Air Accident Investigation Unit Ireland

SYNOPTIC REPORT

ACCIDENT
Airbus A321 neo LR, EI-LRD
Washington Dulles Airport, Virginia, USA

30 August 2023

An Roinn Iompair
Department of Transport

Foreword

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

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

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

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

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In accordance with Annex 13 to the Convention on International Civil Aviation, Regulation (EU) No 996/2010 and the provisions of SI No. 460 of 2009, on 31 August 2023, the Chief Inspector of Air Accidents appointed Ray Jordan as the Investigator-in-Charge to carry out an Investigation into this Accident and prepare a Report.

Aircraft Type and Registration:	Airbus A321 neo LR, EI-LRD	
No. and Type of Engines:	2 x CFM LEAP-1A33	
Aircraft Serial Number:	9187	
Year of Manufacture:	2019	
Date and Time (UTC)[4]:	30 August 2023 @ 19:37 hrs	
Location:	Washington Dulles Airport (KIAD), Virginia, USA	
Type of Operation:	Commercial Air Transport	
Persons on Board:	Crew – 6	Passengers – 145
Injuries:	Crew – 2 (Minor)	Passengers – Nil
Nature of Damage:	Substantial	
Commander's Licence:	European Union (EU) Flight Crew Licence (FCL), Airline Transport Pilot Licence (ATPL) Aeroplane (A), issued by the Irish Aviation Authority (IAA)	
Commander's Age:	47 years	
Commander's Flying Experience:	12,973 hours, of which 10,684 were on type	
Notification Source:	The Operator	
Information Source:	AAIU Report Forms submitted by the Flight Crew AAIU Correspondence Investigation	

[4] **UTC**: Co-ordinated Universal Time. All times in this report are quoted in UTC unless otherwise stated; local time was UTC - 4 hours on the date of the occurrence.

SYNOPSIS

On 30 August 2023, the Airbus A321 neo aircraft departed Dublin Airport (EIDW), Ireland, at approximately 11:55 hrs on a scheduled transatlantic service to Washington Dulles Airport (KIAD) in the United States. During the final approach to land, in gusty conditions, the aircraft became slightly high on the glideslope. In response to this deviation, the First Officer (FO), who was the Pilot Flying, made a nose-down control input which, along with a loss of headwind, resulted in an increased rate of descent near to the ground. During the subsequent landing manoeuvre, a rapid aft control side stick input was made and the aircraft bounced to a low height. During this bounce, the Pilot Flying made an aft side stick input, which caused the aircraft to pitch up beyond its tailstrike limit. Simultaneously with the second touchdown, the Commander took control of the aircraft and a go-around was initiated. Following radar vectors, the aircraft landed again on Runway 01R. A post-flight engineering inspection revealed that a tailstrike had occurred which caused damage to the aircraft. Minor injuries were reported by two cabin crew members located in the rear of the aircraft.

NOTIFICATION AND RESPONSE

The Operator notified the AAIU and the National Transportation Safety Board (NTSB) of the United States on the evening of the occurrence. Following correspondence with the NTSB, the Investigation was delegated to the AAIU in accordance with International Civil Aviation Organisation (ICAO) Annex 13 protocols.

1. FACTUAL INFORMATION

1.1 History of the Flight

On the day of the occurrence, the Flight Crew members reported for duty more than one hour and fifteen minutes (the mandatory advance reporting period) prior to the scheduled departure time of 11:35 hrs. They discussed the enroute/destination weather and the Commander requested a departure fuel of 25 tonnes to complete the flight, which included extra contingency fuel due to the busy nature of KIAD.

The Commander decided that the FO would be the Pilot Flying (PF) for the sector due to the FO's recent familiarity with KIAD and the forecast weather conditions. The Commander stated that prior to the top of descent, the PF gave a structured briefing in accordance with company procedures. This briefing included a discussion on the potential threat of a tailstrike during the landing phase due to the subject aircraft being an A321 (which is a stretched version of the Airbus A320). The aircraft routed down the eastern seaboard of the United States before commencing its final descent for KIAD.

As the aircraft approached KIAD, local Air Traffic Control provided it with a series of radar vectors, frequency changes and altitude clearances, culminating in a final instruction to call visual with the landing Runway (RWY) 01 Right (R). The Flight Crew advised that they were visual with RWY 01R and were subsequently transferred to the tower frequency.

The tower controller gave the Flight Crew a wind check of 310 degrees magnetic at a speed of 12 knots and clearance to land on RWY 01R. This was acknowledged by the Commander, and at approximately 940 feet (ft) above ground level, the FO disconnected both autopilots and continued the approach manually, with autothrust engaged. The FO described the subsequent approach as a bit *'thermally'* which had the effect of *'pushing'* the aircraft up.

At approximately 300 ft radio altimeter[5] (RA), the aircraft deviated above the glideslope[6] and the Commander remarked to the FO that the runway was very long. Passing through 120 ft RA, a nose-down side stick input resulted in a rate of descent of approximately 976 feet per minute (fpm). The associated decrease in the pitch attitude prompted the Commander to make a verbal instruction for the FO to watch the pitch attitude. At 40 ft RA, the flare manoeuvre was initiated with a rapid aft side stick input by the FO which reduced the rate of descent to 150 fpm. The thrust levers were retarded and idle thrust was commanded at 15 ft RA. The aircraft subsequently touched down at a pitch angle of 7.5° and with a vertical acceleration (VRTG) recorded value of + 1.6 g.

Following the initial touch down, the aircraft bounced to a height of 3 ft RA and the pitch angle increased to 10.1°. During the bounce, an aft side stick command was applied, the aural *'pitch pitch'* warning sounded, and the aircraft touched down for a second time, which resulted in a tailstrike. As the aircraft touched down for the second time, which was less than three seconds after the first touchdown, the Commander took control by pressing the priority button on his side stick. The Commander advanced the thrust levers to the TOGA[7] setting, lowered the nose initially before raising it again, and the aircraft became airborne in the go-around. The FO transmitted a *'balked landing'* message to the tower following which the aircraft was advised to route straight ahead and change VHF radio frequency. On the Commander's order, the FO retracted the flaps on schedule, completed the after take-off checklist, and the aircraft was vectored for a downwind leg and a second approach (**Figure No. 1**).

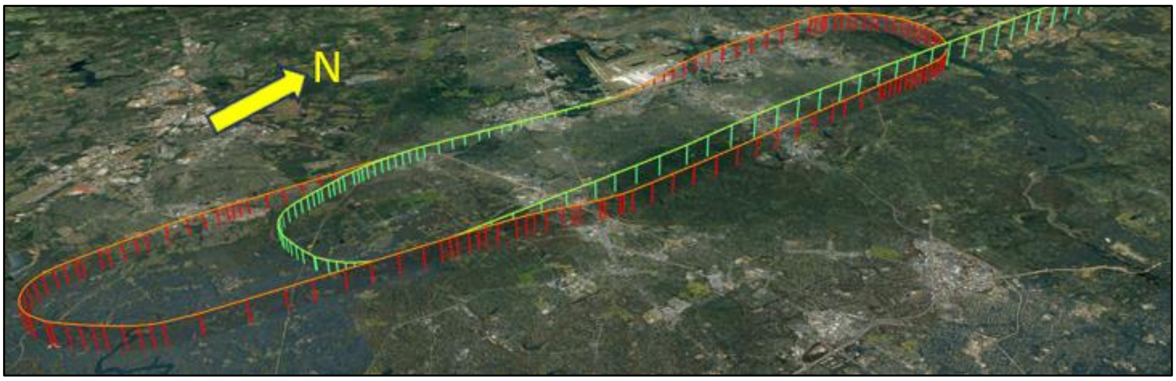

Figure No. 1: First (green) and second (red) approach

[5] **Radio Altimeter:** The aircraft is equipped with dual radio altimeters which provide height above ground information to several onboard systems including the Autopilots and Primary Flight Displays.

[6] **Glideslope:** Part of the Instrument Landing System (ILS) that projects a radio beam upward at an angle of approximately 3° from the approach end of an instrument runway. The glideslope provides vertical guidance to aircraft on the final approach course for the aircraft to follow when making an ILS approach along the localiser path.

[7] **TOGA:** Take-off/Go-around.

When established on the downwind leg (unaware that a tailstrike had occurred), it was agreed that the Commander would fly the second approach. The Commander contacted the Senior Cabin Crew Member (SCCM) over the interphone advising her of the situation and that he intended to return to KIAD for another landing. The Commander also asked the SCCM to make a public address (PA) to the passengers for their reassurance.

The Commander conducted the subsequent approach to RWY 01R and touched down approximately 15 minutes after the balked landing[8]. The aircraft vacated the runway, taxied to its allocated stand and, following engine shutdown, the passengers disembarked. The Flight Crew first became aware that the aircraft had sustained damage was when a locally based engineer entered the flightdeck and informed the Commander. The aircraft was subsequently grounded.

1.2 Injuries to Persons

Two CCMs (Cabin Crew Member) were seated in the rear of the aircraft during the occurrence. Both reported to the Operator that they had sustained minor injuries. One CCM who was seated at door 4 Left (L), reported a lower back *'Ache'* and *'Strain/Sprain'*. The other CCM, who was seated on a crew seat near door 4 Right (R), reported similar injuries. The Operator informed the Investigation that no follow-up reports or medical assessments were submitted by the CCMs seated in the rear of the aircraft and that the CCMs in question operated the return flight home the following evening.

1.3 Interviews with the Crew

1.3.1 Commander

The Commander stated that he was a Type Rating Examiner (TRE) and Training Captain on the aircraft type. He said that it was his first time flying with the FO, who had some recent experience of flying the route. The Commander said that the weather forecast for the Washington DC area did not indicate any adverse conditions that would preclude the FO from flying the outbound sector to KIAD.

During the approach into KIAD, they accepted a visual approach from ATC and elected to leave the autopilot engaged to capture the Instrument Landing System (ILS) for RWY 01R. He recalled that another aircraft, which was following them in the landing sequence, received a wind check that included a gust factor. He believed he may have added one or two extra knots to the approach speed to compensate for this. He stated that nothing unusual caught his attention until the last 100 feet of the approach. He said that his left hand was guarding the controls (his hand was on the side stick) and his thumb was near the priority transfer button. He said that the aircraft pitched down and that he may have verbalised to the FO to manage the pitch attitude. He remarked that the automatic height callouts were noticeably faster than usual (indicating a higher than normal descent rate), but due to the side sticks not being mechanically linked, he *'can't see'* what inputs the FO was making.

[8] **Balked landing:** A go-around from a very low height above the runway or after touchdown.

He stated that everything happened very quickly and that the aircraft, in his opinion, experienced a *'fairly significant bounce'*. The Commander recalled hearing an automated *'pitch pitch'* warning during the bounce. He said that he took control and applied a full nose-down input but the pitch attitude seemed to him to keep on increasing. Upon reflection, the Commander said that it was a *'classic'* tailstrike scenario insofar as *'inappropriate side stick command, spoilers coming up, it's going to keep pitching up'.*

The Commander said that following the go-around, his conversation with the SCCM was relatively brief as he was quite busy managing the missed approach, and that the landing back into KIAD was uneventful. He stated that while he was discussing the balked landing with the FO on the flight deck following engine shutdown, a locally based engineer informed the Commander of damage consistent with a tailstrike. The Commander observed for himself the damage to the underside of the aircraft (**Photo No. 1**), the extent of which he found surprising. He immediately contacted the Operator's Director of Flight Operations by telephone to report the occurrence.

Photo No. 1: Damage to underside of aircraft (external damage ringed in yellow)

The Commander stated that the first time he was informed that the Cabin Crew at the rear of the aircraft heard or felt something during the occurrence was upon arrival at the crew hotel. Regarding tailstrike checklists, the Commander advised the Investigation that there is no ECAM[9] warning to indicate that the subject aircraft may have sustained a tailstrike. He further stated that there is a *'grey bannered'* tailstrike checklist under the miscellaneous section in the aircraft's Quick Reference Handbook (QRH) (the Flight Crew Operating Manual (FCOM) states that an abnormal or emergency procedure that does not appear on the ECAM is on a grey background).

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[9] **ECAM**: Electronic Centralised Aircraft Monitor which presents information about normal and abnormal conditions, including checklist items to be actioned.

In relation to RWY 01R at KIAD, the Commander stated that it is a very long runway and as the aircraft approached 100 ft, they were approximately one quarter of a dot[10] high on the glideslope. He said that the guidance to pilots is if the aircraft can still touch down in the touchdown zone of the runway, then the deviation should be accepted and not chase the glideslope. The Commander stated that balked landing training is provided to FOs during their initial type rating and that following the Covid pandemic, when the Operator began a return to normal operations, all commanders underwent supplementary balked landing training in a flight simulator.

1.3.2 First Officer

The FO commenced employment with the Operator in 2019 as a cadet and *ab initio* flight training[11] was completed in 2020. The FO did not commence line training, whereby newly rated pilots fly the Operator's aircraft under the supervision of a Type Rating Instructor (TRI), until a return to normal operations following the Covid pandemic. The FO successfully completed line training and passed an initial line check in February 2022.

Most of the FO's hours were on the A320 and a differences course was required to be completed prior to operating the A321 variant. The FO informed the Investigation that it was a requirement to have attained 1,000 hours prior to operating transatlantic routes. Training for these routes was completed on the subject aircraft type in April 2023. This training comprised three return sectors, all of which were conducted into KIAD. The FO had operated into KIAD on two further occasions prior to the day of the occurrence. While preparing the paperwork prior to departure, the FO said that the forecast weather at KIAD seemed *'fine'* with light winds.

The FO stated that on the approach to the runway there are trees which may cause some turbulence as you fly over them, especially on hot days. The visibility on the day was considered to be good, as other aircraft could be seen landing on a parallel runway. The FO said that during the latter stages of the approach, the aircraft may have become a little high on the approach path and at about 100 ft the aircraft began to *'sink a bit'* before the initial touchdown. The FO was of the opinion that the cause of the tailstrike was a high rate of descent prior to touchdown, aft stick input following the bounce and the pitch up effect of the spoilers. The FO considered initiating a go-around, but hesitated '*for a second or two'.*

1.3.3 Cabin Crew Members

1.3.3.1 Senior Cabin Crew Member

The SCCM reported for duty approximately one hour and forty five minutes before the scheduled departure time. She informed the Investigation that the flight deck and cabin crew would normally brief independently of each other in different rooms and proceed to the aircraft separately. She recalled that on this occasion, the Commander introduced himself at her briefing table prior to departure.

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[10] The Primary Flight Display on the subject aircraft has a glideslope deviation scale measured in dots. One dot high is equivalent to 0.4°above a typical 3° glideslope.

[11] ***Ab initio* flight training:** In aviation, this refers to a program of flight training that takes an individual with little or no flying experience up to a position where they can operate for an airline.

She stated that the weather in KIAD on the day of the occurrence was clear and sunny, the cabin was secured approximately seven minutes prior to landing, and all CCMs were in their crew seats. Her position was at the front of the cabin next to door 1 L (Left), which is located just aft of the flight deck. She said that during the landing she didn't feel any heavy impact. Following the go-around, she recalled contacting her colleagues on the aft cabin crew seats to inquire if they were '*okay*'. She was under the impression that they were fine but had '*a bit of a fright'.* She did not recall any discussion about them having heard or felt a bang.

The Commander contacted the SCCM over the interphone and advised that they would be returning for a landing at KIAD. He also asked her to make a PA to reassure the passengers as he was quite busy in the flight deck. The subsequent approach and landing was described as being completely normal and she only became aware of the extent of the damage after they had disembarked the aircraft.

1.3.3.2 Cabin Crew Member

The Investigation interviewed a CCM who was seated on her crew seat in the rear of the cabin near to door 4R while another CCM was seated on a crew seat near to door 4L. The CCM seated near to door 4R stated that she was with the Operator for approximately seven and a half years. She said that the first touchdown was similar to a hard landing but she heard a bang during the second touchdown, the source of which seemed to come from underneath the aircraft. She stated that she had experienced hard landings before but nothing like what had happened during the occurrence. She further informed the Investigation that she was not aware of the term *'tailstrike'* before the event and that the subject was not discussed during recurrent safety training.

1.4 Damage to Aircraft

Following the occurrence, a U.S. based repair organisation was tasked with preparing an inspection and damage mapping report for the Operator.

The report stated that external damage was observed to the outer skins between Frame[12] (FR) 62/68 and Stringer[13] (STR) 42L/41R (within the pressurised area of the aircraft) which consisted of material loss with punctures and cracks at the frame stations. Minimal internal defects were found between FR62 and FR67, most notably shear clip[14] deformation at the frames between STR44/43R (**Photo No. 2**).

[12]**Frame:** Frames are structural members used in an aircraft fuselage to provide shape and strength.

[13]**Stringer:** Stringers are longitudinal members that provide strength and together with the frames, support an aircraft's skin.

[14]**Shear clip:** Shear clips are principally used as a support structure for the purpose of joining one structural member to another.

Photo No. 2: Shear clip deformation

At FR63 there were sheared rivets in the floor structure at three locations. At FR 64/65 deformation to a diagonal beam was observed (**Photo No. 3**).

Photo No. 3: Damage to diagonal beam in floor structure

A circumferential crack was observed along FR66 between STR43R and STR44 which measured 3.25 inches (**Photo No. 4**).

Photo No. 4: Damage to outer skin (grid squares are 1 inch x 1 inch)

No damage was observed to the APU components or to the aft pressure bulkhead. The aircraft received minor repairs at KIAD to allow it to be ferried, unpressurised, to Cincinnati/Northern Kentucky International Airport, where major repairs were carried out. There were some delays to this repair that were outside the control of the Manufacturer and Operator, which delayed the aircraft returning to service until January 2024.

1.5 Other Damage

The Airport Authority carried out a *'Special Airfield Inspection'* following the event. A subsequent report stated that approximately 1,300 ft from the runway threshold, scrape marks were observed which were consistent with a tailstrike from the subject aircraft.

1.6 Personnel Information

1.6.1 Commander

The Commander held an EU FCL ATPL (A) issued by the IAA, which contained a valid A320 Type Rating (and Instrument Rating) with an expiry date of 30 November 2023. The licence also contained a Type Rating Instructor (TRI) Certificate, which was valid until 31 October 2023 and a TRE Certificate, which was valid until 30 November 2024. The Commander's Class 1 Medical Certificate was valid until 31 March 2024. The Commander's flying experience is outlined in **Table No. 1**.

Total all types:	12,973 hours
Total on type:	10,684 hours
Total P1:	9,730 hours
Total on type P1:	9,730 hours
Last 90 days:	143 hours
Last 90 days on type:	143 hours
Last 28 days:	45 hours
Last 24 hours:	Nil

Table No. 1: Commander's Flying Experience

1.6.2 First Officer

The FO held an EU FCL Multi-crew Pilot Licence (MPL) (A) issued by the IAA, which contained a valid A320 Type Rating (and Instrument Rating) with an expiry date of 31 October 2023. The FO's Class 1 Medical Certificate was valid until 14 July 2024. The FO's Type Rating was restricted to operating as a *'CO-PILOT ONLY'*. Prior to a return to normal operations post Covid Pandemic, the FO was rostered six full flight simulator sessions. Two of these simulator sessions incorporated go arounds near the ground and Tail Strike Avoidance training. The FO's flying experience is outlined in **Table No. 2**.

Total all types:	1,377 hours
Total on type:	1,293 hours
Last 90 days:	236 hours
Last 90 days on type:	236 hours
Last 28 days:	69 hours
Last 24 hours:	Nil

Table No. 2: FO's Flying Experience

1.6.3 Multi-crew Pilot Licence

The MPL was first introduced in 2006 and unlike a Commercial Pilot Licence (CPL), an MPL does not confer the privileges of a Private Pilot Licence (PPL) unless additional training is completed. The MPL concentrates on the core competencies of pilots of modern jet transport aircraft, with an emphasis on multi-crew operations from the early stages of training. There is a greater focus on training in Flight Simulation Training Devices (FSTD) as opposed to flight instruction in small single engine aircraft. The MPL also introduced mandatory upset and recovery training in an FSTD to increase a pilot's ability to recognise and avoid upset situations and to improve a pilot's ability to recover control, if avoidance is not successful.

1.6.4 A320 Type Rating

The EASA type rating and endorsement list for flight crew of fixed wing aircraft states that an A320 type rating covers the Airbus series of narrowbody aircraft, from the A318 to the A321 neo type. Pilots with an A320 type rating are usually required to complete a short differences training course in order to fly other variants of the A320 narrowbody family such as the A321. This course is normally classroom or e-learning based.

1.7 Aircraft Information

1.7.1 General

EI-LRD is an Airbus A321 neo (new engine option) LR (Long Range) and is a stretched version of the A320. It has a wingspan of 35.8 m, a length of 44.51 m and a total height of 11.76 m. It is fitted with two CFM LEAP-1A33 turbofan engines and has a maximum take-off weight of 97,000 kilograms. EI-LRD has a seating capacity for 184 passengers in a two class configuration and a crew complement of six (two pilots and four cabin crew). The aircraft has a maximum demonstrated crosswind of 38 knots on a dry runway. The aircraft's pitch attitude limit with the main landing gear compressed (i.e. aircraft on the ground) is 9.7°. EI-LRD had a valid Certificate of Airworthiness (CoA), issued by the IAA on 27 February 2020 and an associated Airworthiness Review Certificate (ARC) that was valid until 23 February 2024.

1.7.2 Side Stick Operation and Priority Indication

The flight deck is equipped with dual side sticks for aircraft control in both pitch and roll axes. Their ergonomic characteristics are adapted for use with the left hand at the Commander's station and with the right hand at the FO's station (**Photo No. 5**).

Photo No. 5: Side stick controls (ringed in yellow)

When a side stick is not used, it is spring loaded to the neutral position. If an FO, seated in the right seat is manually flying the aircraft, the Commander may take control by pressing the side stick priority pushbutton on their side stick. This action will deactivate the FO's side stick, and will be accompanied by an aural '*priority left'* call out. A green light will illuminate in front of the Commander when the deactivated (FO) side stick is not in the neutral position. The same logic applies if the FO activates their side stick priority pushbutton, albeit with an aural *'priority right'* call out. The two side sticks are not mechanically linked and movement of one side stick does not result in movement of the other. The side stick inputs are algebraically added, therefore dual inputs must be avoided and will trigger aural and visual alerts.

1.7.3 Flight and Ground Spoiler Architecture

General

Spoiler panels are secondary flight control surfaces mounted on the upper surface of the wing that can be deployed manually by the pilot or, under certain circumstances, they can extend automatically. When extended, spoiler panels increase drag and decrease lift by disrupting the airflow over the wing. Depending on the aircraft type, spoilers can serve as many as three distinct primary functions:

- Ground spoilers (to improve braking performance during the landing roll)
- Roll spoilers (to enhance roll performance)
- Speed brakes (to reduce airspeed while in flight)

On the subject aircraft type there are five spoiler panels on each wing shown in yellow in **Figure No. 2**.

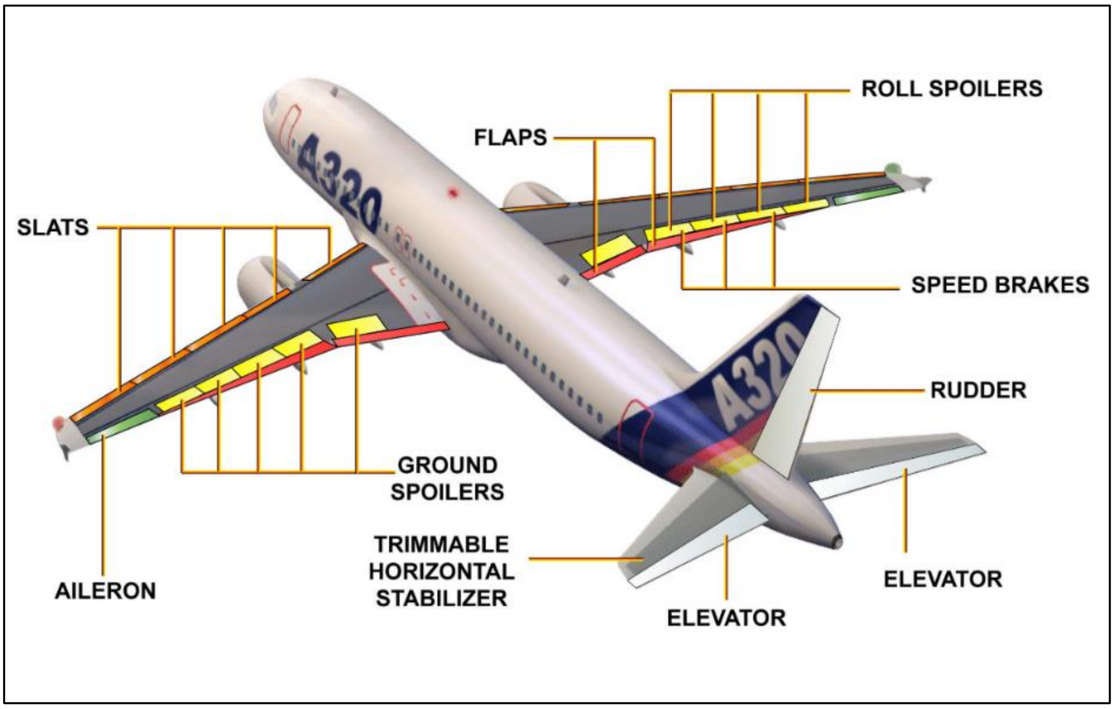

Figure No. 2: Spoiler position on wings (figure provided by Airbus)

These spoiler panels are numbered one to five (**Figure No. 3**). Spoilers 1 to 5 on each wing are ground spoilers and spoilers 2 to 4 on each wing are used for speed brakes in flight. Spoilers 2 to 5 are also used for roll control in flight in addition to the ailerons.

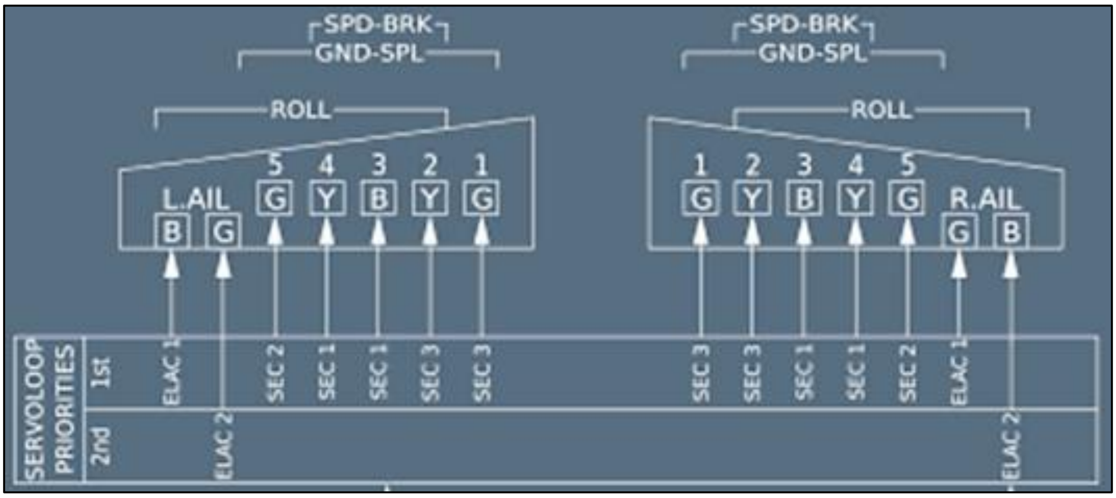

Figure No. 3: Flight and ground spoiler architecture

1.7.4 Spoiler Operation during Landing

The Operator's FCOM states the following regarding ground spoiler full extension during the landing phase:

'The ground spoilers will automatically extend when the following conditions are met:

Speed brake lever not in the retracted position or ground spoilers armed and:

- *Both main landing gears on ground*
- *Both thrust levers at or below idle position, or Reverse selected on at least one engine (and the other thrust lever below MCT position)*

Speed brake lever in the retracted position but ground spoilers not armed and:

- *Both main landing gears on ground*
- *Reverse selected on at least one engine (and the other thrust lever below MCT position)'*

Regarding partial extension of ground spoilers during the landing phase, the FCOM states the following*:*

'In order to accelerate the full spoiler extension, the Phased Lift Dumping (PLD) function allows the ground spoilers to deploy with a reduced deflection when the following conditions are met:

Speed brake lever not in the retracted position or ground spoilers armed and:

- *One main landing gear on ground*
- *Both thrust levers at or below idle position*

Speed brake lever in the retracted position but ground spoilers not armed and:

- *One main landing gear on ground*
- *Reverse selected on at least one engine (and the other thrust lever below MCT position)'*

The Aircraft Manufacturer informed the Investigation that spoiler extension has a pitch up effect *'due to their position on the wing'.* To compensate for this pitching up moment, the ELAC (Elevator Aileron Computer) automatically commands a nose down-down elevator order when all three Spoiler Elevator Computers (SEC) validates both main landing gear on the ground. This ground spoiler compensation is part of the detailed design of the Flight Control Law, and is not described in the FCOM.

1.7.5 Pitch Limit Indicator

A Pitch Limit Indicator is displayed on the Primary Flight Display (PFD) during the approach and landing phase when the aircraft is below 400 feet above ground level (AGL) (**Figure No. 4**). This feature is available in both automatic flight and manual modes. It assists pilots in recognising an impending tailstrike.

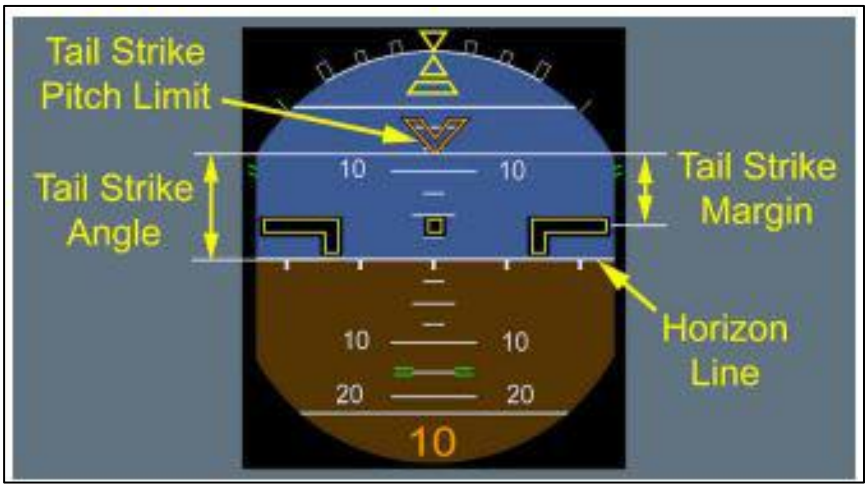

Figure No. 4: Pitch Limit Indicator

1.7.6 Flare Mode

As the subject aircraft type descends through 100 ft RA, it transitions from Flight Mode to Flare Mode. Unlike Flight Mode which provides several flight envelope protections, Flare Mode is a direct stick-to-elevator law without auto trim function and pilots have full elevator authority.

1.8 Operator's Standard Operating Procedures

1.8.1 Visual Meteorological Conditions Landing Technique from 1000 feet with A/THR Engaged

The Operator informed the Investigation that flight crew are trained in accordance with Airbus' Flight Crew Techniques Manual (Approach and Landing Techniques and Flare and Touchdown). In conjunction with the Manufacturer's techniques, the following methodology is also taught to the Operator's pilots during their A320 Type Rating course.

> *'**Approach***
>
> *Establishing the correct flight path early is critical (stabilised approach). Maintain this correct aircraft flight path by scanning both inside and outside the cockpit:*
>
> - *Inside: Scan for Speed / Attitude / HDG / VS (600 to 700 fpm) to maintain both GS & LOC.*
> - *Outside: Laterally, maintain runway centreline. Vertically, maintain approach path by keeping the 1,000' landing zone in the same portion of the windscreen and using the PAPIs for additional guidance.*
> - *Once below 200', the focus should be to maintain the steady approach path, avoid large control inputs or significant changes to the flight path. Don't chase the glideslope. If slightly high, don't drop the nose (or increase the ROD); the divergence should be accepted, adjusting only to regain a steady approach path, as long as a touchdown inside the touchdown zone can be assured.*

- *At 50' (auto call-out), look towards the runway end (horizon line). This will give you better depth perception and help assess the rate of descent as you approach the flare point, and assist in identifying the flare point itself.*

- *From stabilised conditions, the flare height is about 30 ft. Commence a smooth, progressive flare by inputting an aft sidestick force so as to observe a slight increase in pitch attitude. By 20' this change in pitch attitude should be clearly observable, as you continue to look at the end of the runway.*

- *The pitch change required is relatively small, the idea being to simply reduce the ROD sufficiently to allow a safe touchdown (200 to 300 fpm).*

- *Retard thrust levers once the flare is initiated – this will avoid the autothrust adding power to maintain speed which could in turn delay a prompt touchdown.*

- *In light to moderate crosswinds, the 'crab' into wind technique is used on approach to maintain centreline alignment. During the flare, input rudder to de-crab and align the aircraft with Rwy C/L.*

- *After touchdown, 'fly' the nosewheel smoothly but without delay to the runway.*

Notes

- *At any point, if the aircraft becomes de-stabilised, or if it becomes evident that the landing will be outside the TDZ – a go-around is mandatory.*

- *The PM should monitor all parameters and call any exceedance as listed in OMB[15] 2.9.2.1.'*

1.8.2 Tailstrike Avoidance Procedure

The Operator provided the Investigation with its tailstrike avoidance procedure. The relevant extracts from the Flight Crew Techniques Manual are reproduced below:

'Deviations from normal landing techniques are the most common causes of tail strikes. The main reasons for this are due to:

- *Allowing the speed to decrease well below VAPP before the flare. Flying at too low speed means high angle of attack and high pitch attitude, thus reducing ground clearance. When reaching the flare height, the pilot will have to significantly increase the pitch attitude to reduce the sink rate. This may cause the pitch to go beyond the critical angle.*

[15] **OMB:** Operations Manual Part B.

- *Prolonged hold off for a smooth touchdown. As the pitch increases, the pilot needs to focus further ahead to assess the aircraft's position in relation to the ground. The attitude and distance relationship can lead to a pitch attitude increase beyond the critical angle.*

- *Too high flare. A high flare can result in combined decrease in airspeed and a long float. Since both lead to an increase in pitch attitude, the result is reduced tail clearance.*

- *Too high sink rate, just prior reaching the flare height. In case of too high a sink rate close to the ground, the pilot may attempt to avoid a firm touch down by commanding a high pitch rate. This action will significantly increase the pitch attitude and, as the resulting lift increase may be insufficient to significantly reduce the sink rate, the high pitch rate may be difficult to control after touchdown, particularly in case of bounce.*

- *Bouncing at touch down. In case of bouncing at touch down, the pilot may be tempted to increase the pitch attitude to ensure a smooth second touchdown. If the bounce results from a firm touch down, associated with high pitch rate, it is important to control the pitch so that it does not further increase beyond the critical angle.*

AIRCRAFT SYSTEM FOR TAIL STRIKE PREVENTION

The following aircraft systems help to prevent tail strike occurrence:

- *A "PITCH-PITCH" synthetic voice sound when the pitch attitude becomes excessive.*

- *A tail strike pitch limit indicator appears on the PFD to indicate the maximum pitch attitude to avoid a tail strike.*

The "PITCH-PITCH" synthetic voice sound takes into account the actual pitch value and the pitch trend. This can lead to "PITCH-PITCH" synthetic voice sound to be triggered before any PM callout, or before the pitch reaches a high attitude on the PFD.

BOUNCING AT TOUCH DOWN

In case of light bounce, maintain the pitch attitude and complete the landing, while keeping the thrust at idle. Do not allow the pitch attitude to increase, particularly following a firm touch down with a high pitch rate.

In case of high bounce, maintain the pitch attitude and initiate a go-around. Do not try to avoid a second touchdown during the go-around. Should it happen, it would be soft enough to prevent damage to the aircraft, if pitch attitude is maintained.

Only when safely established in the go-around, retract flaps one step and the landing gear. A landing should not be attempted immediately after a high bounce, as thrust may be required to soften the second touchdown and the remaining runway length may be insufficient to stop the aircraft.'

1.8.3 Tailstrike Quick Reference Handbook Checklist

The TAILSTRIKE checklist is listed in the MISCELLANEOUS/ABNORMAL AND EMERGENCY PROCEDURES of the QRH which is stored in the flight deck. The checklist advises the crew to land as soon as possible and has an altitude restriction of Flight Level (FL) 100 or the Minimum Enroute/Off route altitude, whichever is higher. The checklist requires the RAM AIR to be selected on and for both air conditioning PACKS to be selected off. Selecting both PACKS to off depressurises the aircraft by reducing the differential pressure between the cabin and the surrounding atmosphere.

Tailstrikes at landing generally cause more damage than tailstrikes at take-off[16]. The worst case scenario is when the underside of the fuselage strikes the ground first before the aircraft's energy can be absorbed by the landing gear. This can result in substantial damage to the airframe and/or the rear pressure bulkhead. The tailstrike checklist for the subject aircraft is reproduced in **Figure No. 5**.

TAILSTRIKE

Ident: ABN-25-00010928.0001001 / 04 NOV 2021
Applicable to: ALL

LAND ASAP

MAX FL: 100 / MEA-MORA
RAM AIR .... ON
PACK 1 .... OFF
PACK 2 .... OFF

Figure No. 5: Tailstrike checklist

1.9 Meteorological Information

The NTSB was asked to provide details of the weather conditions prevailing at Washington Dulles Airport at the time of the accident. Relevant sections from this report are reproduced below.

1.9.1 Synoptic Conditions

A review of the NWS (National Weather Service) Surface Analysis Chart for 14:00 hrs EDT[17] depicted a cold front moving across extreme southern Virginia and becoming stationary over North Carolina. A high-pressure system at 1022 Hectopascals (hPa) was centred over Wisconsin with a ridge extending to the southwest into Virginia. A slight pressure gradient resulted over Virginia to support north-westerly winds at 10 to 15 knots.

The major weather event during the period was the remains of Hurricane Idalia, which was moving north-eastward and was well to the south of a frontal system over southern Georgia. The hurricane did not impact the Washington DC area and had no effects on the local weather at the time of the tailstrike.

[16] Source: Airbus Flight Operations Briefing Notes, Preventing Tailstrikes at Landing, September 2007.
[17] **EDT:** Eastern Daylight Time which was four hours behind UTC.

1.9.2 Observations

Washington Dulles International Airport (KIAD) had an Automated Surface Observation System (ASOS) which was augmented by contract weather observers. The five-minute ASOS observations for the period just before and after the event were as follows:

Approximately two minutes before the tailstrike, the KIAD ASOS reported a wind from 300° at 11 knots gusting to 19 knots, visibility 10 miles or more with no clouds observed. Temperature 31° Celsius (C), dew point temperature 13° C, altimeter 29.76 inches of mercury, pressure altitude 460 ft, relative humidity 34%, density altitude 2,400 ft, magnetic wind from 310° at 11 knots, gusting to 19 knots. Remarks: automated station with a precipitation discriminator, temperature 30.6° C, dew point 13.3° C.

5-MIN KIAD 301935Z 30011G19KT 10SM CLR 31/13 A2976 460 34 2400 310/11G19 RMK AO2 T03060133

Approximately three minutes after the tailstrike, the KIAD ASOS reported a wind from 310° at 11 knots, gusting to 21 knots, visibility 10 miles or more with no clouds observed. Temperature 31° Celsius (C), dew point temperature 13° C, altimeter 29.76 inches of mercury, pressure altitude 460 ft, relative humidity 34%, density altitude 2,400 ft, magnetic wind from 320° at 11 knots, gusting to 21 knots. Remarks: automated station with a precipitation discriminator, temperature 30.6° C, dew point 13.3° C.

5-MIN KIAD 301940Z 31011G21KT 10SM CLR 31/13 A2976 460 34 2400 320/11G21 RMK AO2 T03060133

1.9.3 Terminal Aerodrome Forecast (TAF)

The TAF for KIAD, issued on 30 August 2023 at 17:29 hrs UTC was as follows:

TAF KIAD 301729Z 3018/3124 33011G18KT P6SM FEW050 BKN180
FM310700 36008KT P6SM BKN250
FM311200 01012G21KT P6SM BKN250
FM312300 01009KT P6SM FEW250=

The period of validity was between 18:00 hrs UTC on 30 August and 24:00 hrs UTC on 31 August. The forecast wind was from a direction of 330° at 11 knots gusting to 18 kts with a visibility above six statute miles. Few clouds at 5,000 ft and broken clouds at 18,000 ft were forecast. Some changes were expected throughout the following day from 07:00 hrs UTC but were not considered relevant to the Investigation.

1.9.4 Sounding

A High-Resolution Rapid Refresh (HRRR) numerical model data was obtained from the National Oceanic and Atmospheric Administration (NOAA) Air Resource Laboratory for 16:00 hrs EDT for the nearest grid point at 38.95° N, 77.46° W.

The HRRR data indicated a near surface wind from 320° at 10 knots with potential gusts to 15 knots, a temperature of 30.3°C (86.5°F), a dew point temperature of 13.5°C (56.3°F), with a relative humidity of 36%, which resulted in a density altitude near 2,466 ft. The wind field did not indicate any significant vertical wind shears[18] or low-level temperature inversions to cause any significant shift in wind direction or speed with height.

1.9.5 Inflight Weather Advisories

A review of the NWS inflight weather advisories indicated that the NWS had no SIGMETs[19], Convective SIGMETs, Center Weather Advisories, or AIRMETs[20] over the region for any low-level turbulence, wind shear, or convection.

1.10 Human Factors

1.10.1 Startle Reflex

The following description of Startle Reflex is contained in a research project published by the European Union Aviation Safety Agency (EASA), titled '*Startle Effect Management*':

> *'Startle and surprise effects can influence pilot performance in many detrimental ways. At the very least, these effects serve as a distraction which can disrupt normal operation and erode safety margins. On a more critical level, they can lead to inappropriate intuitive actions or hasty decision making.*
>
> *The startle reflex is the first response to a sudden, intense stimulus. It triggers an involuntary physiological reflex, such as blinking of the eyes, an increased heart rate and an increased tension of the muscles. The latter are necessary to prepare the body for the fight-flight response (Koch, 1999). The startle response is accompanied by an emotional component which for a large part influences how a person responds to the unexpected event (Lang, Bradley, & Cuthbert, 1990).*
>
> *The duration of the startle reflex, as with most reflexes, is very short and depends on the severity of the reflex. A mild reflex lasts less than one second and a high-intensity response can last up to 1.5 seconds. Startle reflexes are more severe during very low or very high arousal levels. In addition to the involuntary physiological reflexes, startle inhibits the muscular activity, thus a startled person stops doing what he was doing (Koch, 1999). The disruption can last from 100ms to 3 seconds for simple tasks and up to 10 seconds for more complex motor tasks (Rivera et al, 2014).*

---

[18] **Wind shear:** A sudden change in wind velocity and/or direction over a short distance. It can occur in all directions, but for convenience, it is considered along vertical and horizontal axis (Airbus definition).

[19] **SIGMET:** Significant Meteorological Information, a meteorological report issued by a meteorological watch office that gives a description in abbreviated plain language of the occurrence and/or expected occurrence of specified en-route weather phenomena, which may affect the safety of aircraft operations and the development of those phenomena in time and space.

[20] **AIRMET:** Airman's Meteorological Information advises of weather that maybe hazardous, other than convective activity, to single engine, other light aircraft, and Visual Flight Rule (VFR) pilots. However, operators of large aircraft may also be concerned with these phenomena.

On the flight deck the disruption caused by the startle reflex can have detrimental effects, particularly when the startle is elicited when the pilot is performing flight essential tasks. A pilot can lose part of the situational awareness, due to distraction which might cause cognitive tunneling. And pilots might be interrupted in a difficult cognitive process, such as making a decision (Rivera, et al, 2014).'

1.11 Aerodrome Information

1.11.1 Introduction

Washington Dulles Airport, KIAD, is located 20 miles west of Washington D.C. at an elevation of 312 ft above mean sea level. It has four runways designated 30/12, 01L/19R, 01C/19C and 01R/19L. RWY 01R is 11,500 ft long (3,505 metres) with a landing distance available of 11,500 ft. The ILS Glide Slope is set at 3° giving a threshold crossing height of 55 ft.

1.11.2 Precision Approach Path Indicator (PAPI)

The Federal Aviation Administration (FAA) describes the PAPI system as the current standard Visual Glide Slope Indicator (VGSI) which consists of four light boxes arranged perpendicularly to the edge of the runway. It projects a pattern of red and white lights that provide visual approach slope information (**Figure No. 6**).

PAPIs provide a definite white and red light projection pattern along the desired descent path to the touchdown point. PAPIs are designed to reduce Controlled Flight into Terrain (CFIT) and landing distance over and under runs by assisting the pilot in establishing a stabilised descent.

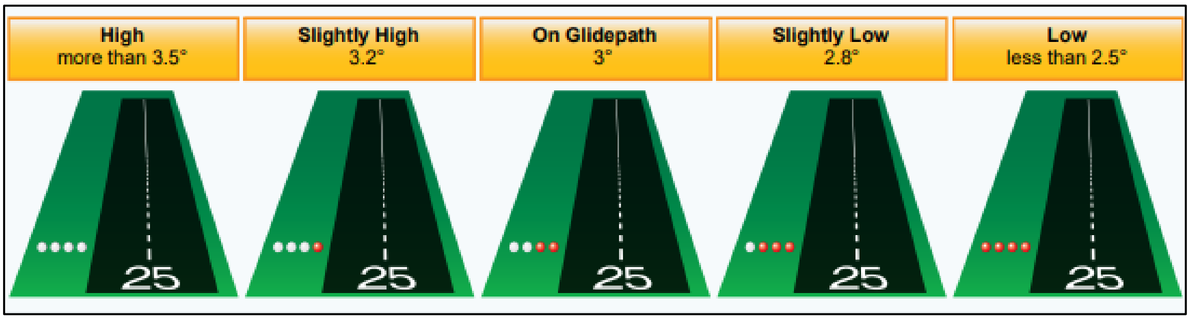

Figure No. 6: PAPI light arrangement (image from PHAK[21])

The PAPIs for RWY 01R at KIAD are set at 3° giving a threshold crossing height of 72 ft.

1.12 Flight Recorders

The aircraft was equipped with a Solid-State Flight Data Recorder, and a Cockpit Voice Recorder. Both devices were downloaded by the NTSB and the data contained therein was provided to the Investigation.

[21] **PHAK:** Pilot's Handbook of Aeronautical Knowledge published by the Federal Aviation Administration (FAA).

1.12.1 Flight Data Recorder

The Flight Data Recorder (FDR) indicated that at time 19:36:29, the aircraft was at an RA of approximately 1,000 ft (Above Ground Level, AGL) and fully configured for landing: flaps 34°/slats 27°, both autopilots engaged, autothrust (A/THR) engaged, landing gear extended, target airspeed of 137 kts and actual airspeed of 138 kts. The rate of descent was approximately 600 fpm, pitch attitude was 1° nose-up, and the aircraft was established on the glideslope/localiser. The FDR data indicates that at time 19:36:39, both autopilots were disengaged while the A/THR was left engaged which is normal procedure. At this time, the aircraft was at approximately 940 ft RA and was being flown manually by the FO.

As the aircraft descended further below 940 ft RA, the aircraft's speed varied between 132 kts and 148 kts (target speed +11 kts) and the rate of descent varied between 450 fpm and 900 fpm. At approximately 300 ft RA, the aircraft began to deviate above the glideslope and at time 19:37:46, it was approximately half a dot above the glideslope (a missed approach is usually initiated when an aircraft is 1 dot above or below the glideslope). As the aircraft descended below 120 ft RA, some nose-down side stick inputs were applied by the FO and the airspeed varied between 148 kts and 139 kts. The rate of descent reached a maximum of 976 fpm at 33 ft RA (**Figure No. 7**).

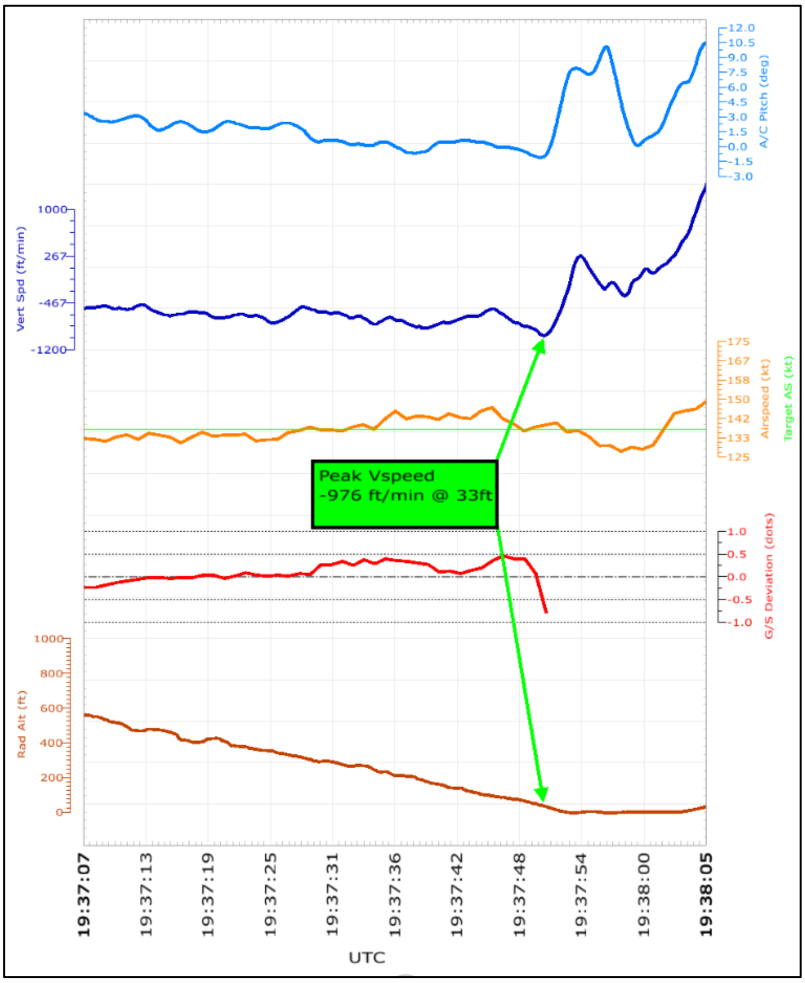

Figure No. 7: Peak rate of descent at 33 ft RA.

1.12.2 Manufacturer's Report

In a report on its analysis of the FDR data, the Manufacturer stated that the aircraft met the stabilisation criteria as it descended through the 1,000 ft and 500 ft gates. The report indicates that at 120 ft RA, some nose-down side stick orders (inputs) up to 1/5th of full deflection were applied by the FO, leading the pitch angle to decrease from +0.5° to -1° (Point (**1**) in **Figure No. 8**).

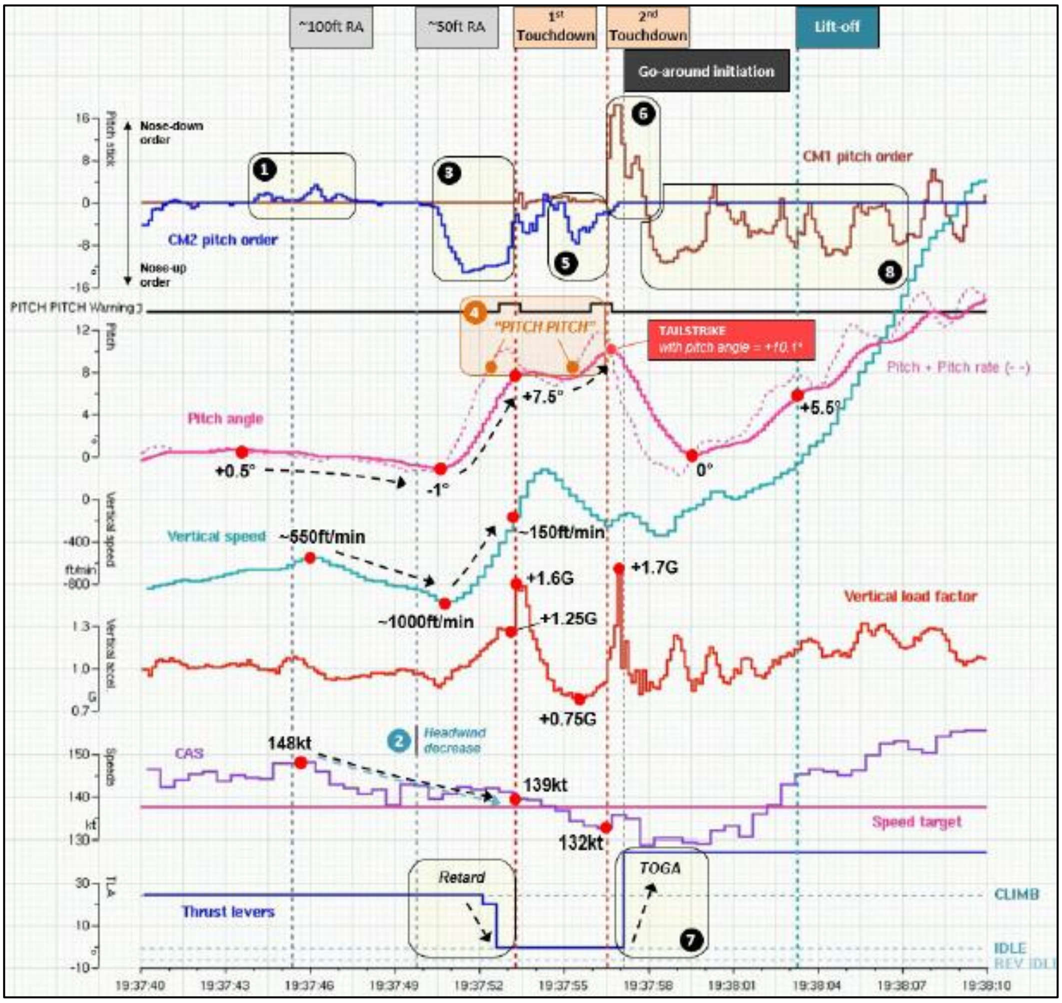

Figure No. 8: Flight dynamics from short finals to lift-off (Manufacturer's graphic)

Below 100 ft RA, there was a reduction in the headwind component (**2**) and the airspeed decreased from 148 kts to 139 kts which led to a partial loss of lift at a low height. At 40 ft RA**,** the flare manoeuvre was initiated with a 4/5th of full nose-up side stick input (**3**) which caused the pitch angle to increase from -1° to + 7.5° with a pitch rate reaching +4.9°/s. The rate of descent decreased from 1,000[22] fpm to 150 fpm. Due to the significant pitch rate during the flare, the predictive pitch (pitch angle value reached after one second if pitch rate is maintained) reached its threshold; therefore, a *'Pitch Pitch'* automatic callout was registered by the FDR prior to the first touchdown (**4**). The aircraft touched down at 19:37:53 with a +1.6 G vertical load factor and at a pitch angle of +7.5°.

[22] The Manufacturer indicated the rate of descent to be 1,000 fpm. The Investigation noted the maximum rate of descent to be 976 fpm.

The Manufacturer noted that during the initial touchdown, the right main gear touched down first, followed briefly by the left main gear. Both right wheels started to spin up followed by the left inner wheel. The left outer wheel did not spin up at first touchdown due to the brief runway contact of the left main gear.

SEC No 1 validated both main gear on the ground which allowed full deployment of ground spoilers No 3 and No 4 on each wing; however, SEC No 2 and SEC No 3 validated only one main landing gear on the ground which activated the PLD function with a partial deployment of spoilers No 1, No 2 and No 5 on each wing (**Section 1.7.4**).

The aircraft momentarily became airborne again (bounced) to a maximum height of 3 ft RA. During the bounce, the FO decreased the nose-up order on the side stick which momentarily reduced the pitch angle. Approximately one and a half seconds after the first touchdown, the FO then applied one half full nose-up side stick which increased the pitch angle to 10.1° (**5**). A second automatic *'Pitch Pitch'* callout was registered during this pitch angle increase and prior to the second touchdown.

The aircraft touched down a second time with a vertical load factor of +1.7G and at a pitch angle of 10.1°. Simultaneously, the Commander took control and initiated a nose-down side stick input (**6**). The thrust levers were advanced to the TOGA position (**7**) and the pitch angle decreased to 0°. The pitch angle subsequently increased as a function of the side stick inputs (**8**) and the aircraft become airborne again in the go-around approximately 10 seconds after the initial touchdown.

1.12.3 Cockpit Voice Recorder

The Investigation reviewed the Cockpit Voice Recorder (CVR) and noted a relaxed, professional and friendly atmosphere on the flight deck, consistent with effective Crew Resource Management (CRM). The CVR recorded several wind checks throughout both the first and second approaches. The wind check provided by the tower with the landing clearance on the first approach was from a direction of 310 degrees magnetic at a speed of 12 knots. A second wind check was from a direction of 310 degrees magnetic at a speed of 15 knots, gusting to 19 knots. This second wind check was given to another aircraft following behind EI-LRD and prompted the Commander to remark that the wind was *'coming over those trees'*.

- At approximately 250 ft RA (18 seconds prior to initial touch down), the Commander remarked that the runway was very long.

- Between the 50 ft and 40 ft RA automated callouts, the Commander announced *'pitch'* which was acknowledged by the FO.

- The CVR did not record any *'Pitch Pitch'* automated callout prior to the first touchdown.

- The 40 ft, 30 ft, 20 ft and *'Retard Retard'*[23] automated callouts are recorded followed immediately by the main gear touching down.

[23] **Retard:** The point at which the thrust levers are closed and the autothrust is disconnected.

- During the bounce, the *'Pitch Pitch'* automated callout was recorded.

- The main landing gear touched down again followed by the automated *'Priority Left'* callout, and the Commander announcing *'Go-around'.*

- The CVR did not record any wind shear warnings or advisories.

The subsequent go-around was uneventful and the Commander remained as the PF throughout. The CVR recorded the subsequent conversation between the SCCM and the Commander. Once the aircraft was stable at 3,000 ft with the autopilot engaged, the Commander conducted a short debrief with the FO as to the factors which led to the go-around. The FO stated that they were *'pitching down too much'* followed by trying *'to pull back too much, then we hit too hard'.*

The aircraft was vectored for another ILS approach to RWY 01R. ATC advised that the wind was from a direction of 310 degrees magnetic at a speed of 13 knots gusting to 16 knots. The aircraft landed again uneventfully and taxied to its allocated stand.

1.12.4 Pitch Pitch Synthetic Voice Message

1.12.4.1 Introduction

The Flight Warning System (FWS) triggers a *'Pitch Pitch'* automatic callout when the predicted pitch exceeds a specific threshold. The FDR data registered two separate automatic *'Pitch Pitch'* callouts (**Section 1.12.2**). The first was registered prior to the first touchdown and the second was registered during the bounce and prior to the second touchdown, however, only the second *'Pitch Pitch'* callout was recorded on the CVR. The Commander reported that if he had heard the first automatic callout, he would have taken control earlier as it would have been *'instinctive'* for him to do so. In order to investigate the missing '*Pitch Pitch'* callout, the Investigation provided the Manufacturer with detailed timings and durations relating to the various automatic callouts recorded on the CVR.

1.12.4.2 Manufacturer's Report

The Manufacturer stated that the audio design principles applicable to the emission of audio synthetic voice messages on the subject aircraft type are as follows:

> *'Audio synthetic voice messages are prioritized. Concerning the event, the messages with a higher priority than the "Pitch Pitch" audio are: - GPWS and TCAS related messages.*
> *- STALL, WINDSHEAR, RUNWAY TOO SHORT and SPEED.*
>
> *- The philosophy is that an audio synthetic voice message already started is never interrupted. Side effects of an interrupted message are not considered better than delaying another announcement whatever the priority. For example: "Don't Sink" followed by "Pull Up" should never become "Don't" "Pull Up".*
>
> *- There is no "queue" in the FWS. If the conditions to trigger a message disappears, the message will either: - continue to be emitted up to its completion if emission has already started (as stated above).* [or]
> *- not be emitted at all if its emission did not start.*

Thus there is a possibility for an audio (for example the "Pitch Pitch") to be hidden if it is temporarily requested while another audio (for example "Retard") is being emitted and the conditions disappear before the end of the other message.'

The *'Retard Retard'* audio message had a duration of 1.773 seconds and is triggered below 20 ft when the throttles are above the idle gate. **Figure No. 9** shows, *inter alia*, the earliest and latest possible *'Retard Retard'* activation in relation to the latest possible end of the *'Pitch Pitch'* triggering conditions. The Manufacturer noted that due to sampling rates, *'the exact occurring time for the parameters state change is not known, especially for the parameters with a lower sampling rate. (Thrust levers, PitchPitchWarning).'*

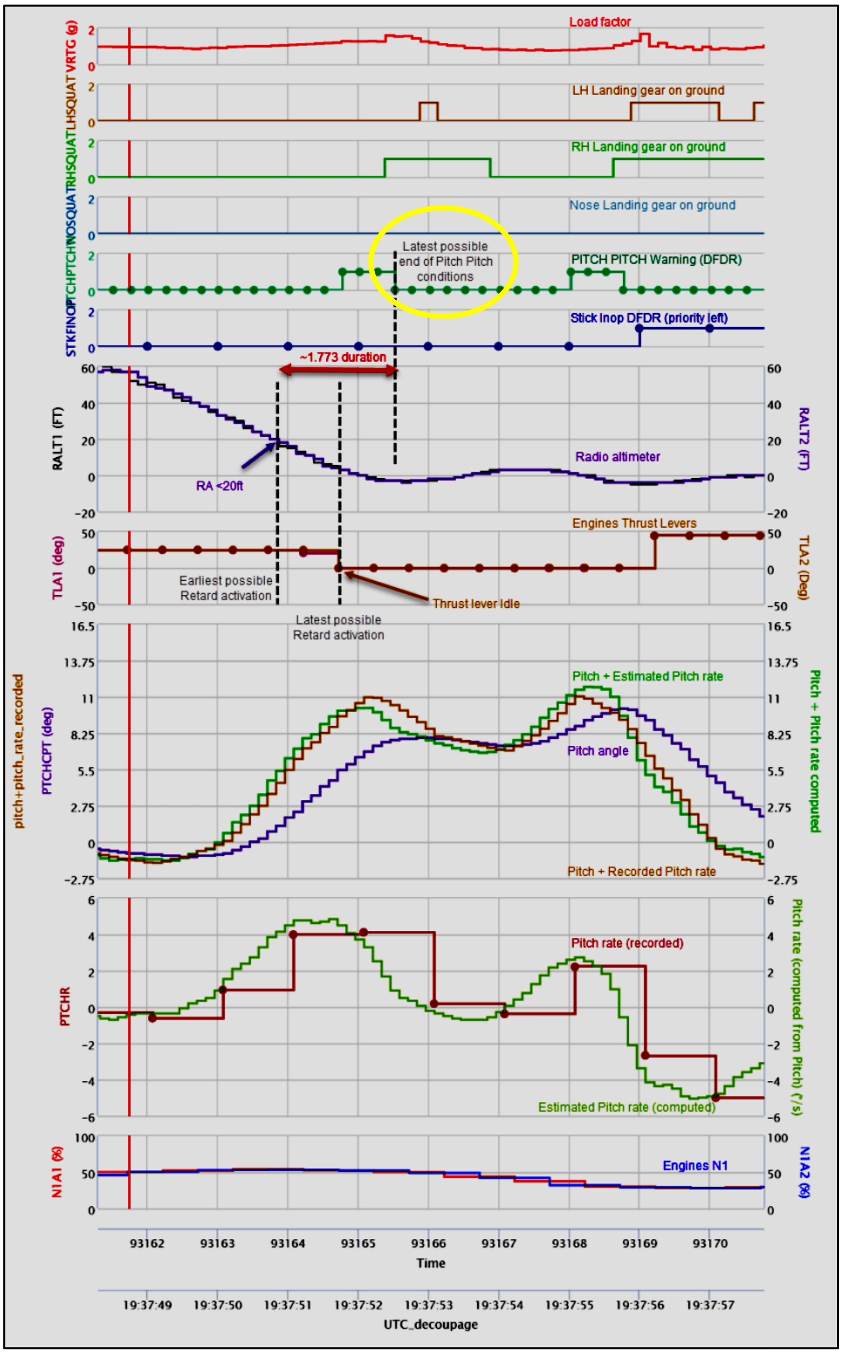

Figure No. 9: Latest possible end of the '*Pitch Pitch'* conditions (ringed in yellow)
(Figure adapted from Manufacturer's graphic)

The Manufacturer's Report concluded that the CVR data provided by the Investigation is compatible with the hypothesis that the *'Pitch Pitch'* audio request was hidden by the *'Retard Retard'* automatic callout with the following sequence of events:

- Start of emission of *'Retard Retard'*
- Transient and short triggering of the *'Pitch Pitch'* audio emission request
- End of the emission of the *'Retard Retard'* when the *'Pitch Pitch'* audio conditions were not met anymore

The Manufacturer's Report further concluded that the sequence of events is compatible with the design of audio messages whereby an audio message that has already started is not interrupted even by a higher priority message. A higher priority message such as the *'Pitch Pitch'* will not be emitted if its triggering conditions are no longer met when the emission could start.

1.13 Safety Actions

1.13.1 The Operator

Following the occurrence, the Operator outlined a number of implemented Safety Actions:

- CCM training during annual recurrent Safety and Emergency Procedures training to include tailstrike awareness and identification.

- Tailstrike awareness simulator training for flight crew.

- Go-around from near the ground simulator training for flight crew.

- Aircraft mishandling and recovery simulator training for flight crew.

- Descent preparation guidance advising flight crew to review the aircraft variant being operated vis-a-vis tailstrike awareness.

- In accordance with Airbus Service Bulletin A320-22-1294, activation of automatic call out and Pitch Limit Indicator on all of the Operator's A320 family of aircraft.

1.13.2 The Manufacturer

In this case, not all SEC computers validated that both main landing gear were on the ground and as a consequence the normal ground spoiler compensation (automatic nose-down elevator order) did not occur due to the nature of the touchdown sequence. To enhance the availability of the ground spoiler compensation, the Manufacturer stated its intention to make *'improvements'* to system logic when only a partial number of SEC computers command full ground spoiler extension. This would have helped to reduce the risk of a tailstrike in this event. The target date for certification of this system logic modification is *'mid 2028'*.

2. ANALYSIS

The aircraft, with six crew and 145 passengers on board, departed EIDW on a scheduled transatlantic flight to KIAD, with the FO acting as the PF and the Commander as the PM. After the subject aircraft had received landing clearance during the approach, another aircraft was given a wind check from a direction of 310 degrees magnetic at a speed of 15 knots, gusting to 19 knots. This gave a crosswind component of approximately 15 kts, including the gust. This wind check prompted the Commander to remark that the wind was *'coming over those trees'* which may have been a reference to the existence of associated low-level mechanical turbulence that can have a destabilising effect on aircraft. Despite the gusty conditions, the Commander was comfortable with the FO's ability to continue with the approach. The maximum demonstrated crosswind for the aircraft was 38 knots and therefore the crosswind was within the aircraft's capability.

2.1 The Occurrence Sequence

The FDR data indicates that at time 19:36:37, the aircraft was fully configured for landing and both autopilots were disengaged. The aircraft's airspeed varied between 132 kt and 148 kt, which is consistent with the weather reports for gusty conditions. At approximately 300 ft RA, the aircraft began to deviate above the glideslope. Based on time stamps and the CVR recordings, this was when the Commander remarked to the FO that the runway was very long This remark by the Commander was in the context of the landing technique trained by the Operator, which states that when the aircraft is below 200 ft, the focus should be to maintain the steady approach path and to avoid large control inputs or significant changes to the flight path and not to *'chase'* the glideslope. If slightly high, don't drop the nose (or increase the ROD); the divergence should be accepted, adjusting only to regain a steady approach path, as long as a touchdown inside the touchdown zone can be assured. Seven seconds before the initial touchdown, the maximum deviation above the glideslope was approximately half a dot. Despite this deviation, and in the absence of any CVR commentary in relation to the PAPIs, the aircraft may have been on the correct PAPI profile (*On Glidepath* as per **Figure No. 6**), when the slight difference in threshold crossing heights between the electronic glideslope and the PAPIs is considered.

As the aircraft descended through 120 ft RA, it experienced a reduction in the headwind component and the airspeed reduced which led to partial loss of lift at a low height. A nose-down command of up to 1/5th of full side stick deflection was commanded which resulted in a pitch angle of -1° and an increasing rate of descent. This nose-down input was likely an attempt to regain the glideslope. Between the 50 ft and 40 ft RA automatic callouts, the Commander announced *'pitch',* which was acknowledged by the FO. This *'pitch'* call was to warn the FO of an undesirable pitch angle. At 40 ft RA, a significant nose-up input was made which reduced the peak rate of descent from 976 fpm to approximately 150 fpm. The FDR registered an initial *'Pitch Pitch'* automated callout prior to the first touchdown; however, this was not annunciated by the FWS and therefore was not recorded on the CVR. An audio message that has already started (*Retard Retard*) will not be interrupted even by a higher priority message. A higher priority message such as the '*Pitch Pitch'* will not be emitted if its triggering conditions are no longer met when the callout could start. The Commander reported that if he had heard this first automated callout, he would have taken control earlier as it would have been *'instinctive'* for him to do so.

The tailstrike avoidance procedure as contained in the Manufacturer's FCTM states that in the event of too high a sink rate close to the ground, a pilot might attempt to avoid a firm touch down by commanding a high pitch rate which may be difficult to control after touchdown, which is what occurred in this case. The aircraft touched down with a +1.6 G vertical load factor and at a pitch angle of + 7.5°. During the initial touchdown, SEC No 1 validated both main gear on the ground which allowed full deployment of ground spoilers No 3 and No 4 on each wing. SEC No 2 and SEC No 3 validated only one main landing gear on the ground which activated the PLD function with a partial deployment of spoilers No 1, No 2 and No 5 on each wing.

As only SEC No 1 validated both main landing gear on the ground, activation of what the Manufacturer described as ground spoiler compensation, which would have initiated an automatic nose-down elevator order, did not occur. In the absence of this ground spoiler compensation, the pitch up moment due to spoiler deployment was not counteracted.

The aircraft became airborne again following the initial touch down and reached a maximum height of 3 ft RA. During this bounce, the nose-up input on the side stick decreased which momentarily reduced the pitch angle. However, a half of a full nose-up side stick input was then applied, which increased the pitch angle to 10.1°. This side stick input was likely an intuitive response intended to ensure a smooth second touchdown. Such a scenario is highlighted in the tailstrike avoidance procedure. The bounced landing guidance in the case of a light bounce, instructs crews to maintain the pitch attitude and complete the landing, while keeping the thrust at idle, and not to allow the pitch attitude to increase, particularly following a firm touch down with a high pitch rate. It is possible that the FO experienced a startle reflex due to the 1.6 G vertical load, bounce and, with the exception of peripheral vision, may have lost sight of the runway through the forward cockpit window due to the increasing pitch attitude. It is also possible that a startle reflex may have affected the FO's decision as to whether or not to initiate a go-around.

2.2 The Go-around and Subsequent Approach

Prior to the second touchdown, a second *'Pitch Pitch'* callout is registered on the FDR and is also heard on the CVR. The aircraft touched down for a second time at a pitch attitude of 10.1°, which exceeded the tailstrike pitch attitude limit of 9.7° and resulted in a tailstrike. Approximately three seconds after the first touchdown and simultaneously with the second touchdown, the Commander pressed the priority pushbutton on his side stick and initiated a go-around.

Once established at the go-around altitude and after the autopilot was engaged, the Flight Crew conducted a short debrief as to the factors which led to the go-around. The FO was of the opinion that it was caused by *'pitching down too much'* followed by trying *'to pull back too much, then we hit too hard'.*

The Commander had a brief discussion with the SCCM and asked her to make a PA to reassure the passengers. The aircraft was vectored around for another ILS to the same runway and landed uneventfully in similar meteorological conditions to the first approach. After landing, the aircraft taxied to its stand and, following engine shutdown, the Flight Crew was made aware of the damage.

2.3 The Cabin Crew

Following the go-around, the Commander had a brief discussion with the SCCM and advised her that they would be returning to land in KIAD. The SCCM recalled talking to her colleagues in the aft cabin crew seats and noted that they were fine but seemed to be somewhat shaken from the occurrence. The CCM seated at door 4R stated in interview that she heard a bang during the second touchdown, the source of which seemed to come from underneath the aircraft.

This experienced CCM was not aware of the term *'tailstrike'* nor trained in how to recognise such an occurrence. Had they been aware that the aircraft could make such an abnormal runway contact, this could have been communicated to the Commander, to prompt the actioning of the appropriate checklist. The Investigation notes the Operator's safety action in this regard.

2.4 Tailstrike Checklist

The TAILSTRIKE checklist was not carried out by the flight crew as they were not aware that one had occurred. The Investigation notes that in the event of a tailstrike, there is no associated ECAM information displayed; however, there is a paper version of the checklist available in the QRH located in the flight deck.

In this occurrence, the rear pressure bulkhead was not compromised and the go-around altitude was quite low with a correspondingly low differential pressure; however, this may not always be the case. During the bounce, the *'Pitch Pitch'* callout was heard prior to the go-around being initiated. The Investigation considers that best practice is for crews of large commercial aircraft to have a healthy suspicion that a tailstrike may have occurred in such circumstances. This suspicion can be reinforced by the gathering of information from several sources such as, but not limited to, cabin crew reports, automatic callouts and runway inspections.

2.5 Summary

The FO had recently operated into KIAD and flew the first approach. There was a gusty wind on the approach which may have contributed to the aircraft becoming slightly high on the glideslope. In an attempt to regain the glideslope, several nose-down control inputs were made, which, along with a loss of headwind, resulted in an increased rate of descent near to the ground. The rate of descent was subsequently arrested with a rapid aft side stick input which triggered a *'Pitch Pitch'* callout on the FDR.; however, this callout was not annunciated due to the system logic. The initial touchdown resulted in a bounce to a height of 3 ft RA..

Following the bounce, nose-up side stick inputs were made due to a possible startle effect and/or in an attempt to ensure a smooth second touchdown. The Commander had limited time to react to the unfolding situation and simultaneously with the second touchdown, he took control and initiated a go-around. The aircraft was vectored around for a second approach and landed uneventfully. The Flight Crew first became aware that the aircraft had sustained damage was when a locally based engineer arrived in the flightdeck and informed the Commander. The aircraft was subsequently grounded.

3. CONCLUSIONS

3.1 Findings

1. Both flight crew members' licences and medical certificates were valid.

2. The aircraft's airworthiness certification was valid.

3. The First Officer was the designated Pilot Flying.

4. The approach was flown in gusty conditions.

5. The aircraft deviated ½ a dot above the glideslope during the latter stages of the approach.

6. The aircraft had an increased rate of descent which was corrected immediately prior to touchdown.

7. The first *'Pitch Pitch'* callout registered on the FDR was not emitted by the FWS, thereby depriving the Flight Crew of an early warning.

8. As the side stick controls are not mechanically linked, the Commander could not have been aware of the control inputs applied by the FO.

9. The aircraft bounced to a height of 3 ft Radio Altimeter.

10. An automatic nose-down elevator order to compensate the pitch up effect of the spoilers did not occur due to the nature of the touchdown sequence.

11. Prior to the second touchdown, the FO increased the pitch attitude of the aircraft. This was possibly due to startle effect and/or in an attempt to ensure a smooth second touchdown.

12. A tailstrike occurred during the second touchdown which resulted in substantial damage to the aft fuselage.

13. The touchdown sequence occurred over a period of approximately three seconds.

14. The Commander had limited time to react to the unfolding situation.

15. The Commander took control simultaneously with the aircraft's second touchdown and initiated a go-around.

16. The Flight Crew was not aware, nor did they suspect that they had a tailstrike event, therefore the TAILSTRIKE checklist was not actioned.

17. The aircraft was vectored for another approach, in similar conditions, and landed uneventfully.

18. Two Cabin Crew Members reported minor injuries.

3.2 Probable Cause

During the second touchdown, following a bounced landing, the pitch attitude of the aircraft exceeded the tailstrike pitch limit.

3.3 Contributory Cause(s)

1. A 976 fpm rate of descent near to the ground.

2. The first *'Pitch Pitch'* callout registered on the FDR was not annunciated.

3. The aircraft bounced following the first touchdown.

4. Nose-up side stick inputs during the bounce, possibly due to startle effect and/or in an attempt to ensure a smooth second touchdown.

4. SAFETY RECOMMENDATIONS

The Investigation notes a number of implemented safety actions by the Operator and the Manufacturer's intention to make *'improvements'* to ground spoiler compensation. Therefore, the Investigation does not sustain any safety recommendations.

- END -

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

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

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