

SERIOUS INCIDENT

Aircraft Type and Registration:	Airbus A319-131, G-EUPM
No & Type of Engines:	2 International Aero Engine V2522-A5 turbofan engines
Year of Manufacture:	2000 (Serial no: 1258)
Date & Time (UTC):	19 October 2016 at 0759 hrs
Location:	Manchester Airport
Type of Flight:	Commercial Air Transport (Passenger)
Persons on Board:	Crew - 7 Passengers - 117
Injuries:	Crew - None Passengers - None
Nature of Damage:	Damage to nose landing gear barrel, axle, torque links, steering actuator cylinder and wiring harnesses
Commander's Licence:	Airline Transport Pilot's Licence
Commander's Age:	46 years
Commander's Flying Experience:	11,900 hours (of which 10,700 were on type) Last 90 days - 169 hours Last 28 days - 62 hours
Information Source:	AAIB Field Investigation

Synopsis

The aircraft experienced nosewheel shimmy following a normal landing at Manchester Airport. As the aircraft entered a rapid exit taxiway at a groundspeed of 30 kt, the nose landing gear upper and lower torque links became disconnected and the aircraft did not respond to further steering inputs. The co-pilot brought the aircraft to a halt on the taxiway. The available evidence shows that the probable cause of the torque link disconnection was damage sustained to the torque link apex pin nut locking components due to contact with a towbarless tractor. A Service Bulletin is available to replace the torque link apex pin assembly with a new design, one feature of which reduces the risk of contact damage with towbarless tractors.

History of the flight

The crew first flew G-EUPM from Newcastle International Airport to London Heathrow Airport on the day of the incident; the commander was PF for this sector. The sector was uneventful apart from "a slight nosewheel shimmy" on the landing roll, which subsided as the aircraft slowed to a taxiing speed.

The co-pilot was PF for the next sector from Heathrow to Manchester Airport. During the turnaround the co-pilot did an external inspection of the aircraft and did not notice anything untoward. The subsequent pushback, start up and taxi to Runway 27L were

without incident. However, during the takeoff run, between approximately 60 KIAS and 100 KIAS (45 kt and 85 kt groundspeed), a loud rhythmic sound was recorded on the CVR. This was commented upon by the crew at the time, who referred to it as having been caused by nosewheel “SHIMMY”. The crew then discussed the previous takeoff and landing, commenting that the takeoff from Newcastle had been uneventful, but they had experienced a similar vibration during the landing roll at Heathrow.

As the flight progressed, the crew further discussed the nosewheel shimmy and the possibility that it may be associated with a problem with either the nosewheels or nose gear torque link. The co-pilot commented that it was difficult to visually inspect the torque link attachments due to them being covered “IN A TYPE OF SEALANT”. The commander advised that he would carry out the walk around at Manchester to see if he could identify the cause of the problem and make an entry in the aircraft’s technical log accordingly.

The approach and touchdown on Runway 23R at Manchester were uneventful, with autobrake LOW selected. The surface wind was 300° at 6 kt and V_{REF} was calculated as 126 kt. On the landing roll, as the airspeed reduced to 100 KIAS, manual braking was applied. Between 70 kt and 40 kt groundspeed, vibration associated with nosewheel shimmy was recorded on the CVR, with both crew commenting on its severity. At a groundspeed of 35 kt, the co-pilot turned the aircraft onto Exit Bravo Delta (BD), whilst gradually applying the toe brakes.

Shortly after entering Exit BD, at a groundspeed of 30 kt, a significant vibration was recorded in the cockpit, accompanied by high alternating lateral accelerations. After about six seconds, the intensity of the vibration noticeably increased. At the same time, a Landing Gear Control Interface Unit (LGCIU) 1 fault indicated on the aircraft’s electronic centralised aircraft monitor (ECAM). The co-pilot continued to apply the brakes, whilst also applying right tiller to try and maintain the taxiway centreline as the aircraft’s heading started to deviate to the left, before bringing the aircraft to a stop. As he did so, he alerted the commander that he had lost directional control and the commander declared a PAN, advising ATC that the nose gear had failed and that they required assistance.

The co-pilot then made a passenger announcement (PA) before briefing the cabin crew. The RFFS arrived at the aircraft shortly thereafter and the APU was started before both engines were shut down to enable the RFFS to make a closer inspection. They spent 5 to 10 mins inspecting the aircraft and subsequently reported that the nosewheel was at 90° to the aircraft’s heading and there was some debris behind the aircraft on Exit BD.

The passengers and crew subsequently disembarked using stairs and were transported to the airport terminal in buses.

Site examination

The aircraft stopped on Exit BD, 200 m from Runway 23R, with the nose slightly displaced to the left of the taxiway centreline (Figure 1). The upper and lower torque links of the nose landing gear (NLG) had separated and the nosewheels had rotated approximately 95° to the left, causing the aircraft to become immobilised. Tyre marks left on the taxiway surface showed that the nosewheels had rotated to the left following the release of the torque link apex pin.

Debris shed from the nose landing gear was distributed on a 70 m path behind the aircraft. The debris included components from the torque link apex pin assembly, along with other parts of the nose landing gear that had been released due to contact with the upper torque link, which had been forced upwards by contact with the left nosewheel. The apex pin and nut were identified amongst the recovered debris (Figure 2). Despite a search of Exit BD and Runway 23R, no parts from the apex pin lock bolt assembly were found.



Figure 1

G-EUPM position on Exit BD, prior to recovery

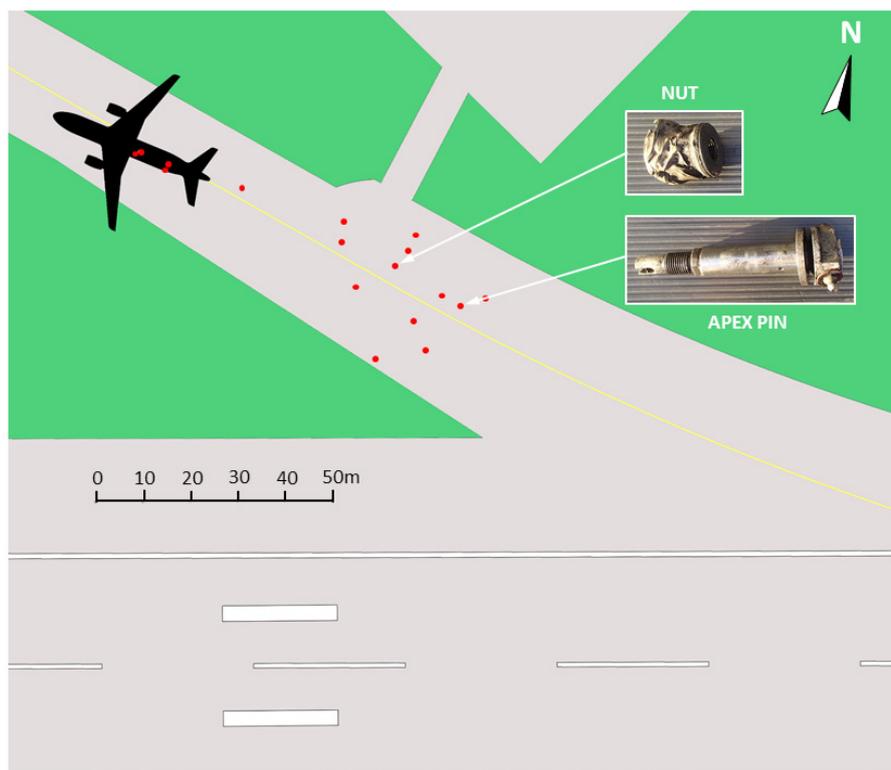


Figure 2

G-EUPM debris locations on Exit BD – red dots indicate recovered debris, including the apex pin and nut

Recorded information

Sources of recorded information

A complete record of the incident flight was available from the aircraft's CVR, FDR and Quick Access Recorder (QAR). The 120 minute CVR record commenced as the aircraft was being prepared for the flight from Heathrow to Manchester and ended 45 minutes¹ after the aircraft had come to a stop on exit Bravo Delta. The FDR contained a total of 14 flights, with the recording ending at the same time as the CVR.

Salient information from the CVR and FDR has been included in the history of flight. Figure 3 shows pertinent parameters recorded during the landing at Manchester Airport.

CVR and FDR automatic start/stop

The Airbus A319/A320/A321 family of aircraft, which includes G-EUPM, are fitted with a system that automatically starts and stops the CVR and FDR.

The start/stop logic uses a signal from LGCIU 1 to indicate if the aircraft is in the 'air' or on the 'ground'. The status of this signal is derived from a number of sensors, including

Footnote

¹ Due to the failure of LGCIU 1, the FDR and CVR were not automatically stopped five minutes after the engines had been shut down.

the left weight-on-wheels (WOW) proximity sensor fitted to the nose landing gear. When the LGCIU 1 signal is set to 'ground', both recorders will stop five minutes after the last engine has been shut down. This is intended to ensure that the most recent recordings are preserved.

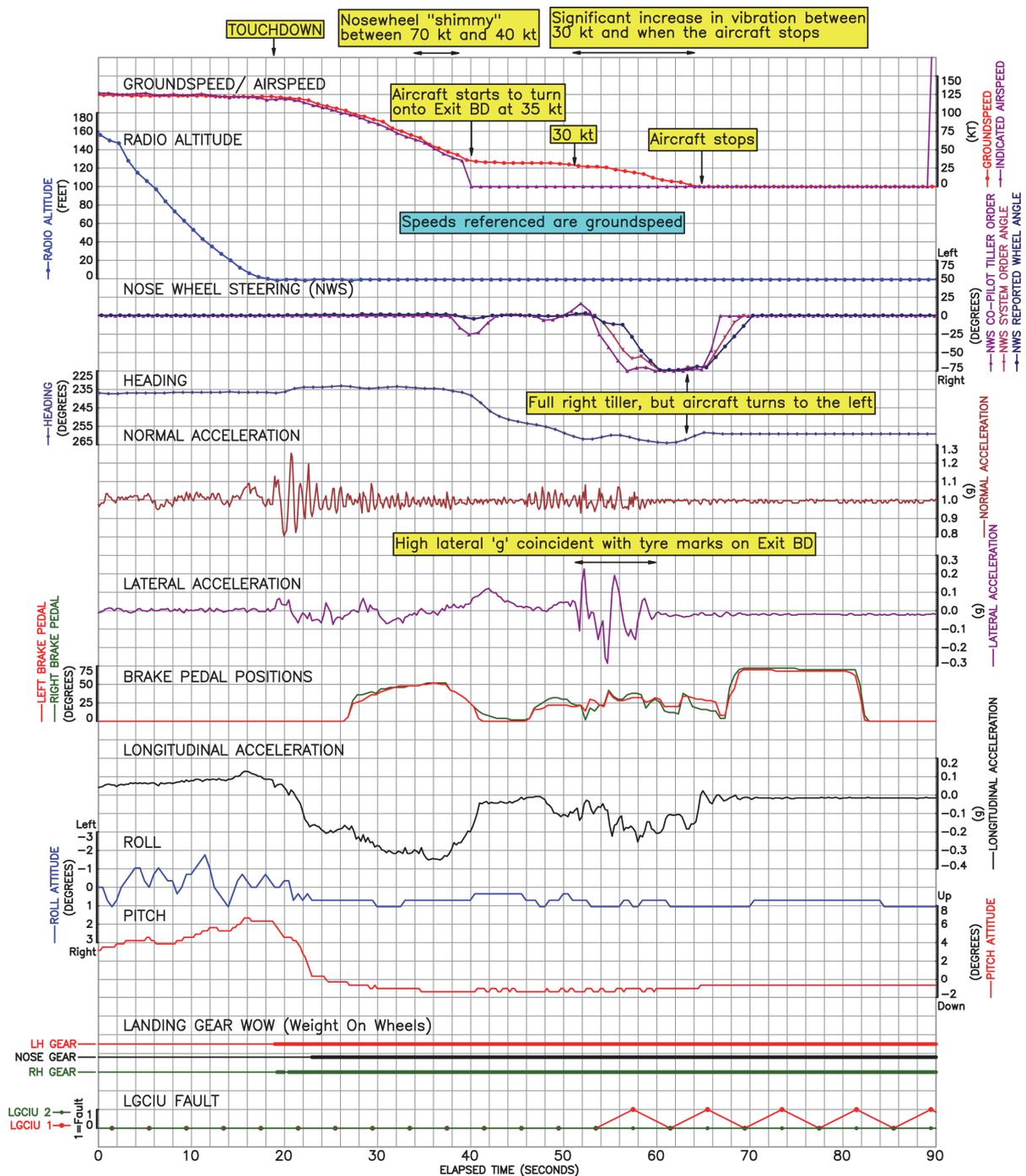


Figure 3
Landing at Manchester Airport

The nose gear is also equipped with a right WOW proximity sensor that provides a signal to LGCIU 2. This signal was recorded on the FDR and indicated that the nose gear shock absorber was compressed.

The aircraft manufacturer reviewed the FDR data from G-EUPM and confirmed that the LGCIU 1 fault was triggered due to damage to the left WOW proximity sensor. This resulted in the LGCIU 1 signal to the flight recording system being set to the 'air' condition and so both recorders continued to operate after the engines were shut down.

CVR and FDR preservation

The aircraft's engines were shut down just over six minutes after the aircraft had come to a stop, however the CVR and FDR continued to operate due to the LGCIU 1 fault. Thirty five minutes later, the RFFS upgraded the 'incident' status to an 'accident'. The operator's maintenance control department (MAINTROL) then requested that the crew preserve the CVR and FDR records by opening the circuit breakers in the cockpit. The continued operation during this period on the ground resulted in the CVR record of the previous landing at Heathrow being overwritten.

Commission Regulation (EU) 965/2012 part CAT.GEN.MPA.105 states that it is the responsibility of the aircraft commander to preserve the CVR and FDR records following '*an accident or an incident that is subject to mandatory reporting*'. The operator's CVR and FDR preservation procedure stated that it should only be invoked when it was '*the considered opinion*' of the Operational Duty Engineering Manager at MAINTROL and the Duty Air Safety Manager that the incident is '*of sufficient gravity and circumstances to deem it necessary*'. This procedure did not provide guidance as to the circumstances when the recorders should be preserved and no guidance was provided to commanders concerning their responsibility.

The AAIB, and other safety investigation authorities, continue to experience CVRs that have been overwritten due to delays in preserving their records. Considering the relatively short recording duration of the CVR, it is often the aircraft commander, rather than the operator's engineering or safety department that is best placed to ensure the timely preservation of recordings. The AAIB is aware that other operators have addressed this by providing guidance information directly to crews. This has included examples as to when the CVR and FDR should be considered for preservation and require an entry is made in the aircraft's technical log, such that an aircraft shall not be dispatched with the recorders inadvertently disabled.

Safety action taken

Following this event, the operator of G-EUPM made changes to its procedures to ensure that the commander is aware of his responsibility to ensure that the recordings are preserved.

Aircraft information

The Airbus A319 nose landing gear is a retractable two-wheel unit equipped with an oleo-pneumatic shock strut and a nosewheel steering system. Two LGCIUs control the extension and retraction of the landing gear and the operation of the landing gear doors. The LGCIUs also supply information about the landing gear to the ECAM for display, and send signals indicating whether the aircraft is in flight or on the ground to other aircraft systems.

Nosewheel steering is performed by a hydraulic actuating cylinder attached to the landing gear barrel. The hydraulic actuator rotates the upper torque link, which transmits torque through the lower torque link to rotate the nose wheels. The upper and lower torque links are attached by an apex pin (Figure 4), providing articulation of the torque links to accommodate vertical displacement of the oleo strut.

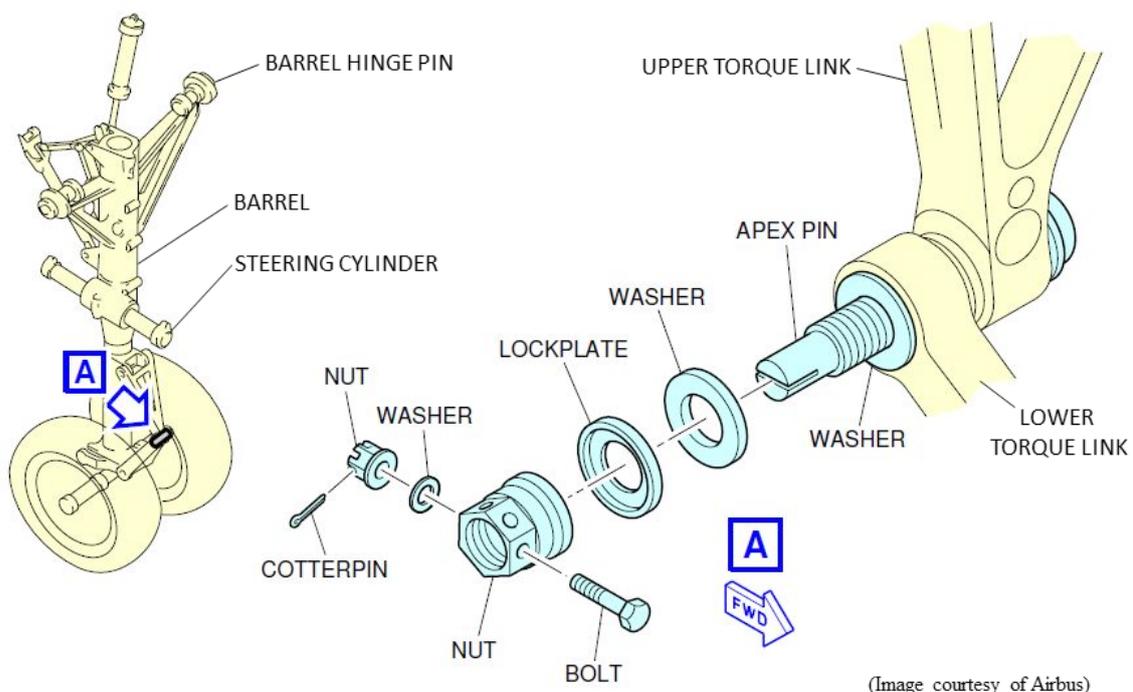


Figure 4

Nose landing gear torque link apex pin assembly

The apex pin is a $\frac{3}{4}$ inch diameter steel pin, secured in position by a nut. The end of the apex pin has a slot, and the apex pin nut has a hole through each face to permit the insertion of a $\frac{1}{2}$ inch diameter lock bolt, to prevent the apex pin nut from rotating once installed. The $\frac{1}{2}$ inch lock bolt is itself secured in position with a castellated nut and cotterpin. Once installed, the head of the lock bolt and the castellated nut and cotter pin are required by the Aircraft Maintenance Manual (AMM) to be encapsulated in sealant.

Maintenance history

The aircraft underwent a 1C² scheduled maintenance inspection in February 2016, during which the NLG torque link apex pin was disassembled as part of a routine check for excessive play. The NLG torque links were reassembled on 23 February 2016, which was the last recorded disturbance to these components. The apex pin reassembly was carried out at the operator's base maintenance facility by a maintenance mechanic and checked by a supervising technician. When interviewed, the mechanic stated that he recalled conducting the apex pin reassembly and that the task had been carried out in accordance with the AMM instructions, including the installation of the locking bolt assembly and securing cotter pin. The mechanic also applied sealant to the locking bolt, castellated nut and cotter pin. The supervising technician could not recall the apex pin installation task on G-EUPM in any detail, due to the passage of time, although he did state that he did not remember anything unusual about the task. He also stated that it was his usual practice to check for the presence of the securing cotter pin before allowing a mechanic to apply sealant on the apex pin nut.

The aircraft's technical records were reviewed to ascertain whether the NLG torque links were disturbed following the 1C check. The only relevant recorded maintenance event occurred on 10 July 2016, relating to a nosewheel steering (NWS) fault whilst the aircraft was at Linate Airport, Italy. The aircraft's technical log recorded that this fault had been rectified by replacement of one of the NLG's two steering angle sensors, using procedures contained in the AMM. The two maintenance technicians who carried out this maintenance task were interviewed by the ANSV³ and both stated that they had not disturbed the NLG torque link apex pin during the task. They also stated that such a disturbance was not required by the AMM procedures they had followed in isolating the NWS sensor fault, and replacing the NWS sensor.

The aircraft had completed 1,323 flight cycles between the 1C check in February 2016 and the NLG event at Manchester Airport on 19 October 2016.

Maintenance procedures

The AMM requires that the locking bolt passing through the apex pin nut is assembled with a washer and a castellated nut, and that the castellated nut is secured by the insertion of a steel cotter pin. The AMM permits two methods of cotter pin installation for this assembly (Figure 5); a '*First Procedure*' in which the cotter pin is installed perpendicular to the bolt axis, and the projecting prongs of the cotter pin are bent around the sides of the castellated nut and, optionally, are bent inwards into the castellated nut slots. Alternatively a '*Second Procedure*' may be used, where the cotter pin is installed parallel with the bolt axis and the projecting upper prong of the cotter pin is bent tightly against the shank of the bolt, and the lower prong is bent tightly against the base of the nut.

Footnote

² A 1C check is a scheduled maintenance inspection carried out at 18 month intervals.

³ The Agenzia Nazionale per la Sicurezza del Volo (ANSV) is the Italian aircraft accident investigation authority.

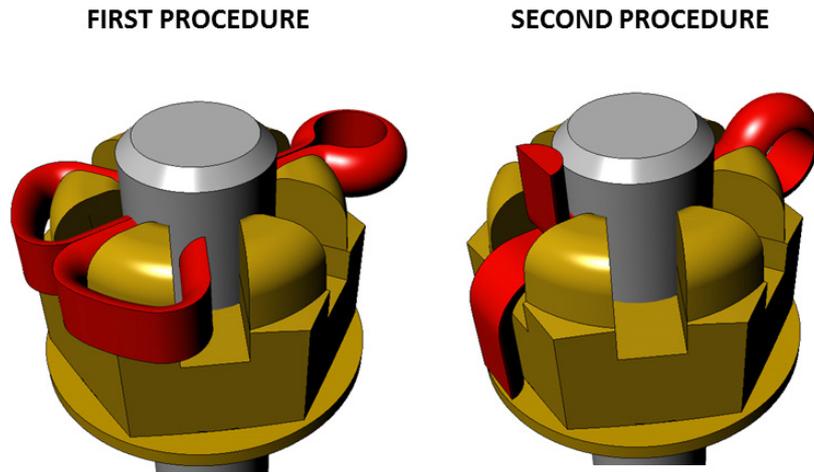


Figure 5

Approved methods of cotter pin installation for apex nut lock bolt

Aircraft examination

The NLG had rotated to approximately 95° to the left and the upper torque link had contacted the left nosewheel tyre, forcing the torque link upwards. The upward movement of the upper torque link caused it to fracture the NLG WOW detector enclosure and displaced the NLG WOW proximity detector target and sensor assemblies. The left WOW proximity detector had detached from its wiring harness due to its connector having pulled out of the proximity detector body. The subsequent open circuit condition of the left WOW proximity detector wiring harness was sensed by LGCIU 1, triggering the LGCIU 1 fault condition.

The left nosewheel tyre sustained abrasion damage to the inner sidewall but remained inflated, despite being heavily loaded due to the forward rake angle of the NLG (Figure 6). When the NLG was disassembled it was found that the nosewheel axle was bent, the barrel hinge pins were deformed and the rear steering cylinder had sustained an impact depression. The bottom edge of the NLG barrel sustained circumferential gouging damage⁴ due to contact with the displaced NLG WOW proximity detector enclosure. The TPIS⁵ wiring harness was severed at its attachment point on the upper torque link.



Figure 6

Displaced nose landing gear following release of the torque link apex pin

Footnote

⁴ Following a detailed examination of the NLG barrel, the manufacturer considered the damage to be repairable, preventing the need to scrap the item.

⁵ Tyre Pressure Indication System, deactivated on G-EUPM.

The apex pin, nut and associated washers and lockplate were recovered from Exit BD. The apex pin and nut were in good condition and did not exhibit any evidence of abnormal loading. The threads on the apex pin and nut were undamaged and when assembled, the nut freely screwed onto the pin without binding. The apex pin nut was covered in light grey cured sealant (Figure 7).

Witness marks in the sealant showed that the 3/16 inch diameter locking bolt, washer, castellated nut and cotter pin had been present when the sealant was applied, although these components were absent at the site. The sealant witness marks were examined by microscope at the AAIB (Figure 7).

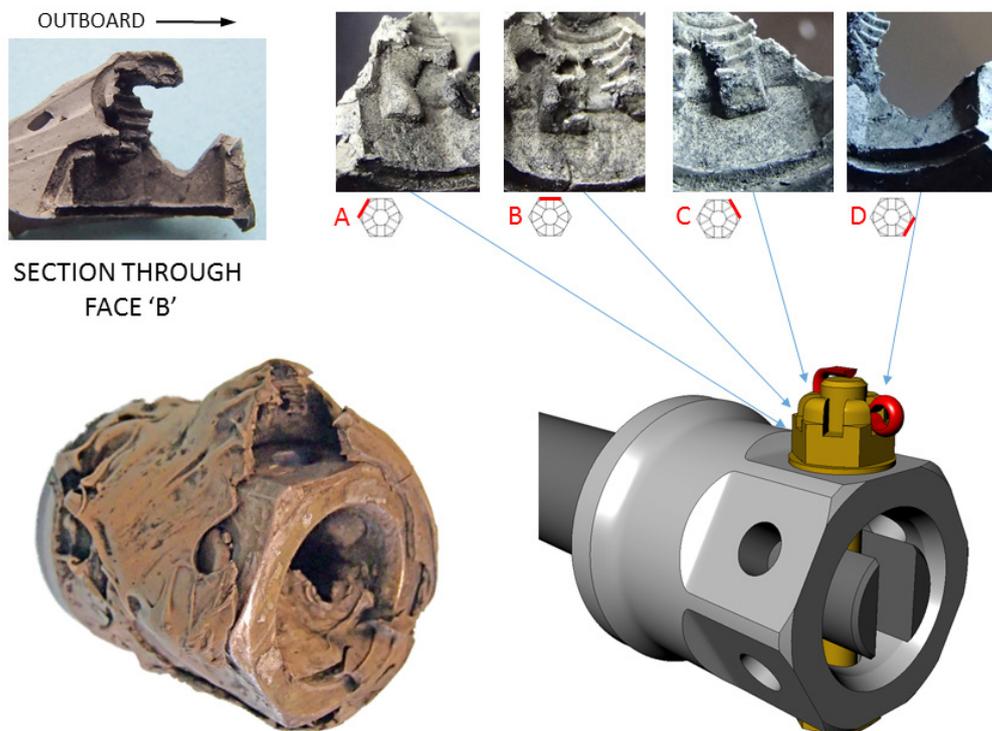


Figure 7

Apex pin nut sealant witness marks

The sealant witness marks showed that the locking bolt had been assembled with a cotter pin prior to the application of the sealant, with the cotter pin oriented parallel to the locking bolt as per the AMM 'Second Procedure'. The head of the cotter pin had been pointing outboard as shown in the diagram in Figure 7. There was an area of missing sealant in the vicinity of the outboard edge of the castellated nut. The edges of this area of missing sealant were of a torn appearance, consistent with this area having detached from the main mass of sealant at some point after the sealant had been applied and cured.

Previous occurrences

Previous cases of A320-series⁶ NLG torque link separation have occurred in which the apex pin nut has detached due to overload rupture of the apex pin, following contact with a towbarless (TBL) tractor paddle. During towing and pushback operations, the left TBL tractor paddle is in close proximity to the apex pin nut and any significant lateral misalignment of the tractor to the aircraft can cause the left paddle to contact the apex pin nut. The contact can occur either when the tractor paddles rotate upwards to retain the nosewheels, or when the tractor rotates the nosewheels to steer the aircraft which imposes a side-load on the nosewheel tyres, causing tyre sidewall lateral deflection.

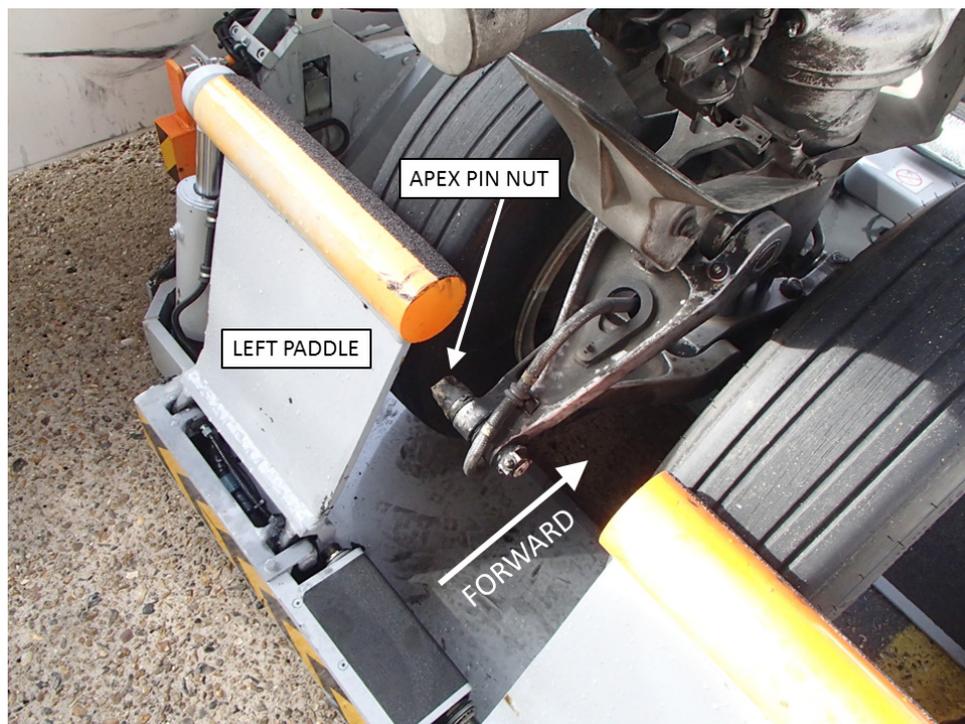


Figure 8

Apex pin nut and TBL tractor left paddle proximity

The operator's internal occurrence reporting system contained three relevant records:

- February 2005 – An A319 NLG apex pin nut separated from the apex pin due to overload, caused by contact from a TBL tractor paddle during pushback.
- August 2007 – Damage to an A320 NLG apex pin nut lock bolt was found during a pre-flight inspection. The lock bolt had fractured through the cotter pin hole and the sealant covering the lock bolt, castellated nut and cotter pin had been '*scraped*' back, consistent with an impact from a TBL tractor paddle.

Footnote

⁶ 'A320-series' includes all variants of Airbus A318/319/320/321 aircraft.

- October 2010 – An A319 NLG apex pin nut lock bolt was found to be bent and the castellated nut damaged, with the cotter pin missing. This damage was recorded as being consistent with the apex pin nut having been stuck by something substantial, possibly a TBL tractor paddle.

In 2009, in response to in-service NLG apex pin fracture events, the aircraft manufacturer launched a redesign of the apex pin assembly. This activity resulted in a *'Technical Follow-up'* notice to operators, TFU 32.21.27.002, which described the in-service cases of NLG torque link separation following apex pin rupture due to TBL tractor contacts. This TFU also drew attention to Service Bulletin (SB) A320-32-1400, issued in June 2012, which introduced a new apex pin with a redesigned nut assembly, reducing the lateral projection of the apex pin nut by 7 mm. In addition to other improvements, the new design was *'developed to reduce the exposure to towbarless tractors'*, and was introduced as standard equipment on production A320-series aircraft at MSN 5154 (although, due to aircraft and parts sequencing during production, not every MSN immediately thereafter is to the post-modification standard). The aircraft manufacturer confirmed that approximately 2,400 in-service A320-series aircraft have been delivered with this modification embodied during production and none of these aircraft has experienced a torque link separation event. SB A320-32-1400 is available for retrofit to all A320-series aircraft.

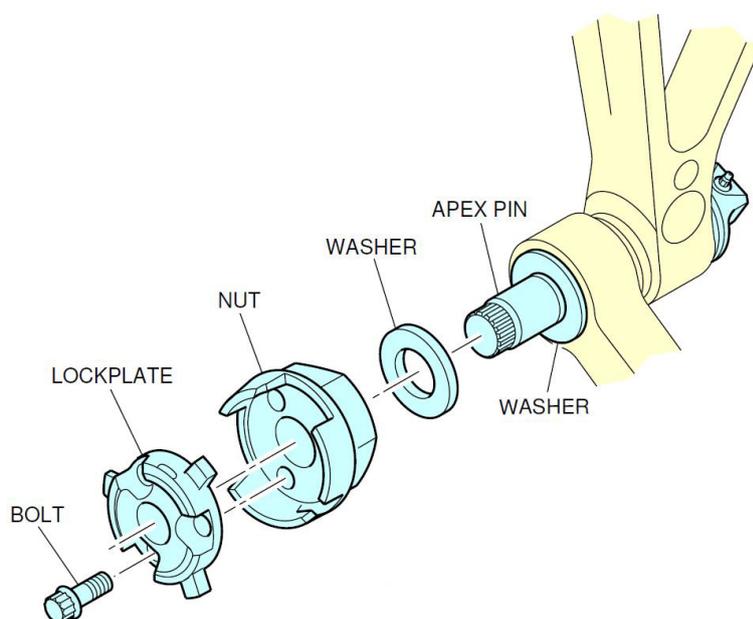


Figure 9

New design of NLG apex pin, nut and locking assembly introduced with SB A320-32-1400

Tests and research

TBL tractor inspections at Heathrow Airport

Immediately following the G-EUPM event the operator carried out an inspection of the TBL tractor, registration AT0935, which had pushed G-EUPM back from its stand at Heathrow Airport prior to the incident flight to Manchester, along with 10 other TBL tractors also in use by the operator at Heathrow. The inspection of AT0935 did not reveal any faults with the tractor, although a rusty witness mark was noted on the inboard edge of the left paddle, at a position adjacent to where the apex pin nut sits when the tractor has engaged an A320-series aircraft. This model of TBL tractor is also used to push back and tow Boeing 767 aircraft, and to push back Boeing 777-200 aircraft although neither of these aircraft types' NLGs have protuberances that could have caused the left paddle witness marks. The corrosion on AT0935's witness mark demonstrated that a paddle contact had not occurred during pushback prior to the incident flight.

Inspection of the other 10 TBL tractors revealed witness marks on the left paddle inboard edges on eight of the units examined, Figure 10.



Figure 10

Example of a TBL tractor left paddle witness mark

NLG apex pin nut survey at Heathrow Airport

The AAIB carried out a survey of 34 A320-series aircraft, none of which had SB A320-32-1400 embodied, at Heathrow Airport as part of the G-EUPM investigation. Five of the aircraft surveyed had damaged sealant at the outboard end of the NLG apex pin nut, indicating possible TBL tractor left paddle contacts (Figure 11), although none of the aircraft surveyed had visible damage to components of the lock bolt assembly.



Figure 11

Apex pin nut sealant damage observed during AAIB survey

Analysis

Assessment of the recovered components from G-EUPM's NLG indicates that the torque links separated because the apex pin released from the torque links after the apex pin nut had unscrewed and detached from the apex pin. The close proximity of the recovered apex pin and nut to the aircraft shows that once the apex pin had released, the nosewheels rapidly rotated to an extreme left angle.

The apex pin nut was able to unscrew because the locking bolt became detached from the apex pin nut prior to the landing at Manchester, although it is uncertain when this occurred. The occurrence of NLG shimmy on landing during the sector preceding the incident flight, and during takeoff and landing on the incident flight, is consistent with a loss of apex pin nut torque at least one flight prior to the incident flight.

Witness marks in the apex pin nut sealant show that the lock bolt, washer, castellated nut and cotter pin had been correctly assembled prior to the sealant application. The available evidence shows that this occurred during the 1C maintenance check in February 2016, 1,323 flight cycles prior to the torque link separation.

The cotter pin had been installed in the lock bolt in accordance with the AMM '*Second Procedure*', with the head of the cotter pin oriented outboard. The missing area of sealant on the apex pin nut was in the same position as where the head of the cotter pin had been. The torn edges of this area of missing sealant indicate that it had detached in service, after the sealant had been applied and cured.

Similar sealant damage was observed on five other A320-series aircraft in the operator's fleet, from a sample of 34 aircraft; such sealant damage is most likely caused by contact with the left paddle of a TBL tractor during pushback and towing operations. In addition, nine out of eleven of the operator's TBL tractors had impact witness marks on the left paddle, adjacent to the position where the apex pin nut sits when the tractor is engaged with A320-series aircraft, further indicating that paddle contacts are occurring in routine operation.

Therefore, it is probable that contact with the left paddle of a TBL tractor damaged the sealant and the lock bolt cotter pin, castellated nut or lock bolt itself, leading to their subsequent detachment from the apex pin nut. This led to the eventual release of apex pin from the NLG torque links.

Previous occurrences of damage to apex pin nuts and locking bolts prompted the aircraft manufacturer to modify the design of the apex pin nut, with the narrower apex pin components becoming available in June 2012.

Safety action being considered

As a result of this event, the operator is considering the embodiment of Service Bulletin A320-32-1400 on its A320-series fleet, in a rolling programme as the aircraft undergo scheduled maintenance.

Conclusion

The detachment of the NLG torque link apex pin was most probably caused by damage sustained to the torque link apex pin nut locking components due to contact with a towbarless tractor. A Service Bulletin is available to replace the torque link apex pin assembly with a new design, intended to reduce the risk of contact damage with towbarless tractors.