ACCIDENT

Aircraft Type and Registration:	Boeing 787-8, G-ZBJB	
No & Type of Engines:	2 Rolls-Royce Trent 1000-AE3 turbofan engines	
Year of Manufacture:	2013 (Serial no: 38610)	
Date & Time (UTC):	18 June 2021 at 0651 hrs	
Location:	London Heathrow Airport Stand 583	
Type of Flight:	Commercial Air Transport (Cargo)	
Persons on Board:	Crew - 2	Passengers - None Other - 6
Injuries:	Crew - 1 (Minor)	Passengers - N/A Other -1 (Minor)
Nature of Damage:	Underside of forward fuselage, door 2L and forward lower engines cowlings damaged	
Commander's Licence:	Airline Transport Pilot's Licence	
Commander's Age:	47 years	
Commander's Flying Experience:	8,364 hours (of which 587 were on type) Last 90 days - 26 hours Last 28 days - 0 hours	
Information Source:	AAIB Field Investigation	

Synopsis

The aircraft was on stand being prepared for a cargo flight from London Heathrow to Frankfurt. A ground maintenance team was working to address three fault messages associated with the Nose Landing Gear (NLG) doors while the flight crew prepared the aircraft for the flight. The Dispatch Deviation Guide confirmed that rectification of the defects could be deferred to a later date providing the landing gear was recycled to confirm the NLG doors functioned correctly. To prevent the landing gear from retracting when UP was selected, the landing gear downlock pins were fitted. However, when the lead engineer selected the landing gear lever to UP, the NLG retracted. The aircraft's nose struck the ground causing significant damage to the lower front section of the aircraft and inflicting minor injuries on the co-pilot and one of the cargo loading team.

The NLG downlock pin had inadvertently been inserted in the downlock link assembly apex pin bore instead of the downlock pin hole. The design of the aircraft nose landing gear downlock assembly created an opportunity for error when inserting the NLG locking pin, with two holes located so close together that the pin could be inadvertently inserted in the incorrect location. A Service Bulletin and Airworthiness Directive was available that would have prevented the accident, but this had not yet been completed on G-ZBJB.

The operator and the airport have introduced a number of Safety Actions which cover the adoption of corrective modifications to the aircraft, changes to maintenance and incident response procedures.

History of the flight

The aircraft was scheduled to operate a freighter flight from London Heathrow Airport to Frankfurt Airport. The aircraft was planned to be operated by two pilots accompanied by an Overseas Engineer (OSE) to provide technical support down route. The pilots arrived at the operator's Crew Reporting Centre at approximately 0520 hrs and collected the flight briefing pack. The pilots met the OSE prior to briefing but he had some engineering matters to attend to, so did not attend the flight crew briefing.

The briefing pack referred to an outstanding technical issue with the aircraft related to the NLG door solenoids. The pilots consulted the relevant Minimum Equipment List entry and confirmed that the defect caused no operational or aircraft performance issues. The rest of the briefing was routine and the crew went through security and reunited with the OSE at the crew bus gate at approximately 0620 hrs. The aircraft was parked on a remote stand and the crew arrived at the aircraft at approximately 0625 hrs.

Three ground engineering personnel were on the flight deck when the pilots and the OSE arrived. They informed the crew that they were attempting to resolve a number of Engine Indicating and Crew Alert System (EICAS) status messages related to the NLG door solenoids. The OSE offered his assistance to the ground personnel in dealing with the issues but was told he was not required. The OSE left the flight deck to perform his pre-departure checks of the cabin. The commander asked the Licensed Aircraft Engineer (LAE) for an estimated timeframe for rectification of the issues and was told it would take around 40 minutes. The commander then left to conduct the aircraft walk around checks. During the walk around checks the commander did not recall seeing any landing gear locking pins installed.

Two of the ground engineers left the flight deck and the LAE remained in the left seat working through the engineering procedures on a laptop. The co-pilot sat in the right seat and began his pre-departure checks. The co-pilot had limited interaction with the LAE as he was focused on his own task. He did recall that the engineer pressurised a hydraulic system. The co-pilot received the flight departure clearance by datalink at 0650 and very shortly after that recalled the LAE raising the gear lever to UP. The co-pilot recalled hearing the gear system actuate and then the aircraft nose struck the ground. Though the co-pilot sustained a minor injury the engineer was unhurt.

Following the NLG retraction, the co-pilot recalled that alternating current (AC) electrical power had been lost and that the Auxiliary Power Unit (APU) had shut down. The co-pilot then moved the APU selector to SHUT OFF but left the aircraft battery ON to facilitate RTF communications. He did not make a RTF call to inform ATC of the incident.

At the conclusion of their walk round checks the commander reboarded the aircraft and was in the galley adjacent to the R2 door, along with the OSE and the Turn Round Manager (TRM), when the NLG retracted. Although some hot drinks were spilled onto the TRM none of the personnel in the galley were injured. An engineer who was seated in the forward cabin was also uninjured. A member of the cargo loading crew who was standing on a Unit Load Device (ULD) Loader next to the forward cargo door was struck on the head by the cargo door as the aircraft fell to the ground. He suffered minor injuries and was taken to hospital for examination.

After checking there were no injuries in the cabin, the commander and the OSE went to the flight deck. The commander and co-pilot left the flight deck to check for safe egress routes from the aircraft. The OSE then turned off the inertial reference system and all electrical power.

The airport RFFS arrived and entered the aircraft through the L2 door which had been extensively damaged by contact with the access stairs when the NLG retracted. The RFFS suggested that all on board should vacate through the L2 door but due to safety concerns related to the escape slide in the damaged door, the commander suggested that R1 was used when additional steps arrived.

When the crew exited the aircraft, they were confronted by a large number of people who wished to gain information from them. The crew described the situation as “mayhem” and felt the pressures from ground staff impeded their conduct of post-incident duties.

History of ground maintenance actions

Assigning maintenance teams

The maintenance shift started at 0530 hrs and the ramp maintenance management team assigned an experienced LAE, a technician and two mechanics to prepare the aircraft for flight. The technician was known to the LAE but had not worked with the other team members before and was not experienced on B787 aircraft maintenance operations. Of the two mechanics, one was experienced (Mech 1) on the B787 aircraft and had worked extensively with the LAE before. The other (Mech 2) had been seconded from the Cabin Excellence Team (CET) to pass on knowledge and experience of cabin and seat maintenance to the rest of the team whilst unofficially gaining knowledge and experience of ramp maintenance himself. It was a two-way process. The cabin work undertaken by the CET was being subsumed into the ramp maintenance teams’ responsibilities because the CET role was to be discontinued.

The maintenance team reached the aircraft to carry out their routine external checks at 0605 hrs. Once complete, the two mechanics plus the technician made their way to the flight deck to switch the aircraft batteries on whilst the LAE applied external ground power to the aircraft. Mech 1 plugged in the maintenance laptop to review any EICAS status messages as various aircraft systems were brought online.

NLG solenoid error messages

Once on the flight deck the LAE found that the maintenance laptop showed three NLG solenoid faults as well as an existing Acceptable Deferred Defect (ADD) for a NLG door solenoid fault from 13 June 2021. The LAE accessed the information related to the fault in the Aircraft Maintenance Manual (AMM), the Dispatch Deviation Guide (DDG) and the Fault Isolation Manual (FIM) and judged that there would be insufficient time to rectify the faults before the aircraft's scheduled departure time at 0720 hrs. The LAE consulted the DDG which confirmed rectification of the three NLG solenoid faults could be deferred providing the NLG doors were recycled to determine that they functioned correctly. To recycle the NLG doors, the landing gear downlock safety pins would have to be fitted to prevent the landing gear from retracting on the ground, the hydraulics applied to the aircraft and the landing gear selector lever set to UP and then back to DN (Down).

Inserting landing gear downlock pins

During the LAE's assessment of the faults, the flight crew arrived, so the technician and both mechanics left the flight deck and moved to the galley area to await instructions. The LAE was sat in the left seat with the maintenance laptop and an electronic tablet on his lap whilst also consulting the aircraft tech log screen. The FO was sat in the right seat to begin crew preparations. The LAE asked Mech 2 to put the downlock pins in and Mech 2 relayed the message to Mech 1. Mech 1 asked Mech 2 if he had inserted downlock pins into the landing gear of a B787 before. Mech 2 stated he had not, so Mech 1 retrieved the five landing gear downlock pins from the flight deck stowage and exited the aircraft with Mech 2. The technician also left the aircraft to sit in the team's vehicle to stay out of the way of the now busy flight deck and galley area.

Mech 1 looked for a set of small steps which would enable him to reach the NLG lock link downlock pin hole but could not see any. However, as Mech 2 was tall enough to insert the pin without needing steps, Mech 1 decided to show Mech 2 where to insert the pin. As both mechanics crouched down to the left side of the NLG and looked up into the NLG bay, Mech 1 pointed to the downlock pin hole and asked Mech 2 to insert the pin. Mech 2 reached up and inserted the pin into the NLG while Mech 1 moved back to give him room. Mech 1 heard the pin "click" as it was inserted and, as Mech 2 moved out of the way, he looked up to see the pin was inserted, although he did not consciously check that it was inserted in the correct position. He pulled on the pin warning flag that was hanging down from the NLG downlock pin to confirm that the pin was held firmly in place.

Both mechanics left the NLG bay and, after locating a set of large steps, Mech 1 fitted the Main Landing Gear (MLG) downlock safety pins. The steps were moved a few feet from the inboard, left MLG door to avoid contact during the slight movement of the landing gear when hydraulics were applied.

Preparing for application of hydraulics

Both mechanics returned to the flight deck and informed the LAE that the downlock "pins were in." The mechanics then exited the aircraft and Mech 1 collected a headset from their vehicle to enable communication with the LAE on the flight deck. Once the headset was plugged in to the NLG bay connection, the LAE instructed Mech 1 to make sure the cargo loading team were clear of the aircraft because the "landing gear moves slightly" when hydraulic power is applied. There was a risk of damage if the cargo door or surrounding fuselage structure moved and hit the ULD Loader. In addition, loading team personnel standing on the ULD Loader's platform might be injured when the aircraft moved. As he was positioned to the left of the NLG bay, Mech 1 ducked under the fuselage to talk to the loader who was standing on the ULD Loader at the forward cargo door on the front right side of the aircraft. He asked the loader to lower the platform and move clear of the aircraft.

Mech 1 asked the LAE to switch on the aircraft's anti-collision lights to warn personnel working in the vicinity not to approach the aircraft. From his position left of the NLG bay he could see no feet visible on the ULD Loader and two loading personnel walking away from the aircraft. He informed the LAE that the loaders were clear of the aircraft. The LAE asked if they were "clear for hydraulics?". From his position near the NLG, Mech 1 quickly looked underneath the fuselage, and the right, rear and left sides of the aircraft. All areas appeared to be clear of personnel and equipment sufficiently far from the aircraft to avoid contact with the aircraft. He confirmed the area was clear and the LAE applied hydraulic power. The LAE then asked Mech 1 to confirm that the downlock pins were fitted and that the landing gear could be cycled.

Mech 1 completed a final visual check and observed that the landing gear ground lock pins warning flags were visible; one flag showing from the NLG bay and two each from the MLG bays. Mech 1 asked Mech 2 to step back from the aircraft and confirmed to the LAE that they were ready for the gear up selection. The LAE announced he was selecting "gear up", pressed LOCK OVRD (override) and moved the landing gear selection lever to UP.

The aircraft shuddered as the NLG retracted and the nose of the aircraft struck the ground.

Accident site

The aircraft was parked on Stand 583 in the Terminal 5 area of Heathrow when the event occurred, (Figure 1).

On the stand, the aircraft was resting on its nose with no NLG visible (Figure 2) but with both MLGs down and their down locks in place.

The front lower fuselage and both NLG doors were badly damaged, and the doors were partially detached from their hinges. Crushed underneath the nose was a metal articulated conduit containing the ground power supply cables (Figure 3).

On the left side of the aircraft, aft of the NLG bay, deep vertical scratches were scored into the fuselage skin where it had been in contact with the fixed power unit when the nose lowered to the ground. The fixed power unit was also deformed and damaged by the impact with the aircraft (Figure 4). There were signs of distressed rivet heads along the bulkhead rivet lines forward and aft of the NLG bay.

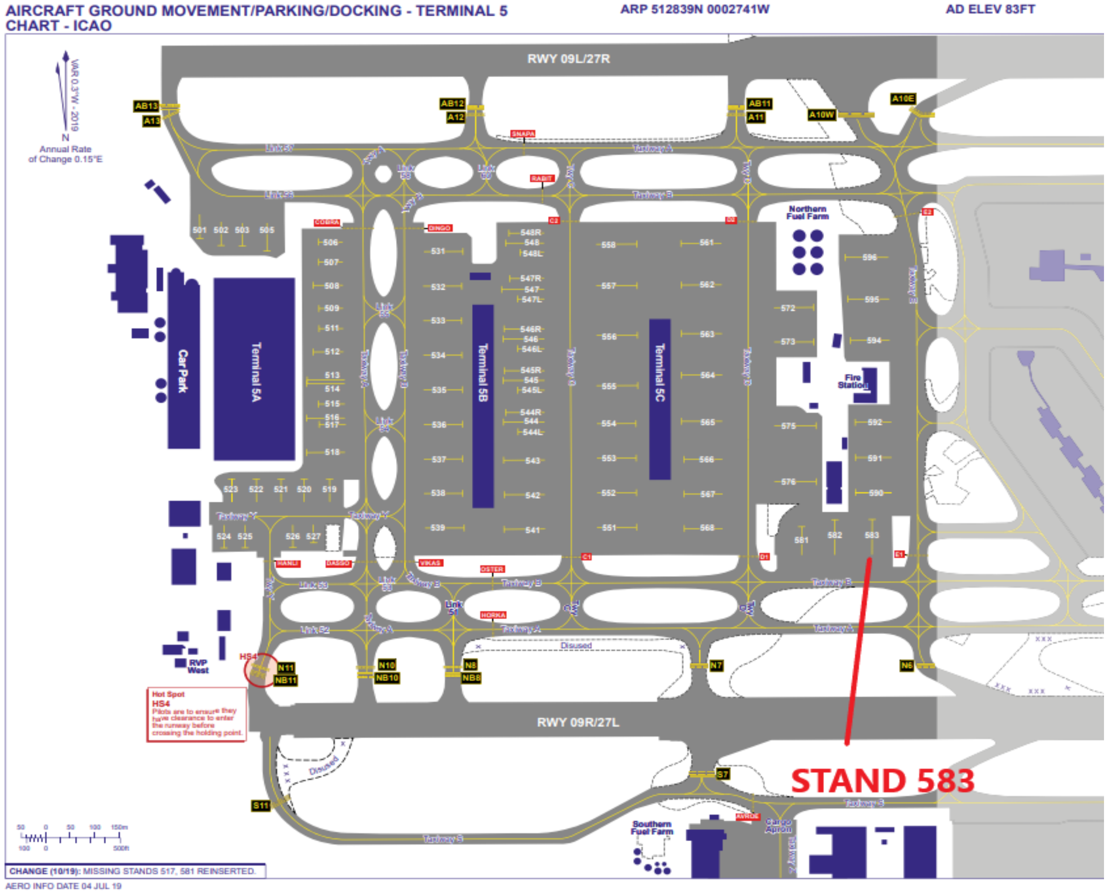

Figure 1

London Heathrow Terminal 5 parking stands

Figure 2

View of right and left side of the aircraft following NLG retraction

Figure 3

View of the damaged NLG doors and crushed ground power supply cables

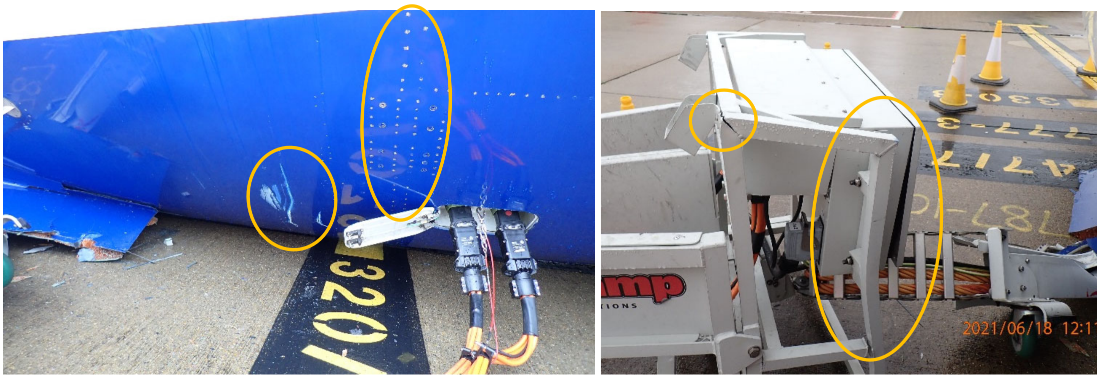

Figure 4

Score marks and distressed rivet heads (left) and damage to fixed power unit (right)

At door L2, motorised covered passenger stairs were still in place. The aircraft passenger door hinges had been disrupted during the accident sequence and the door was resting on the horizontal platform at the top of the stairs. The stairway's platform was approximately 2 feet higher than the lower door frame (Figure 5).

The aircraft's engine cowlings were resting on the ground and the inboard left MLG door had been damaged by contact with the large steps positioned nearby. The steps' safety handrail had bent slightly following contact with the MLG doors.

On the right side of the aircraft was an access stairway that had been positioned at door R2 to allow safe access to the aircraft after the accident. At the forward cargo door was the ULD Loader for raising cargo pallets to the height of the aircraft cargo hold and transferring them to the aircraft. There was slight damage to the aft vertical cargo door frame caused by contact with the ULD Loader when the aircraft nose lowered to the ground (Figure 6). The rear cargo door was also open but there was no ground support equipment at that location.

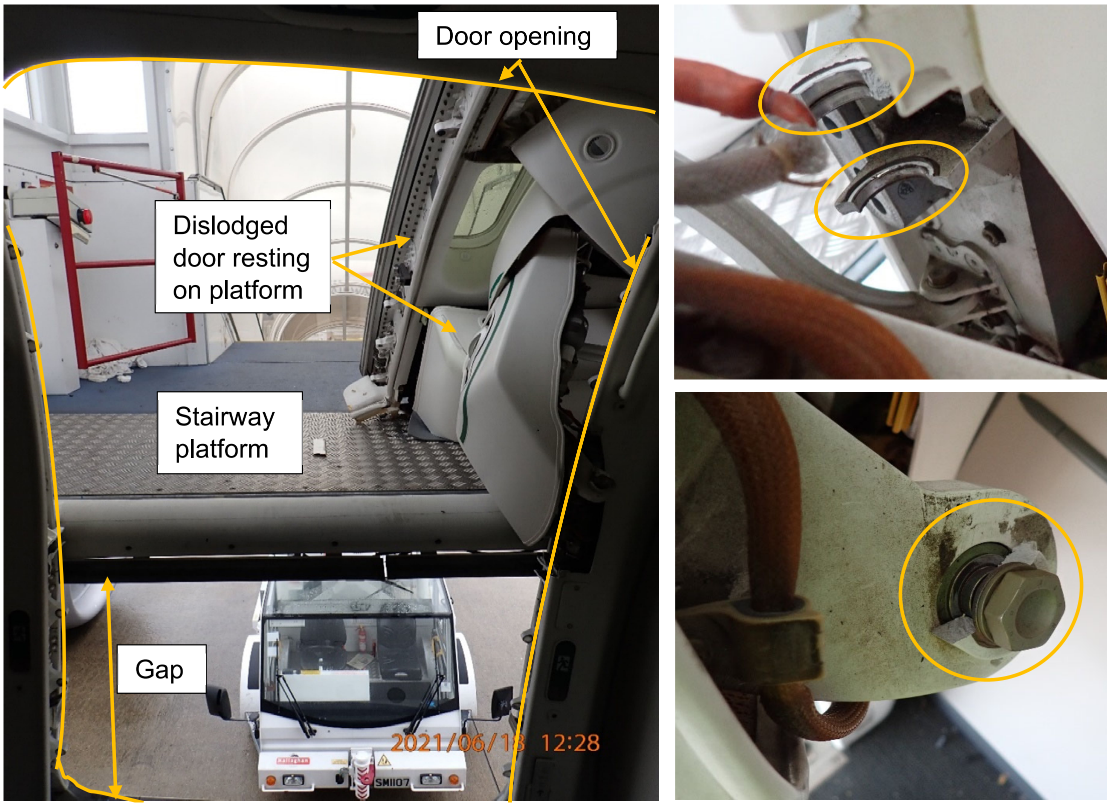

Figure 5

View from inside the aircraft showing the door resting on staircase and disrupted door hinges

Figure 6

ULD Loader (left) and impact damage to aft side of cargo door frame (right)

In the cabin, the force of the impact with the ground as the aircraft's nose lowered was sufficient to cause some of the passenger oxygen masks to drop down from their containers and some overhead baggage compartment doors to open.

On the flight deck, the landing gear selection lever remained in the UP position (Figure 7) but AC power had been lost when the nose of the aircraft crushed the ground power cables.

The aircraft batteries had been switched off by the OSE to make the aircraft safe following the accident. The CVR and FDRs were recovered and sent to the AAIB for data retrieval and analysis.

Figure 7

Landing gear selector lever in the UP position

Recovery action commenced by raising the aircraft nose using a system of pneumatically inflatable mats. As the nose was raised, the NLG lowered under gravity, (Figure 8), until it was in its down position.

Figure 8

Aircraft nose was lifted using pneumatic inflatable mats

NLG downlock pin location

When the NLG bay was accessed, the NLG downlock pin was found to be in the leg's apex bore hole rather than the downlock pin hole (Figure 9). The downlock pin was transferred to the correct position to lock the gear down and to allow the inflatable mats to be removed so the aircraft could be towed to a suitable quarantine hangar.

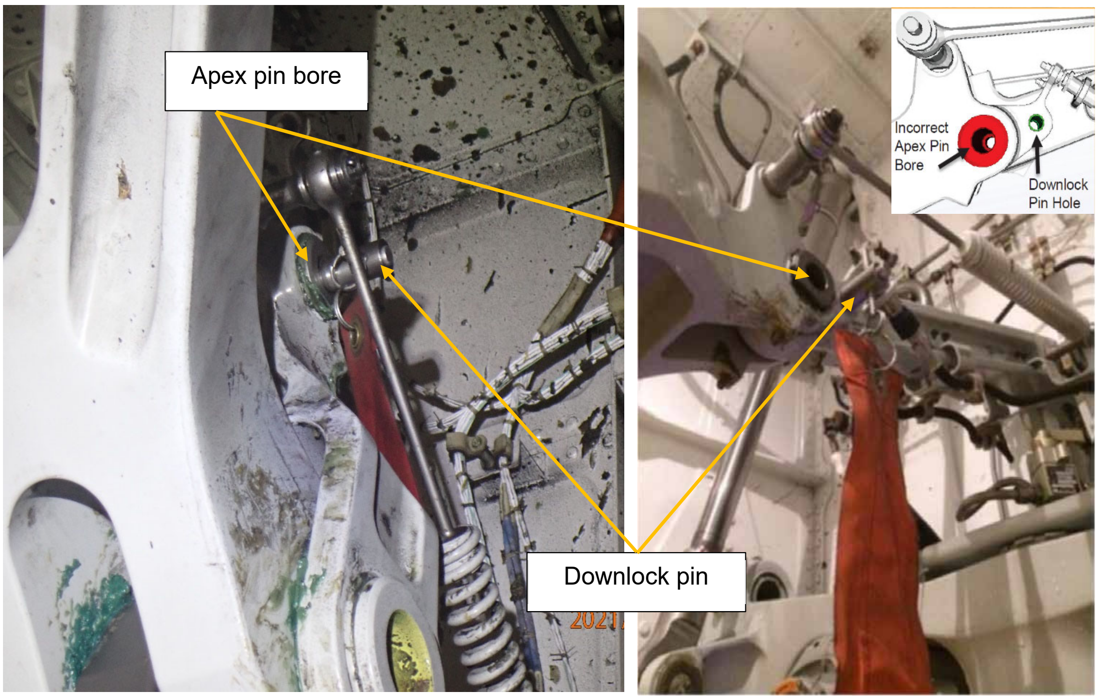

Figure 9

Downlock pin incorrectly fitted to the apex pin bore (left) and an example of the correct location of the pin for comparison (right)
Image used with permission

Post-Incident Response

Immediately following the event at 0651 hrs the operator's personnel on Stand 583 telephoned their Maintenance Office to inform them of the event. They then phoned the Airport Operations Centre (APOC) at 0653 hrs and 48 seconds, on 222, the internal emergency number, to alert the Emergency Services. The operator found the caller difficult to hear due to background and wind noise. The airport operator triaged the call and, in this case, passed the event to the Fire Desk at 0654 hrs and 39 secs. The Fire Desk officer also had difficulties with the audio on the call due to the background and wind noise and had to repeat questions to be sure of gathering the correct details. At 0655 hrs and 55 seconds the Fire Desk called Heathrow ATC[1] to request a deployment under the terms of Local Standby Ground (LSBYG).

LSBYG is a local definition for events where there is no visible fire or smoke and no reported injuries. It is used where an event is sufficiently serious to warrant an emergency response but below a threshold that would require support from agencies outside of Heathrow. The description of LSBYG from the airport Emergency Orders is at Figure 10.

Local Standby - Ground

G. LOCAL STANDBY - GROUND

General Information

Definition	An Aircraft on the ground is involved in an incident of a lesser nature than an AIRCRAFT GROUND INCIDENT. There are NO reports of smoke, fire, or injured persons from or on an aircraft. Non-exhaustive Examples: An aircraft on the ground: • Requires External Assistance (i.e. an inspection by the AFRS) • Hydraulic Leak • Fuel Leak / Spill • Vehicle / Ground Handling Equipment Hit Aircraft • Deployment of Aircraft Evacuation Chutes Known to be Accidental • A domestic fire where an aircraft is at risk.
Emergency Services Response	Police alerted and AFRS attend
Initiated by	ATC, using the EMERGENCY Line
Upgrade	Yes, by ATC to AIRCRAFT GROUND INCIDENT on the CRASH Line ATC to nominate the RVP THREAT TO AIRCRAFT (By Police only)
Downgrade	None
Cancellation	By ATC on the EMERGENCY Line following confirmation that the incident is over from the AFRS Incident Commander.
Overall Co-ordination	AFRS Incident Commander

Figure 10

Emergency Orders description of LSBYG

A LSBYG event is co-ordinated by the RFFS incident commander. When he arrived on scene, he observed there was no smoke or fire and no injuries were reported to him. He

Footnote

1 All events at the airport are initiated under the authority of ATC.

was therefore content to retain the LSBYG classification. The Police Duty Inspector for the airport attended the scene and had a briefing with the RFFS incident commander at which the LSBYG classification was discussed. The Police Inspector did not agree with the categorisation, but as the RFFS commander considered no off airport resources were required, he decided to maintain the LSBYG status.

The next higher category of incident is an Aircraft Ground Incident (AGI). The description of AGI from the airport Emergency Orders is shown at Figure 11.

Aircraft Ground Incident

D. AIRCRAFT GROUND INCIDENT

General Information

Definition	An aircraft on the ground is involved in an incident of a lesser nature than an AIRCRAFT ACCIDENT, there **ARE** reports of smoke / fire or odours and / or there **ARE** reports of persons injured. It is not necessary for another aircraft or a vehicle to be involved in an AIRCRAFT GROUND INCIDENT. Non-exhaustive examples: • Smoke, Fire or Fumes on or within aircraft • Smoke or Fire on equipment attached to aircraft • Smoke or Fire on stand, whilst an aircraft is on stand • Emergency deployment of aircraft evacuation chutes (non-accidental) • Unknown reason for deployment of aircraft evacuation chutes • Injury of individual / multiple Injuries • Incapacitated Aircraft without smoke / fumes or fire
Emergency Services Response	Full
Initiated by	ATC, using the CRASH Line
Upgrade	Yes, to AIRCRAFT ACCIDENT, by ATC on the CRASH Line
Downgrade	Yes, to LOCAL STANDBY GROUND, by AFRS Incident Commander through the Heathrow Fire Desk to ATC, then broadcast by ATC on the EMERGENCY Line
Cancellation	By AFRS Incident Commander through the Heathrow Fire Desk to ATC, then by ATC on the EMERGENCY Line
Overall Co-ordination	A senior Police Officer is appointed as the Police Incident Commander and is responsible for taking charge of the overall co-ordination of activities at the incident site.

Figure 11

Emergency Orders description of AGI

The descriptions of LSBYG and AGI give examples of the types of event expected to be covered by the classifications. The examples in Figure 12. include an '*incapacitated aircraft without smoke/fumes or fire*'. Some personnel in the airport response organisation concluded from the incapacitated aircraft statement that the event should have been categorised as AGI.

The Police and the Ambulance Service initially deployed their predetermined response for an AGI but these resources were stood down.

The airport Emergency Orders are published and controlled by an Emergency Orders Group which draws representation from a wide range of stakeholders at the airport.

Due to the proximity to one of the operator's maintenance offices a large number of the operator's personnel were quickly at the scene of the event. While some of these personnel, such as the members of the operator's aircraft recovery team, had a legitimate reason for their presence the majority were not required. The Emergency Services had a limited number of personnel at Heathrow and they were focused on their operational role. They did not have the capacity to release personnel to conduct crowd or traffic control. In the airside environment it was not appropriate to use incident tape to cordon a scene due to the FOD risk presented by the tape. The RFFS commander considered that the large numbers of uncontrolled personnel in the vicinity caused a reduction in the safe conduct of the incident response.

When the flight crew left the aircraft, they were immediately met by a number of personnel from various organisations who began to question the crew on the event and their actions. The flight crew reported that this impeded the conduct of their duties in the time immediately following the incident. Some of the maintenance personnel involved were taken from the scene by one of the operators Quality engineers for their wellbeing. The airport Police were concerned that it may have represented an attempt to coach witnesses on their statements as it took a significant period of time before the location of the witnesses could be subsequently established. The operator stated that the personnel involved were taken off the ramp to facilitate their preparation of statements.

The airport Emergency Orders give predetermined actions for many individual agencies to create a rapid and cohesive response to events on the airport. For an AGI an automatic response for airport security to attend the scene and provide a cordon is included. This provision is not part of the automatic response to a LSBYG and so no personnel were deployed to cordon the event.

Also included in the AGI response is the creation of an Equipment Assembly Point on the airport. This is defined in the airport Emergency Orders as '*The Equipment Assembly Point (EAP) is a nominated stand where equipment and personnel assemble prior to being called forward to the scene of an accident or incident under Airport Escort Vehicle escort. The EAP is relayed to the Airline / Handling Agent, Airport Control (APOC) and other appropriate agencies by the Airfield Control Room following consultation with the Aircraft Operations Unit'.* The EAP provision is not part of the LSBYG actions.

If an AGI is declared the London Fire Brigade have a predetermined immediate response which consists of four pump appliances and some specialist units. This would require a deployment from at least two fire stations. While this is a significant response the Fire Brigade stated that it could be accommodated without disruption to other operations.

The London Ambulance Service predetermined response consists of two ambulances, two response vehicles with management personnel and a Hazardous Area Response Team with four vehicles. The Service views this as a significant response but it is manageable without serious impact on other operations.

The operator deployed a passenger coach to the site of the incident, and this was used to conduct on site operational briefings and some initial witness interviews. It also provided shelter from the inclement weather. The airport does not have a command post vehicle to fulfil such a role.

The Operator's emergency response system

The Operator has an internal incident response system to manage serious events. This is based around an escalation scale of four levels dependent on the severity of the event and its likely impact on the operation. The definitions of the four levels are shown in Figure 12.

Escalation levels

Normal Ops is the day-to-day management of global operations, airport and engineering operations, with regular coordination meetings, communication messages and interactions to deliver the planned schedule. Includes management of minor 'on-the-day' ad hoc adjustments to the schedule where there is no overall pattern or causal reason
Bronze command is established to coordinate the management of customer impact incidents within key operational teams and control centres – e.g. delays, diversions & cancellations of scheduled services where 'Normal Ops' processes would not provide adequate control and resolution of issues from both an operational and customer point of view. It also may be stood up to oversee the implementation of an Operations Planning Group (OPG) plan. It should also be stood up in anticipation of a deterioration of operational performance based on agreed triggers, led by the Accountable Manager Operations. To oversee recovery and de-escalation.
Silver command is established to coordinate the management of significant global disruption events causing large scale global regularity and punctuality impacts for prolonged periods. It also may be stood up to oversee the implementation of an OPG plan. Representation is from selected departments within and outside of 'operational' areas. It should also be stood up in anticipation of a deterioration of operational performance based on agreed triggers, led by the Crisis Management Team Leader. To oversee recovery and de-escalation.
Gold command is established to manage any corporate crisis such as serious aircraft incidents or threats to life and/or assets. A full 'corporate response' may be required which will be determined by the Crisis Management Team Leader. It also may be stood up to oversee the implementation of a Contingency Planning Group (CPG) plan.

Note: Silver and Gold can both be run at the same time. In this instance, Silver would manage the recovery of the global operation and Gold would manage the crisis

Figure 12

Operator's Incident Response Levels

The system is designed to facilitate the management of any crisis which affects the operator's network and therefore makes provision for dealing with weather, commercial, security and technical events as well as airfield emergencies. The response levels do not therefore correlate directly with those of the airport. At Silver and Gold levels the operator's response is led by the Crisis Management Team (CMT) Leader who reports to the Chief Operating Officer. At Silver level the CMT has representation from selected departments within the organisation. At Gold Level the operator's Crisis Management Centre (CMC) is activated and all departments of the company are represented. The operators orders allow for the CMC to be activated at Silver but this was not done for this event. Also at Gold, an Incident Site Leader is appointed by the operator to liaise with the Emergency Services and to feed information to the Safety and Security team in the CMC.

In this event Silver command was declared and so the CMC was not activated, and no Incident Site Leader was appointed.

The operator stated that in general Gold level events were generally declared for incidents that involved large numbers of passengers.

The operator has an Emergency Liaison Vehicle (ELV) at Heathrow which can be used to facilitate communications with the emergency services on scene. The airport Emergency Orders for LSBYG call for the operator to prepare to deploy equipment, but to only deploy to the EAP when an AGI or greater is declared. In this event the ELV was not deployed.

Engineering Aspects

Authorised maintenance personnel

Under the terms and within the scope of work of UK Part 145[2] Approval, the Operator's engineering organisation had been approved to issue maintenance certification authorisations to suitably qualified and competent staff for the purpose of performing and certifying maintenance activities on their aircraft.

The Operator's aircraft maintenance authorisations were designed to align with UK Part 66 licence categories as far as possible and incorporated multi-trade activities linked to aircraft types. Engineering training courses, which support maintenance authorisations, were aligned to these certification requirements and structured accordingly. Engineering maintenance authorisations, their UK Part 66 category and UK Part 145 certifications were related as follows (Table 1):

Engineering Authorisations	Part 66 Licence Category	Part 145 Certification of Maintenance
M7 – Mechanic identification stamp only M6 – signifies competence in cabin M5 – signifies competence on a specific type	None	None
A3/A4 – Technician must be trained on type to issue a Certificate of Release to Service (CRS)	Category A	Limited Line Maintenance Certifier
B1/B2 – Licensed Aircraft Engineer with type rating	Category B	Line Maintenance Certifier

Table 1

Authorisations and equivalent UK Part 66 and UK Part 145

Footnote

[2] Part 145 Approval – Approval for maintenance of any Part 21 aircraft and engines or fitted components. Part 21 regulates the approval of aircraft design and production organisations and the certification of aircraft products, parts and appliances.

The LAE was a category B1 licensed engineer (aircraft structure, powerplant, mechanical and electrical systems and limited avionics systems) who was type rated on the Boeing 787 in October 2017. He had 11 years of experience as a B1 engineer. His authorisations were current, and he had received some team leader training.

The technician held an A3 Authorisation for the Boeing 777 from 2006 and an M6 (interiors) Authorisation for all the Operator's aircraft types. Other than the M6 (Interiors) no further authorisations for the Boeing 787 were held. The technician had joined the ramp shift in December 2020.

Mech 1 had worked for the Operator since 2012. He held M5 Authorisations for the Boeing 777-200 (including landing gear familiarisation) and M6 (interiors) on all aircraft. Both were valid at the time of the accident. He had completed a five-day B787-8/-9 General Familiarisation course in 2013 which included fitting landing gear downlock pins, and an A3 course in 2014. Although he held no specific B787 Authorisations, he was working on his basic license modules and experience log prior to the accident. His last competency assessment was July 2020 which was valid for 4 years.

Mech 2 held M6 (interiors) and M7 (greasing) Authorisations on the Airbus A380 and had received some familiarisation training on the A380 landing gear. No Boeing 787 Authorisations were held. The mechanic worked within the CET until seconded to the ramp maintenance teams in January 2021 to pass on accumulated knowledge of interiors maintenance. Mech 2 was eager to widen his experience and was undertaking informal on-the-job training by assisting with other ramp maintenance tasks where possible.

Access to electronic aircraft documentation

Chapter 32-00-30 of the AMM contains the instructions for fitting the landing gear downlock pins. The instructions are 12 pages long despite the task being regarded as relatively straightforward. Both the LAE and Mech 1 felt familiar enough with the instructions in the AMM to be able to complete the task without reference to it. The mechanics were issued with company iPads that had a 'Pinpoint' application installed for accessing aircraft maintenance data and manuals. However, the B787 (and Airbus A350) manuals were not installed, therefore, the Mechanics could not have used their iPads to view the task or for Mech 1 to step Mech 2 through the instructions to fit the pins. Whilst the AMM could have been accessed via the Maintenance Laptop, this was already in use by the LAE on the busy flight deck.

NLG mechanism and operation

The NLG consists of a shock strut, an extension and retraction mechanism, (Figure 13), two unbraked wheels, a torque link and a nosewheel steering system. The shock strut provides shock absorption to dissipate the vertical forces experienced during aircraft taxi, takeoff and landing. The strut uses a mixture of compressed air, which acts as a spring to absorb vertical shock loads, and hydraulic oil, which provides damping to reduce the harmonic bouncing effect of the compressed air spring.

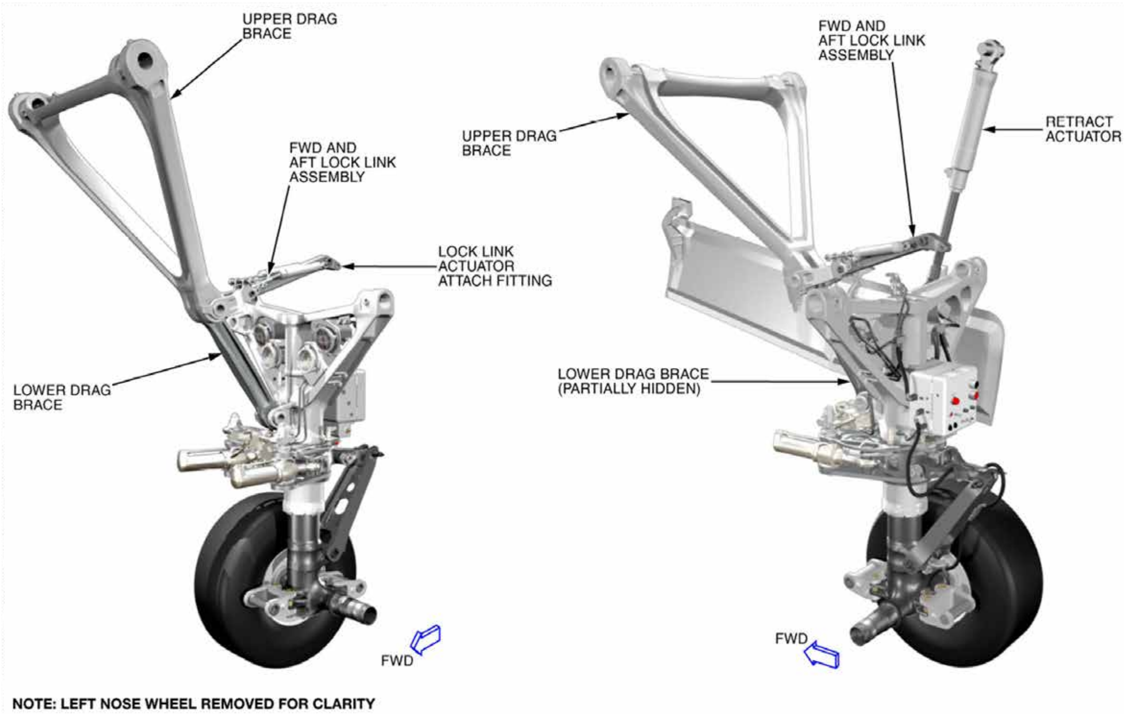

Figure 13

NLG showing the extension and retraction components
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The extension and retraction mechanism employs a hydraulic NLG lock actuator to lock and unlock a lock link assembly. The lock link assembly is designed to form a geometric lock when it is in an over-centre position which prevents the landing gear from retracting or extending. Lock link springs hold the over-centre position when there is no hydraulic pressure to the actuator. During the NLG retraction process, hydraulic pressure forces the lock link actuator piston to retract which in turn causes the lock link assembly to move away from the over-centre position, unlocking the NLG. Hydraulic power to the NLG retract actuator then forces the NLG to retract into the wheel bay. The lock link actuator piston moves the lock link assembly to the over-centre position again where the actuator and springs fix it in position, thereby locking the NLG in the up position (Figure 14).

During the NLG extension process, hydraulic pressure is supplied to the lock link actuator piston to remove the over-centre position of the lock link assembly and unlock the NLG.

The NLG pivots down under gravity. Once down, the lock link actuator drives the lock link assembly into the over-centre position where springs and the actuator hold the assembly in place. This locks the NLG in the down position (Figure 15).

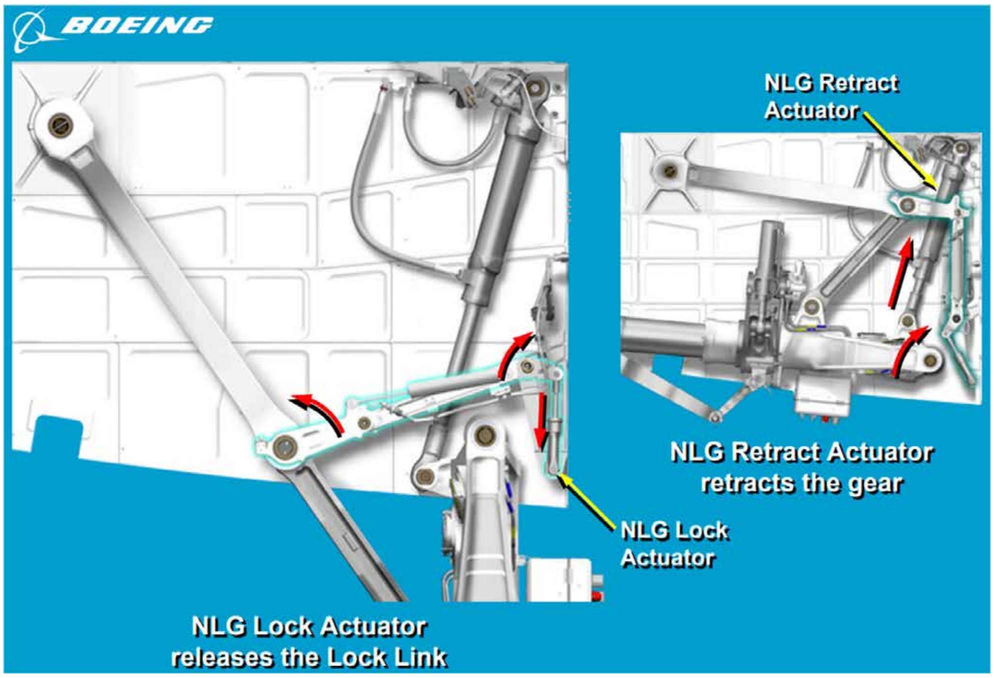

Figure 14

NLG lock link release from over-centre and gear retraction process

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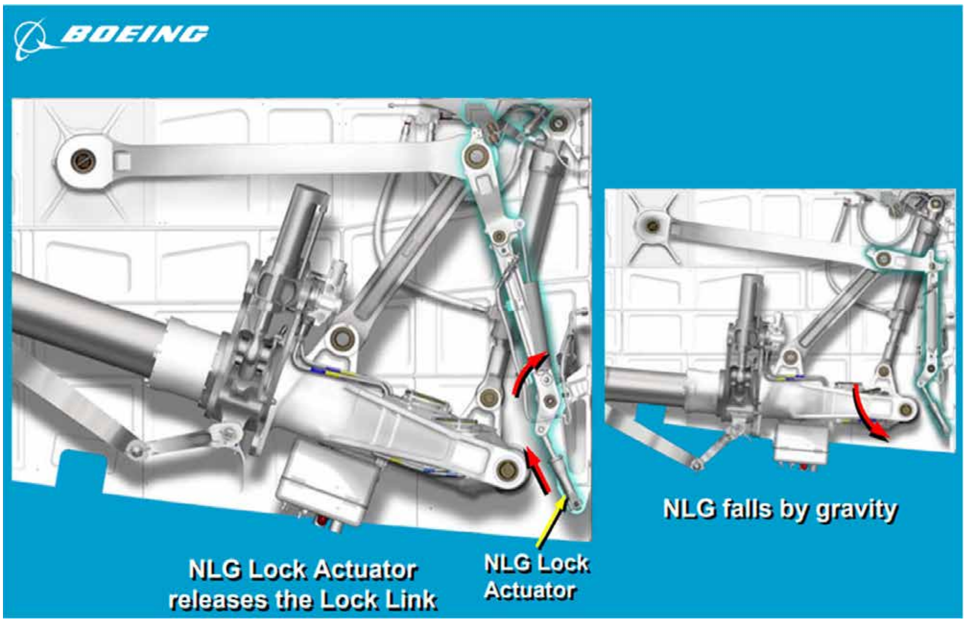

Figure 15

NLG lock link release from over-centre and gear extension process

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The lock link assembly can be prevented from moving away from the over-centre position with the aircraft on the ground and during maintenance procedures by using a downlock pin. The pin is inserted in the downlock hole, aft of the lock link assembly apex pin bore hole, to fix the lock link in position and prevent retraction of the NLG even with hydraulic power applied and the landing gear selected to UP (Figure 16).

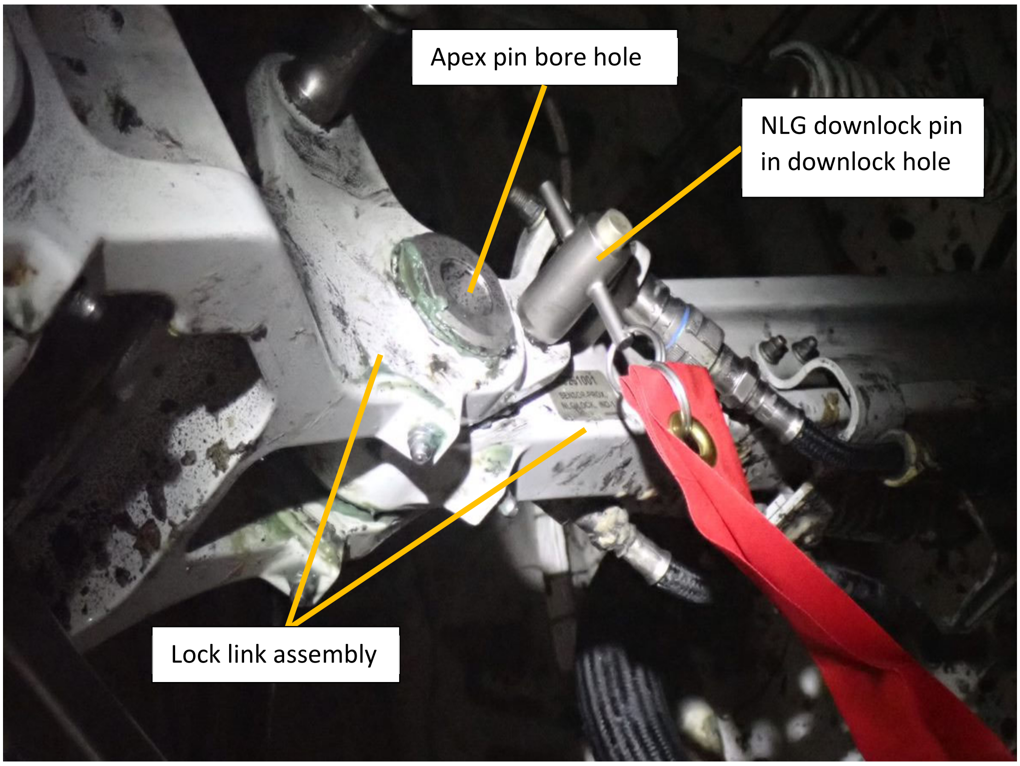


Figure 16

NLG downlock pin inserted into lock link assembly downlock hole

Assessment of the NLG pin insertion task

A specific small set of steps (not the same as those needed to fit the main landing gear pins) was required to fit the NLG downlock pin, unless the maintainer was tall enough to do this as an overhead task or chose to climb on the wheels to reach the downlock pin hole. The position of the NLG doors and the limited amount of space in the NLG bay did not allow two people to stand upright together and look at the area where the pin must be fitted. Even in daylight, light in the bay was limited and a torch was required to properly see the area. There were no distinguishing markings or labels to identify the downlock pin hole and the apex bore hole.

The design of the B787 NLG downlock is unique and significantly different from other Boeing aircraft. The downlock pin can be easily inserted into the apex pin bore hole. When it was fitted in this position it made a ‘click’ noise similar to the noise made when fitted into the correct downlock pin hole. The pin, when seated in the apex pin bore hole, had enough friction to stop it moving or coming out when the attached ‘*remove before flight*’ flag was tugged.

History of incorrect insertion of the NLG downlock pins

By 2018 there had been two incidents reported to Boeing of B787 NLG retractions on the ground with weight on wheels because the NLG downlock pin had accidentally been fitted to the apex pin bore when landing gear UP was selected. The second occurrence was at the Boeing facility in March 2018. The manufacturer initially raised a Service Related Problem (SRP) to investigate the NLG downlock pin problem and to identify corrective action[3].

Notifying Operators

Boeing determined immediate interim corrective actions that would reduce the overall fleet risk. As a result, they released a Multi-Operator Message (MOM) on 21 March 2018 which described the NLG downlock pin location problem and included an illustration of the correct and incorrect positions of the pin.

MOMs are distributed to a pre-arranged list of recipients which includes Boeing Field Service Bases that support customer operations. Field service bases maintain communication with customers about MOMs to ensure they are aware of the content. Boeing's Heathrow field service base confirmed that they had received it and discussed the content with the airline at the operator's Fleet Team Conference on 23 October 2018. The option to fill the apex bore hole with silicone sealant to prevent the downlock pin from being incorrectly fitted, and a Fleet Team Digest (FTD)[4] article which would provide more detailed information, were also presented at the conference.

The MOM was followed by the publication of the Boeing FTD[5] article on 3 May 2018. The article described the NLG retraction incidents, the risk of inadvertent insertion of the downlock pin in the apex pin bore and provided a reference to AMM 32-00-30. The reference contained the procedure for fitting the NLG downlock pin and illustrations showing the correct location. The FTD also provided details on the option to fill the apex pin bore with PR1422 sealant in accordance with the Boeing Standard Overhaul Practices Manual (SOPM) 20-50-19. G-ZBJB's operator stated that they regarded the FTD publications as a good source of information and they proactively accessed FTDs issued by the manufacturer. No immediate action was mandated by the FTD although the publication was later referenced in an article in the operator's Technical News (explained later in the report) to inform maintenance personnel of the problem.

Development of the Service Bulletin and Airworthiness Directive

Boeing evaluated the two reports of prior inadvertent nose gear retractions on the 787 fleet and determined that a Service Bulletin (SB) should be generated to provide

Footnote

3 An SRP is an internal document to Boeing and was not for release to aircraft operators.

4 FTDs are intended to convey up-to-date technical information to operators at a working level on in-service issues. FTDs are published by Boeing on the 'My Boeing Fleet (MBF)' web portal and the content is searchable by operators who use the service. Operators can be alerted to new FTD articles using communications such as MOMs.

5 787-FTD-32-18003.

corrective action to operators. The FAA and Boeing worked independently to assess the task, collaborating during various stages, to consider the risks, evaluate the criticality to the fleet of any corrective actions, provide a priority rating, determine a compliance time and assess the complexity of any corrective actions. Following a period of evaluation, an Airworthiness Directive (AD) was raised by the FAA to mandate the SB. A 'sanity check' was also completed whilst evaluating the AD compliance times. If the corrective actions were relatively easy and materials readily available, the FAA reserved the right to adjust the compliance time to reduce the risk to the fleet sooner than indicated by the analysis.

Boeing released Issue 001 of SB B787-81205-SB320040-00 on 12 March 2019 as a 'Special Attention' category[6] bulletin with a three-year compliance time from the date of the SB. Although the SB only refers to a single event plus receipt of a safety report, the SB highlighted '*the risk of accidental NLG retraction due to easy installation of the NLG downlock pin into the lock link assembly apex pin'.* The SB provided instructions, including details of a kit of parts, to install an insert into the NLG lock link assembly apex pin inner bore to prevent inadvertent insertion of the downlock pin (Figure 17).

The FAA evaluated the SB using their risk analysis process to assess the statistical risk to safety. The process determined the Risk Outer Marker Time (ROM-T) which was divided into three event times: corrective action development time, rulemaking time and compliance time. The times were agreed between Boeing and the FAA with specific dates the FAA would receive the manufacturer's proposed corrective actions. The FAA's evaluation established that a Notice of Proposed Rulemaking (NPRM) with a priority rating[7] of 'normal' was appropriate. The NPRM was published in the Federal Register on 23 July 2019. Following a period of consultation with B787 operators, AD 2019-23-07 was issued on 12 December 2019 with a three-year compliance period beginning on 16 January 2020.

The compliance period was calculated jointly by Boeing and the FAA based on an assessment of risk encompassing all inadvertent landing gear retractions that had occurred to Boeing aircraft since the 1970s. Based on this data set, inadvertent gear retractions on in-service B787s had been reported at a rate of one event per million flight cycles with no reports of injuries. The statistical models at Boeing and the FAA indicated an exposure period greater than 20 years, therefore, the compliance time for the SB and AD was set to 36 months. The aircraft manufacturer confirmed that the location of the B787 NLG downlock pin hole, directly adjacent to the apex bore hole, was unique to the B787 series of aircraft which had been in service with the operator since 2013.

Footnote

6 The Special Attention category generally involves safety issues such as personal hazards that do not threaten immediate airplane airworthiness. It is also used to address issues which have a high economic impact if not incorporated.

7 Priority ratings determine if the FAA needs to generate a normal NPRM, a high priority NPRM or an immediate adoption rule. The FAA has legal standard rule making times associated with each type of rulemaking action.

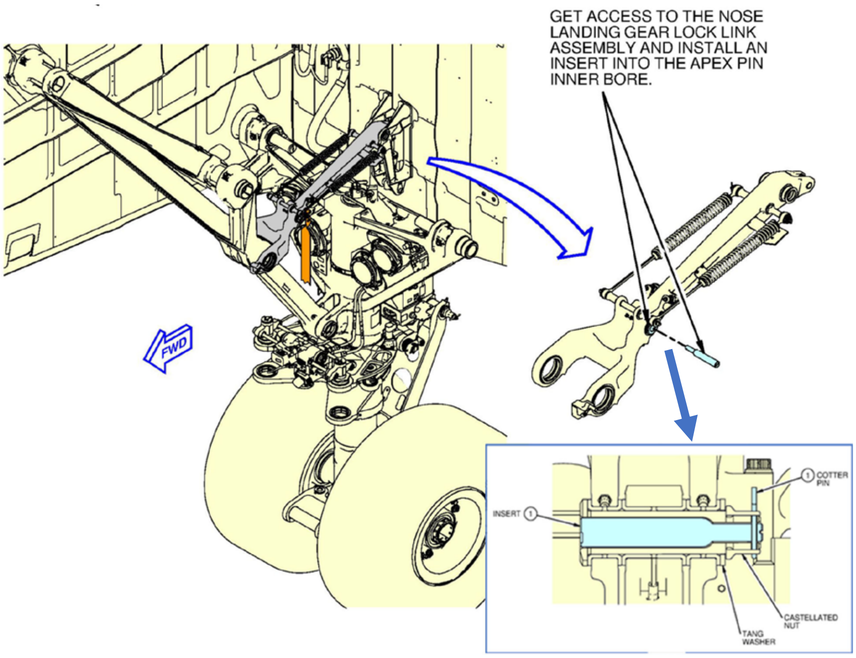


Figure 17

SB illustration of NLG lock link assembly and apex inner bore insert
Copyright Boeing. Used with permission

The operator's response to the SB and AD

Although SB Issue 001 was received by the Operator's Technical Information Management (TIM) team and a Technical Document Response (TDR) raised to review the SB within 30 days of receipt[8], no further actions were deemed necessary at that time. In addition, the apex pin insert modification kits were not made available until 25 June 2019. The Airworthiness Directive (AD) mandating the SB was received by the TIM team on 12 December 2019, one month prior to its effectivity date. It was reviewed within seven days of receipt and another TDR request raised to manage the progression of the AD.

To prepare for installation of the apex pin bore insert and to raise the appropriate modification paperwork, a Technical Order Modification (TOM) process was started in March 2020. However, progression of the SB was put on hold in April 2020 because of the disruption caused by COVID 19 measures. As a mitigation measure, a Technical News article (No ITI-10279007-000-00) was issued in April 2020 to inform engineering teams of the release of the SB and AD and to highlight the potential unsafe condition caused by inserting the NLG downlock pin in the apex bore pin hole.

A two-month review extension was applied to the TDRs to allow time for the modification to be presented to the maintenance organisation's Modifications Committee for embodiment during A and C maintenance checks. This would have achieved fleet implementation

Footnote

8 As required by the Operator's CAMO-Tech Document Evaluation BACOMPANYDOCS-CAMO-01-01-0020-00000-041A-D. Non mandatory documents to be reviewed within 30 days, mandatory documents within 7 days.

by December 2022 and within the three year compliance period of the AD. To defer spending because of the financial impact of COVID, a delay was granted in May 2020 and implementation of the modification replanned to begin between late 2021 and early 2022. However, the Modifications Committee did not meet after the COVID restrictions were imposed in March 2020, so the modification was never presented to the committee, and it remained a work in progress TDR. During this period, all such modifications were to be approved and signed-off by the appropriate stakeholder, in this case the maintenance organisation. Once the modification became free of charge, it was not necessary to seek the approval of the Modification Committee.

Technical News process

The Technical News process was the operator's engineering department's way to communicate important information to staff. It included technical, quality, health and safety and environmental bulletins.

The core content of the technical news was subject to a mandatory read and sign process for everyone in the operator's engineering organisation. Teams were also allocated additional relevant articles according to their role, such as those relating to a specific aircraft type.

Each time a staff member logged on to the technical news application they would be presented with all articles that had been published since the last time they completed the read and sign process. If there had been a long interval since logging on, many pages of information would be presented which would take a number of attempts over time to read and sign for. In 2020, there were 219 articles published of which up to 182 were applicable to the maintenance team.

The software used to present the technical news and record the signature offered little opportunity to filter or prioritise the articles. For the system to consider an article as read, it only needed to be opened. Read and sign compliance was monitored monthly and authorisation to work could be removed if compliance lapsed.

Whilst the read and sign process provided a mechanism for identifying who had read each article, there was no process to determine if the information provided in the articles was effective in raising the awareness of its intended audience.

Downlock pin - Technical News

The *787 NLG downlock pin installation* Technical News was initially issued in April 2020, then re-issued in December 2020 as the 6-month validity date of the original article had expired (Figure 18). It was due to be re-issued again in June 2021.

Technical News

787 NLG DOWNLOCK PIN INSTALLATION

This Tech News is being re-issued to highlight that it may be possible to install the NLG downlock pin in the incorrect position until a preventative modification can be actioned. 787-FTD-32-18003 refers.

BACKGROUND

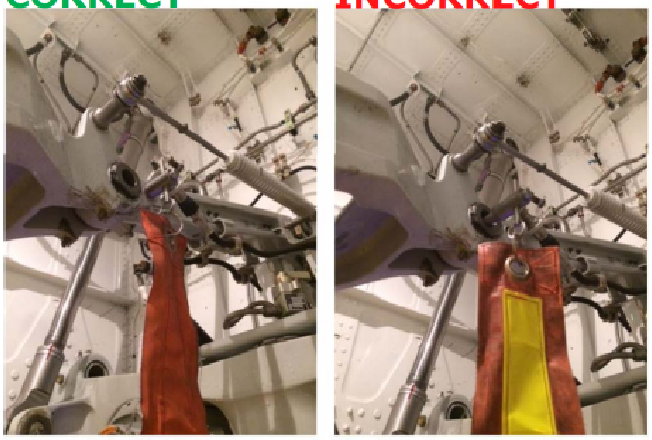
Boeing has received reports of the NLG downlock pin being incorrectly installed in the inner bore of the apex pin on the NLG lock link assembly, adjacent to the correct hole. The correct location is shown in Fig 1 of AMM Task B787-A-32-00-30-00A-720A-A Landing Gear Downlock Pin Installation.

The FAA issued AD 2019-23-07 to address this issue, which could result in the NLG retracting on the ground, possibly causing serious injuries and substantial aircraft damage. The associated SB 320040 installs an insert into the apex pin bore to prevent incorrect installation of the downlock pin. The current 787-8 and -9 fleets will have this SB incorporated before the compliance end date (Jan '23). 787-10 G-ZBLA and all subsequent deliveries will have this change from production.

ACTION

Please ensure that the NLG downlock pins are always installed in the correct location IAW the AMM. The correct and incorrect locations are shown below for reference.

CORRECT INCORRECT



<Correct Installation> <Incorrect Installation>

Note:	1. 2.	This Technical News expires 6 months from the issue date above. Persons performing a supervisory function are responsible for informing their appropriate staff of the content of this document.
Authority:	3.	Head of Engineering Quality & Technical

Figure 18

Tech news article explaining correct/incorrect location of the downlock pin

Prior to the accident, all G-ZBJB's engineering team had signed to confirm they had read the article. None of the team recalled the article until reminded about it after the accident. Table 2 shows the date when each member of the team signed for the December 2020 issue of the technical news article and approximately[9] how many articles in total were required to be read and signed for in the same batch. This was a higher than usual number of articles for some team members due to an accumulation of articles during periods of COVID19 furlough.

Footnote

[9] The data are approximate due to limitations of the operator's historical recording system for tech news articles.

Team member	Date 787 NLG downlock pin article signed for	Total number of articles
LAE	02/01/2021	16
Technician	01/02/2021	36
Mech 1	08/12/2020	12
Mech 2	03/01/2021	40

Table 2

Read and sign dates for the Technical news article explaining correct/incorrect location of the downlock pin and number of articles required to be read in the same batch (including NLG article)

Reviewing the priority and potential safety risks of the SB and AD

The engineering fleet technical team believed that, when compiling the AD and the SB, the FAA and the manufacturer had assessed multiple risk types including Health and Safety, Flight Safety and Airworthiness. Whilst the primary risk analysis conducted by the manufacturer used the regulated airworthiness requirements, Boeing reported that both personal and aircraft level safety were considered during the compliance time evaluation. As a result, the wording in the SB included the following text:

> *'If this Service Bulletin is not done, the NLG can be retracted on the ground during maintenance or fault isolation if the NLG pin is accidentally installed in the apex pin inner bore, which can cause damage to the airplane and injuries to personnel.'*

Similarly, the AD also included the following safety statements:

> *'Summary*
>
> *The FAA is issuing this AD to address the unsafe condition of these products.*
>
> *(e) Unsafe Condition*
>
> *This AD was prompted by reports that the nose landing gear (NLG) retracted on the ground, with weight on the airplane's wheels, due to the incorrect installation of a NLG downlock pin in the apex pin inner bore of the NLG lock link assembly. The FAA issued this AD to address the NLG downlock pin being incorrectly installed in the apex pin inner bore of the NLG lock link assembly, which could result in the NLG retracting on the ground, possibly causing serious injuries to personnel and passengers and substantial damage to the airplane.'*

The SB had been categorised by the aircraft manufacturer as '*Special Attention*' which was a category used to specifically highlight safety issues such as personal hazards that do not immediately threaten airworthiness but can have a high economic impact if not incorporated.

The technical team reviewing the SB and AD consisted of a team leader and several technical engineers. The procedures the engineering organisation used to evaluate technical documentation[10] from manufacturers stated the following may be considered but not all decisions had to be documented:

'a. *The actioning Technical Engineer conducts a high-level review of the document to understand its contents and technical intent. The following lists the subjects that may be considered:*

i. It's applicability to aircraft or components for which the engineering department holds technical responsibility.

ii. Is the task mandatory?

iii. Compliance requirements - Mandatory or not?

Note: Alert, Special Attention and Alert Operator Transmissions technical documents are classed as mandatory by the Technical Safety Group (TSG).

All Alert and Special Attention Service Bulletins and Alert Operator Transmissions (Airbus), require adoption on the fleet, with sign-off by the Specialist Technical Engineer or Team Manager. By exception, the Alert, Special Attention Service Bulletin or Alert Operator Transmissions are to be brought to the TSG by the owning Team Manager for their agreement when embodiment action is not to be taken.

iv. It's effect in enhancing safety.

NOTE: Alerts and Special Attention documents are classed as mandatory by the TSG unless a safety case is presented to the TSG meeting for decline.

v. Whether it offers improvements to an existing task or product data can be gathered by reviewing our own fleet, world fleet, Original Equipment Manufacturer (OEM) and other operator experiences / data.

vi. Whether the beneficiary is to the Operator / Owner.

vii. Its ETOPS[11] implications.

Note: If the TDR is ETOPS significant then a detailed entry describing the implications, including any actions being taken to address or mitigate the implications, must be recorded in the long text of the TDR.

viii. Whether it is linked to other documents.'

Footnote

[10] CAMO-Tech Document Evaluation BACOMPANYDOCS-CAMO-01-01-0020-00000-041A-D.
[11] ETOPS - Extended Range Twin-engine Operational Performance Standards.

Whilst this procedure considers these items and others such as reviewing the Boeing FTD, cost and reliability, it does not require a documented risk assessment showing which risks have been considered.

The first stage of the review by the senior technical engineer concluded that the SB did not represent a safety issue despite its 'special attention' category status and the potential for serious injury of personnel and passengers warning in AD sub paragraph (e) 'Unsafe Condition.' Although the assessing personnel did consider the potential safety impact of an aircraft in an unmodified state, the assessment only focused on the potential impact on flight safety and airworthiness.

A subjective decision on the embodiment timeline was made by drawing on the experience of the personnel making the assessment.

Safety Management Systems (SMS)

A safety management system (SMS) in aviation refers to a collection of processes, tools and methodologies to formally manage a structured safety programme. Many aviation service providers have processes in place to mitigate for hazards and risks. Aviation SMS programmes are based on the ICAO standards or recommendations and guidelines for managing safety programmes at a state and individual operator level, found in ICAO Document 9859.

The operator had a mature SMS in place but it was only employed within their Operations and Management departments rather than their maintenance organisation. Their system had a structured risk assessment process which covered hazard analysis, risk assessment, perspective categorisation[12], risk ownership, mitigation activity and risk tolerability. The outcome of the SMS processes identified gaps in safety so the operator could produce strategies to reduce, manage or eliminate the identified safety risks.

Whilst the operator did have an SMS in place, the system had not been adopted by their maintenance organisation because there was no legislated requirement for them to do so in the CAA Part 145 regulations. The operator's TDR process to embody the AD considered flight safety, airworthiness and the AD's 'effect' in enhancing safety, but there was no documented evidence of any health and safety risks considered.

The CAA has proposed that the requirement for an SMS is introduced into the Part 145 regulations by the end of 2022. The operator has stated that they have already started implementing an SMS risk system within the maintenance organisation.

Footnote

[12] *'Risks can be categorized from two perspectives: Perspective 1 – Technical, programmatic or performance, supportability or environment: Such as people, equipment, reliability, maintainability etc. Perspective 2 - Cost: Such as sensitivity to technical risk, overhead, estimating errors etc. Schedule: Such as degree of concurrency, number of critical path items, sensitivity to cost etc.'* Abhilash Gopi '*Categorization of Risks in Project Risk Management*', 29 November 2008. Available at www.pmhut.com/categorization-of-risks-in-project-risk-management [accessed May 2022].

Organisational information

Maintenance organisation

The AAIB interviewed relevant maintenance personnel and their managers and conducted observations of ramp maintenance. The operator's internal investigation was also reviewed. The following relevant organisational features were found:

The impact of the COVID19 pandemic

The operator experienced a sudden and significant downturn in operations because of the pandemic. This resulted in operational changes within the maintenance organisation and an immediate need to minimise costs. The ramp maintenance team involved in the accident did not report that any of the changes had affected their individual performance.

Ramp maintenance team structure

Licenced aircraft engineers are expected to oversee the technicians and mechanics working within their team and have some leadership training to support this. Technicians and mechanics are not expected to oversee the work of their colleagues and have no leadership training. However, it is common for mechanics, technicians, and licenced engineers to observe each other and work together as a means of on-the-job training and to gain experience.

Workload

Overall, the workload within the engineering team where the accident occurred was considered by management and the engineers who were interviewed to be comfortably achievable. Maintenance staff were not working full days. Removal of pitot probe covers and cabin inspections had been added to the standard ramp maintenance schedule as additional duties. The removal of pitot covers was an unfamiliar task across all of the operator's aircraft fleet resulting from incidents of insects blocking the sensors whilst aircraft had been parked for long periods during COVID. This extra task included a detailed visual inspection by the LAE but also increased the time taken to complete ramp maintenance. Cabin inspections were necessary due to the revised structure of the CET. Most of the mechanics from the CET had been seconded to aircraft maintenance ramp teams to pass on their knowledge of interior maintenance. Although this was more work on each aircraft, it was considered by management that additional resource had been made available to cover it.

Analysis

The aircraft was undergoing a corrective maintenance task to allow the deferment of three NLG Solenoid faults in accordance with the DDG. The task required cycling of the landing system. Maintenance personnel inserted locking pins into all three undercarriage legs before the LAE in the flight deck selected the landing gear to UP. The locking pin for the NLG had been inserted in an incorrect position and therefore did not function as intended. When the LAE selected the landing gear to UP the NLG retracted as designed. The aircraft nose then fell to the ground.

Design of the aircraft NLG

The design of the aircraft nose landing gear created an opportunity for error with two holes located close together that the locking pin could be inserted into. When the pin was inserted into the wrong hole, it made a 'click' noise like the noise made when it was inserted into the correct hole, and it fitted with sufficient friction to remain seated even in response to tugging from below. This meant that there were powerful auditory and tactile cues that could easily mislead someone to believe the pin was correctly inserted even when it wasn't. There were no strong visual indications to distinguish between the correct and incorrect placements. A visual inspection would therefore be unlikely to reveal incorrect placement unless the person checking was specifically looking for it.

Performance of the ramp team

To select the landing gear to UP, the LAE needed to be on the flight deck. Time before the aircraft's scheduled departure was limited so he delegated the fitting and checking of the landing gear pins and the external check for hazards around the aircraft to Mech 1. Mech 1 was experienced, and the LAE trusted him based on their history of working together. The LAE supervised Mech 1 and Mech 2 remotely from the flight deck and communicated with Mech 1 via a headset. The LAE could be heard on the CVR leading the team through the checks in the procedure. However, there was no briefing for the team before leaving the aircraft establishing who would do what and what the hazards of the task were.

Mech 1 asked Mech 2 to fit the NLG pin because the smaller steps needed to access the NLG bay were not immediately available at the remote stand and Mech 2 was tall enough to do it without the steps. Mech 2 was also taking the opportunity of his secondment to the ramp maintenance team to further his experience, and this may have seemed to Mech 1 like an appropriate task for him to learn. Mech 1 pointed to the location to fit the pin, monitored the fitting of the pin and checked it by listening, looking and pulling the flag. The limited space available within the NLG bay and the location of the hole above their heads made it difficult to clearly indicate the correct pin location, especially without access to a picture such as that in the AMM. Mech 1 did not have in mind the hazard of incorrect placement, so he did not emphasise this to Mech 2 or consciously check for it.

The AMM was available to the maintenance team on a laptop, but this would have required time and is not a convenient device to use outside the aircraft and in the rain. The operator issued iPads with maintenance information included via an App, but they did not contain the necessary B787 manuals.

Mech 1 attempted to clear the outside of the aircraft of other personnel and check everyone was clear, but the visual check was ineffective due to the restricted view available from Mech 1's position by the NLG. It is also likely that he believed people only had to be clear enough for a small movement of the aircraft as hydraulic power was applied and did not consider the possibility the aircraft nose could drop.

The operator did not have any procedure or rule to prohibit or control the hazards of this type of task during loading or passenger boarding. The team tried to complete the task as quickly as possible while performing the required safety checks in the AMM but did not set up a safe system of work that effectively controlled the hazards. The resources available within the team were not used to best effect to assist Mech 1 during preparations for cycling the NLG doors. The NLG pin was fitted by Mech 2 who had no experience of the task and was not given an adequate explanation. The experienced technician and OSE who were available to help with the pin fitting and external visual checks for people working around the aircraft were not utilised.

Mitigation effectiveness using the technical news

The possibility of installing the NLG downlock pin in the incorrect position was a known hazard and a modification was available to eliminate the risk of it happening. Pending incorporation of the modification, the operator sought to mitigate the risk by raising awareness of the issue through a technical news article. However, the interim mitigation using the technical news read and sign process was not effective. Even though all members of the accident ramp maintenance team had signed to say they had read the article, none of them appeared to have in mind the risk of incorrect pin installation. This was probably because of the volume of information in the technical news, and the need for maintainers to remember the information between the time of reading and the next fitting of NLG pins on the B787. The accident occurred more than five months after the LAE and the two mechanics signed for the relevant technical news article. For Mech 2 there had been approximately 40 articles in the same batch. There was no process to monitor the effectiveness of the interim mitigation. The operator has introduced a new software application for technical news that has an improved interface and requires each page of every article to be displayed before it can be signed. The new software offers the capability to highlight documents that are mandatory or safety related. When this functionality is deployed, users will have to read and sign when they access the system. Additional functionality has also been added to allow engineers to bookmark documents of interest.

Access to aircraft documentation

Access to B787 maintenance data and manuals via the company iPads may have provided an opportunity for Mech 1 to step Mech 2 through the procedure for inserting the NLG downlock pin. The procedure contained illustrations showing the correct and incorrect locations for the pin which might also have jogged their respective memories regarding the warning notice in the Technical News article. The operator has now provided access to Boeing technical data, documents and manuals via the company iPads.

The manufacturer and regulator's response to the hazard of incorrect pin insertion

The NLG design issue was known to the manufacturer and the regulator because of previous incorrect ground lock installation events. When the manufacturer became aware, they acted, starting an internal investigation and then issuing a MOM followed by a Fleet Team Conference presentation that included a suggested temporary fix using sealant. This information was supplemented by the publication of a FTD article on the manufacturer's web portal six weeks after the MOM was issued which provided additional details.

It was roughly a year after the MOM was released before the manufacturer issued a SB with a permanent fix that required a kit of parts and had a three-year compliance time. The AD followed ten months later and reset the three-year compliance time so that compliance was required by 16 January 2023. The AD highlighted that the safety and economic risk '*could result in the NLG retracting on the ground, possibly causing serious injuries to personnel and passengers and substantial damage to the airplane*.' But the compliance time meant that it would be up to four years and nine months between the issue being recognised and all aircraft being modified to prevent incorrect installation of the NLG downlock pin.

The compliance date for the SB and AD was calculated using occurrence data from Boeing 787 models, however, the relative risk of personal injury was determined by considering data from all large Boeing aircraft types dating back to the 1970s. Boeing's safety review process considered statistical analysis methods that included the possibility of human error, because it is a common contributor to aviation accidents and incidents. The potential for human error during airplane maintenance formed the basis of the Safety Issue determination. The potential for a serious injury within the lifetime of the 787 fleet was also assessed in the compliance time determination.The operator's response to the SB and AD during COVID pandemic.

The SB and AD were assessed by engineers in the operator's engineering department and within the timescales prescribed. The SB only refers to a single incident of NLG retraction plus a safety report, so the Operator's assessment was based on a single event not the two events that had been reported to Boeing prior to the release of the SB. Their assessment concluded that the issue was not flight safety related or an airworthiness risk and embodiment towards the end of the compliance period was acceptable. Despite the warnings in the AD, the potential risk of serious injury to personnel working around the aircraft and boarding passengers was not given sufficient consideration. Nor was the design characteristics of the 787 NLG downlock pin and the adjacent apex pin holes. Had these risks been given greater significance, embodiment of the modification may have been given greater priority. Action to begin the embodiment process was initiated but was put on hold and repeatedly deferred due to the economic impact of the COVID19 pandemic. A further consequence of the restrictive COVID measures was the suspension of the Modifications Committee leaving the embodiment decision to stakeholders via a Sharepoint workflow. This modification remained a TDR work in progress prior to the accident and was never presented to stakeholders for sign off; although once the SB became free of charge, approval of the Modification Committee was not necessary. The SB was signed off by the Modifications Committee and incorporated soon after the accident as a matter of urgency.

As a result of this accident, the operator has reviewed the processes used to assess SBs and ADs and has developed appropriate organisational structures to identify and manage health and safety risks more effectively in the TDR process.

Emergency response

Although the co-pilot was in the cockpit when the event occurred, he did not make a PAN or MAYDAY call to ATC, instead relying on the phone calls made by the ground personnel. As a result, ATC were not initially aware of the incident. Had they been, then ATC could have issued an alert over the airport's dedicated crash system. This would have simultaneously informed the RFFS, the Police, airport ground operations and security and reduced the response time to the event. It is possible that ATC would have declared the incident an AGI and triggered the associated security response.

During the post incident response, the principal issue was the large number of uncontrolled personnel who converged on the site. As the incident had been declared a LSBYG, airport security were not directed to provide a cordon and so there was no control of personnel entering the scene. The request to declare the incident a LSBYG was made by the RFFS commander on receipt of information from the APOC Fire Desk and confirmed by ATC. Once on scene the RFFS commander considered that local resources were sufficient to manage the situation and discussed this with the police commander. Declaration of an AGI would have triggered a predetermined response from the London Fire Service and the London Ambulance Service, diverting resources that were not required on scene and the RFFS commander wished to avoid this. Both the LFB and LAS stated that the predetermined responses to an AGI, while significant, would not unduly disrupt their other operations.

The creation of an EAP would have possibly created a focus for personnel assembly away from the incident site and diverted unnecessary personnel.

The operator declared the incident as a Silver in their internal management process. At this level the CMC was not activated, and no Incident Site Leader was appointed. Therefore, there was no clear chain of command for company personnel at the event site. If an AGI had been declared the operators ELV would have automatically deployed to the EAP and would have been available to liaise with the Emergency services on scene. This may also have been of assistance in controlling the presence of the operator's personnel. In response to the event the operator has commenced a review of their incident management process.

Future SMS Policy

Whilst there was no requirement for SMS within maintenance organisations at the time of the accident, the AAIB wishes to highlight the safety benefit that future adoption of SMS in maintenance is expected to provide in a situation like this. There would be a systematic response to the safety intelligence received from the manufacturer and regulator and the risk holders would have visibility of that. Comprehensive risk assessments would be carried out and appropriate hazard mitigations would be identified and recorded. The hazards and the effectiveness of those mitigations would be monitored. Had the aircraft been boarding passengers when the NLG retracted, the consequences could have been much more severe.

The CAA have already taken measures to close the policy gap for maintenance organisations. Their aim is for Government approval of an SMS to be introduced into the Part 21 and Part 145 regulations by the end of 2022. The operator has stated that they have started implementing an SMS risk system within their maintenance organisation.

Safety actions taken

As a result of the accident the aircraft operator has taken the following safety actions:

> The AD and SB has been fully installed on all the operator's applicable Boeing 787 aircraft.
>
> The operator has reviewed their processes to assess SBs and ADs and has developed appropriate organisational structures to identify and manage health and safety risks more effectively in the TDR process.
>
> The adoption of an SMS within the Operator's maintenance organisation is already underway following the CAA's rulemaking announcement for the introduction of an SMS into the Part 21 and Part 145 with the aim of Government approval by the end of 2022.
>
> The operator has provided ramp maintenance personnel with access to manufacturers' technical data, documents and manuals via their issued iPads.
>
> The operator has introduced a new software application for tech news that has an improved interface including filtering and prioritisation functions and requires each page of every article to be displayed before it can be signed.
>
> The operator has begun a review of their Incident Response Manual.

The airport operator has also taken the following safety actions:

> The airport Emergency Orders (EO) Action Cards for each stakeholder will be amended to include a requirement for each Business Unit to make an individual assessment of the incident categorisation and communicate that to the RFFS Commander.
>
> The airport EO Action Card for the RFFS Commander will be amended to include a consideration of a change in categorisation in liaison with other stakeholders.
>
> The airport EOs will include a cordon requirement in all categories for the Campus Security Manager

Conclusions

The aircraft NLG retracted on the ground when the landing gear selection lever was selected to UP as part of a maintenance procedure. The NLG downlock pin had inadvertently been inserted in the downlock link assembly apex pin bore instead of the downlock pin hole. When the nose of the aircraft struck the ground, significant damage was caused to the lower front section of the aircraft and minor injuries to the co-pilot and a member of the cargo load team.

The design of the aircraft nose landing gear downlock assembly created an opportunity for error when inserting the NLG locking pin, with two holes located so close together that the pin could be inadvertently inserted in the incorrect location. There were powerful auditory and tactile cues that could easily mislead someone to believe the pin was correctly inserted even when it wasn't and there were no strong visual indications to distinguish between the correct and incorrect placements.

The determination of the risk of incorrect installation of the NLG downlock pin in the manufacturer's SB and the regulator's AD did take account of the design of the B787 NLG and the associated probability for error. The operator's process to embody ADs and SBs considered flight safety, airworthiness and the AD's 'effect' in enhancing safety, but there was no documented evidence that health and safety risks had been fully considered. Had these risks, that were clearly highlighted in the AD and SB, been given greater significance by the operator during the embodiment process, the priority of the modification may have been escalated and avoided the decision to defer implementation to the end of the compliance period.

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