinguish the yellow in-transit light, thereby giving the impression to the Pilot that the landing gear was functioning normally. As a normal retraction of the undercarriage was indicated, the Pilot continued with the flight unaware of an issue with the unsecured retainer tube.

[11] **Piper Cherokee Service Manual:** Part Number 753-586, dated January 31, 2008, Landing Gear Troubleshooting Table. Page. 2J12, Landing Gear and Brake System.

2.3 Landing Gear Installation

A review of the aircraft's maintenance history indicates that the last time the right-hand main undercarriage was removed and reinstalled was in May 2012, when the aircraft was being serviced by a UK CAA-approved EASA Part 145 maintenance organisation. The aircraft at that time underwent a '*port and starboard undercarriage refurbishment'.* A review of the maintenance records for the refurbishment indicate that while a number of items of hardware were replaced with new items, the aft retainer tube and its attachment bolt and barrel nut were not recorded as having been replaced at that time.

2.4 Recent Landing Gear Issues and Maintenance

2.4.1 General

A review of the maintenance work completed on the aircraft 12 flying hours before the occurrence shows a number of undercarriage checks, both scheduled and unscheduled, were completed during a 100 hour inspection. Additionally, two flying hours before the occurrence flight, work was completed with regard to a specific nose landing gear down-lock issue. A number of these checks, as part of the rectification process, required retraction and extension of the landing gear, with the aircraft on jacks, in order to verify the correct operation of the landing gear post-maintenance.

2.4.2 Pilot Action

On 19 February 2018, the Pilot (who was also the Owner), being aware of a landing gear issue at the time the aircraft commenced its 100 hour inspection, requested that the maintenance organisation investigate the issue, **REF**: *100 Hr Inspection Input - Unscheduled task*, '*Task No. 12: 'At Owners request, carry out inspection MLG* [Main Landing Gear]*'*. In addition, troubleshooting completed on 27 June 2018 on the nose undercarriage with regard to the down-lock system issue was also highlighted in the aircraft logbook and a release to service certificate was inserted into the logbook detailing the work completed.

With the recent history of undercarriage issues associated with the aircraft, it may have been prudent for the Pilot to have returned the aircraft to the departure airfield when the undercarriage in-transit indication issue occurred. However, the nature of general aviation flying is such that a considerable amount of calendar time may elapse between flights. The 100 hour inspection was completed 12 flying hours previously, which was four months prior to the occurrence flight. The nose gear down-lock issue occurred two flying hours previously, which was 5½ weeks prior to the occurrence flight. The additional retraction and extension, completed during the troubleshooting touch-and-go, may have served to exacerbate and hasten the final migration of the retainer tube.

2.4.3 Maintenance Organisation Action

The aircraft had undergone several undercarriage inspections within the previous 12 flying hours as outlined earlier. A number of these inspections required retraction and extension checks in order to verify proper operation. In addition, the instructions for the lubrication/servicing and general landing gear checks completed on the 100 hour inspections draw attention to the landing gear's retainer tube and attachment bolt, and the security of same.

The attachment bolt and washer found in the wing space following the occurrence had evidence of old grease on the shank and threads, indicating that it had not been tightened into the barrel nut for a considerable, but indeterminate, period of time.

A visual inspection of the attachment point is through an inspection hole on the underside of the wing, and although the retainer tube and bolt would protrude from the aft fitting when incorrectly located, the exact position may be obscured by servicing grease. In addition, there is no requirement to torque check the undercarriage attachment bolts as part of the recommended maintenance schedule. The Investigation asked the Aircraft Manufacturer if there is a requirement to perform a scheduled torque check on the landing gear attachment bolts after initial installation. The Aircraft Manufacturer referred to the aircraft Service Manual, Section II, paragraph 2-8b, step d, Torque Requirements, which instructs the maintainer as follows:

> *'After the final torque, apply a slippage mark to the nut or bolt or screw head as applicable'.*

The Investigation did not observe any evidence of a slippage mark on the bolt, washer or the retainer tube. The securing mechanism for the attachment bolt is by way of a barrel nut with a nylon locking insert (Nyloc). Prescribed maintenance practice directs that a Nyloc-type locknut should only be used, or reused, providing the nut can meet the prevailing torque value for the installation. This requirement is referenced in FAA Advisory Circular 43.13-1B, Section 7, para 7-64, f, as outlined in **Section 1.9.1.**

2.5 Retainer Tube Examination

When correctly installed and secured with the retainer bolt, the retainer tube should be secured within the undercarriage strut housing and aft support fitting bearing in one position only. However, a detailed examination of the retainer tube to bearing contact surface identified a wear pattern, which indicates that the retainer tube had been fitted in at least two distinct positions over its operating lifetime – one correct, and one incorrect. The contact surface for the correct position displayed a heavier wear pattern than for the incorrect position.

In addition, the wear pattern on the retainer tube surface that had been in contact with the bearing suggests that, while the retainer tube had been incorrectly located, the undercarriage had been cycled over an indeterminate period of time. Therefore, at some point during its operating life, the retainer tube had not been secured in the correct position by its attachment bolt. The measured difference in the seating of the retainer tube between correct installation and incorrect installation was approximately 9 mm. This was also the length of the axial gouge marks on the retainer tube.

When the attachment bolt is displaced by a distance of 9 mm, the threads of the bolt will not engage with the fixed position nyloc barrel nut sufficiently to ensure correct security and in accordance with *FAA Advisory Circular (AC) 43.13-1B, Section 7, paragraph 7-37* as outlined in **Section 1.9**.

> *'All bolt installations which involve self-locking or plain nuts should have at least one thread of the bolt protruding through the nut'.*

For reference purposes, **Figure No. 2** represents a 9 mm shift in the position of the retainer tube and associated attachment bolt. Refer also to **Figure No. 1** for additional orientation.

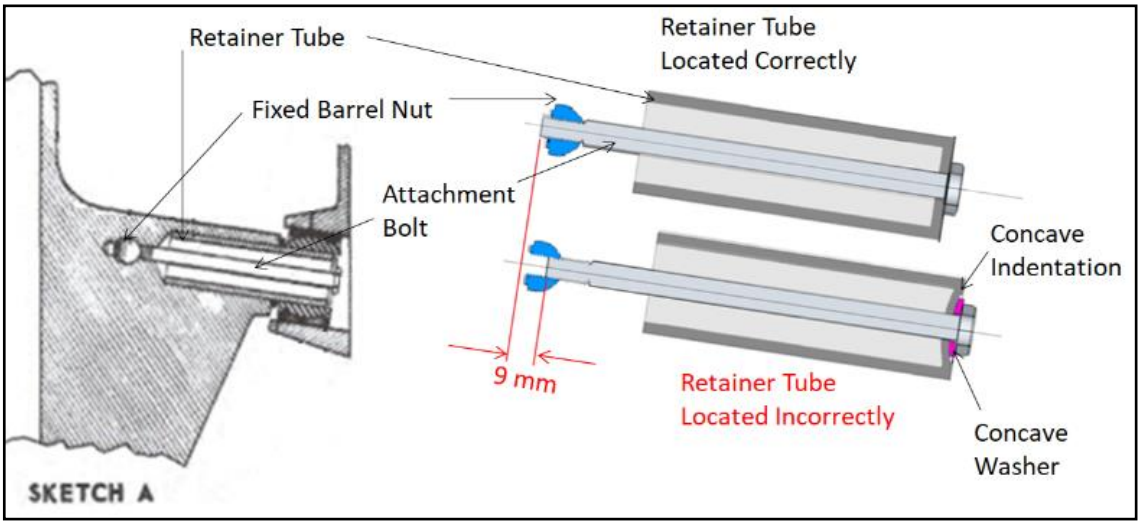

Figure No. 2: Consequence of a 9 mm shift in location of retainer tube
(Refer also to **Figure No. 1)**

2.6 Retainer Tube Fitting Damage

On inspection of the aircraft after the occurrence, the aft support retainer tube and bolt were located loose within the right-hand wing.

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In addition to the wear marks (highlighted in **Photo No. 6)**, the retainer tube had sustained damage to two distinct areas: axial gouge marks (highlighted in **Photo No. 5**) and concave distortion on its face, (**Photo No. 9**). The damage noted on the face and body of the retainer tube suggests that, at some point during the insertion of the retainer tube into the aft support fitting, and onward into the landing gear housing, it had been installed incorrectly and with considerable force.

The axial gouge marks are approximately 9 mm in length, which is approximately the extent by which the retainer tube was misaligned within the spherical bearing as evidenced by the wear pattern on the retainer tube. The concave distortion, of 1.5 mm at its maximum, on the face of the retainer tube, was found to be consistent with the concave distortion of the washer which was used with the attachment bolt. There is no requirement for a washer to be installed in this area.

The gouging and distortion damage may indicate that, during a previous landing gear installation, the retainer tube and the bolt-washer-barrel nut combination were used in an attempt to pull the retainer tube into place in order to overcome any resistance experienced by either a tight fit or pre-existing axial gouging.

It is probable that during the most recent installation, the retainer tube and attachment bolt were deemed to be correctly located, however, the retainer tube was not correctly (fully) seated in the right-hand undercarriage. Accordingly, the bolt was likely only partially threaded into the barrel nut within the undercarriage strut housing. Consequently, over time, it resulted in the eventual loosening, and ultimately the migration, of the attachment bolt and retainer tube from the installed position and back into the wing space.

There was no evidence that a slippage mark had been applied on the bolt head which is at variance with the instruction in the aircraft Service Manual '*paragraph 2-8b Torque Requirements, step d'* as outlined above.

Photo No. 9: New retainer tube (gold-coloured) and old retainer tube

2.7 Attachment Bolt and Washer Examination

Examination of the attachment bolt, found loose within the right wing, showed evidence of aged grease on the shank and threads, indicating that it had not been tightened into the barrel nut for a considerable but indeterminate period of time. The incorrect installed position of the retainer tube, combined with the addition of a washer on the tube's attachment bolt, reduced the effective grip length of the attachment bolt and the overall security of the installation. The washer was found to display the same concave distortion as that witnessed on the retainer tube face.

The left-hand undercarriage assembly also had a washer installed between the retainer tube and attachment bolt. However, the addition of a washer, on its own, in this location would not reduce the attachment bolts grip length sufficiently to cause the migration of the retainer tube, as it occurred, on the right-hand side.

2.8 Aircraft Manufacturer Response

The Aircraft Manufacturer was informed of the occurrence and the findings of the Investigation. The Investigation asked it, in light of the findings of the subject aircraft, if it would consider issuing a service publication alerting operators on potential airworthiness concerns relating to the main landing gear on PA28 series aircraft. The Aircraft Manufacturer was also asked if there had been any previous instances of this nature within the PA-28R-180 fleet.

The Manufacturer informed the Investigation that searches of the US Federal Aviation Administration's (FAA) Service Difficulty Reporting (SDR) database, dating back to 1995, for PA28R, PA32R, PA34 and PA44 series models using the term '*landing gear collapse'* identified five events.

They further noted that the number of aircraft in service is currently estimated to be 17,000. The Aircraft Manufacturer further evaluated the SDR database findings using the FAA's Small Airplane Risk Analysis (SARA) Handbook methodology. Based on their interpolation of the risk assessment, the Aircraft Manufacturer advised the Investigation that '*according to guidance published by the FAA, no field action is warranted*'.

Notwithstanding the results of the SDR and SARA analysis, the Aircraft Manufacturer was asked by the Investigation to consider the addition of a scheduled re-torque requirement for undercarriage attachment bolts to the maintenance schedule. The Aircraft Manufacturer responded that it did not believe that the addition of such a check would appreciably improve safety.

3. CONCLUSIONS

3.1 Findings

1. The airworthiness certification for the aircraft was valid.

2. The Pilot was in possession of a valid licence and medical certificate.

3. The aircraft experienced an undercarriage in-transit indication warning after take-off from Weston Airport (EIWT).

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4. The Pilot completed a landing gear extension and a touch-and-go manoeuvre at EIWT to troubleshoot the in-transit indication.

5. Following the touch-and-go manoeuvre and a second retraction, all landing gear indications for the retraction appeared normal.

6. During roll-out after landing at Sligo Airport (EISG) the aircraft experienced a partial collapse of the right-hand undercarriage.

7. The right-hand undercarriage punctured the upper skin of the wing.

8. The aircraft was inspected by a local maintenance organisation where it was identified that the undercarriage collapse was due to the absence of the aft support fitting retainer tube and bolt assembly, which fixes the undercarriage to the aircraft.

9. The aft support retainer tube and bolt assembly were located loose within the right-hand wing.

10. The retainer tube was found to be in poor condition.

11. Analysis of the retainer tube and bolt suggests that both had been incorrectly installed on the aircraft at some point during its service life.

12. Incorrect installation of the retainer tube resulted in the attachment bolt being unable to ensure correct security within the nyloc barrel nut.

13. The addition of a washer between the retainer tube and the attachment bolt served to reduce the effective grip length of the attachment bolt.

14. The right forward support fitting, although significantly damaged from the occurrence, remained sufficiently connected to the aircraft, which prevented the total collapse of the right-hand undercarriage.

15. Aircraft maintenance records indicate that the undercarriage was last removed and reinstalled 201 flying hours earlier, during a hangar visit and undercarriage refurbishment in May of 2012.

16. Aircraft maintenance records indicate that the last visual inspection carried out on the right-hand undercarriage aft support fitting was during a scheduled 100 hour inspection completed on 20 March 2018.

17. The aircraft had operated for 12 hours (four calendar months) since a scheduled 100 hour inspection and two hours (5.5 calendar weeks) since unscheduled nose undercarriage maintenance, both of which required retraction checks to be completed.

3.2 Probable Cause

Migration and separation of the aft retainer tube and attachment bolt leading to a partial collapse of the right-hand main landing gear on landing.

3.3 Contributory Cause(s)

1. Incorrect installation of the right-hand main undercarriage aft support retainer tube and attachment bolt.

2. A visual inspection for the presence of the retainer tube and attachment bolt through the under-wing access panel, may not, on its own, sufficiently identify if the bolt was correctly secured.

4. SAFETY RECOMMENDATIONS

This Report does not sustain any Safety Recommendations.

- END -

In accordance with Annex 13 to the Convention on International Civil Aviation, Regulation (EU) No. 996/2010, and Statutory Instrument No. 460 of 2009, Air Navigation (Notification and Investigation of Accidents, Serious Incidents and Incidents) Regulation, 2009, the sole purpose of this investigation is to prevent aviation accidents and serious incidents. It is not the purpose of any such investigation and the associated investigation report to apportion blame or liability.

A safety recommendation shall in no case create a presumption of blame or liability for an occurrence.

Produced by the Air Accident Investigation Unit

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