AIRCRAFT ACCIDENT INVESTIGATION REPORT

AIRFRAME DAMAGE FROM LIGHTNING STRIKE IN FLIGHT

ALL NIPPON AIRWAYS CO., LTD.

BOEING 787-9, JA891A

AT AN ALTITUDE OF APPROXIMATELY 1,500 M, ABOUT 77 KM EAST-SOUTHEAST OF NARITA INTERNATIONAL AIRPORT

AT ABOUT 16:15 JST, MARCH 20, 2024

January 24, 2025
Adopted by the Japan Transport Safety Board
Chairperson TAKEDA Nobuo
Member SHIMAMURA Atsushi
Member MARUI Yuichi
Member SODA Hisako
Member NAKANISHI Miwa
Member TSUDA Hiroka

1. PROCESS AND PROGRESS OF THE AIRCRAFT ACCIDENT INVESTIGATION

1.1 Summary of the Accident	On Wednesday, March 20, 2024, a Boeing 787-9, JA891A, operated by All Nippon Airways, Co., Ltd., took off from Los Angeles International Airport on a scheduled Flight 5 of the company, and was struck by lightning while descending toward Narita International Airport, resulting in damage to the forward right side fuselage. There were 207 people on board, consisting of the Pilot in Command (PIC), 11 other crew members and 195 passengers, but no one was injured.
1.2 Outline of the Accident Investigation	Upon receiving the accident occurrence notification, on April 3, 2024, the Japan Transport Safety Board (JTSB) designated an investigator-in-charge and an investigator to investigate the accident. An accredited representative of the United States of America, as the State of Design and Manufacture of the aircraft involved in this accident, participated in the investigation. Comments on the draft Final Report were invited from parties relevant to the cause of the accident and the Relevant State.

2. FACTUAL INFORMATION

2.1 History of the Flight

According to the statements of the flight crew members (the PIC, the Acting PIC*1, and the Co-pilot) as well as the records of the EAFR*2 and the air traffic control (ATC) communications records, the flight history was as outlined below.

On March 20, 2024, at approximately 05:05 Japan Standard Time (JST: UTC + 9hrs, unless otherwise stated all times are indicated in JST on a 24-hour clock), a Boeing 787-9, JA891A, operated by All Nippon Airways, Co., Ltd., took off from Los Angeles International Airport, and at approximately 15:50 on the same day, began its descent for landing at Narita International Airport (Figure 1).

Figure 1: Estimated Flight Route and Lightning Strike Point

The PIC took the left seat as the PF*3, the Acting PIC took the right seat as the PM*3, and the Co-pilot in a rear seat in the cockpit (observer seat).

According to the information obtained by the flight crew members during the pre-flight briefing, there was no information about other aircraft being struck by lightning on the aircraft's approach path.

According to the information confirmed by the flight crew members during the flight using the application on the tablet provided by the company, there were a slightly strong echo*4 to the south of the waypoint located on

＊1 "Acting PIC" refers to a person who acts as a relief pilot on behalf of the PIC only during cruise while the PIC is away from the pilot's seat to rest.

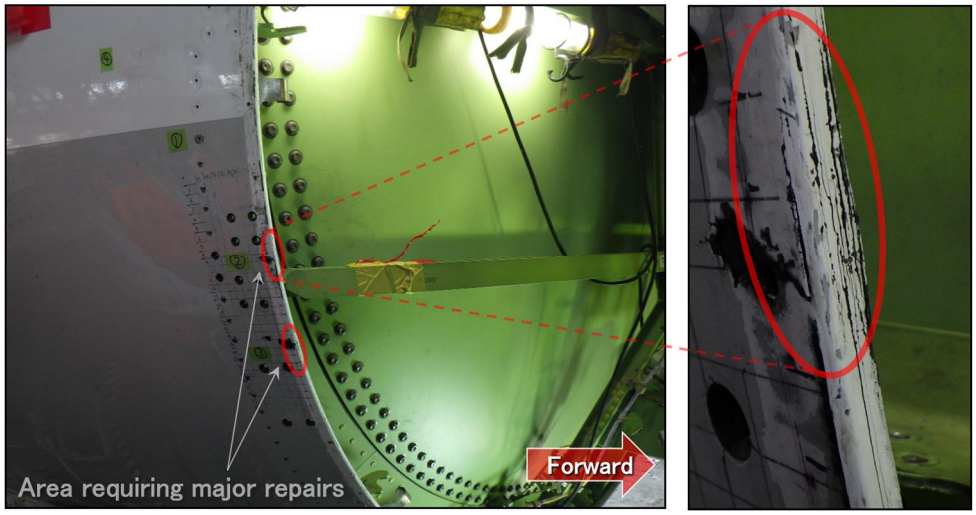
＊2 "EAFR" stands for Enhanced Airborne Flight Recorder and refers to an integrated flight recorder capable of providing a combination of Flight Data Recorder (FDR) and Cockpit Voice Recorder (CVR) functions.

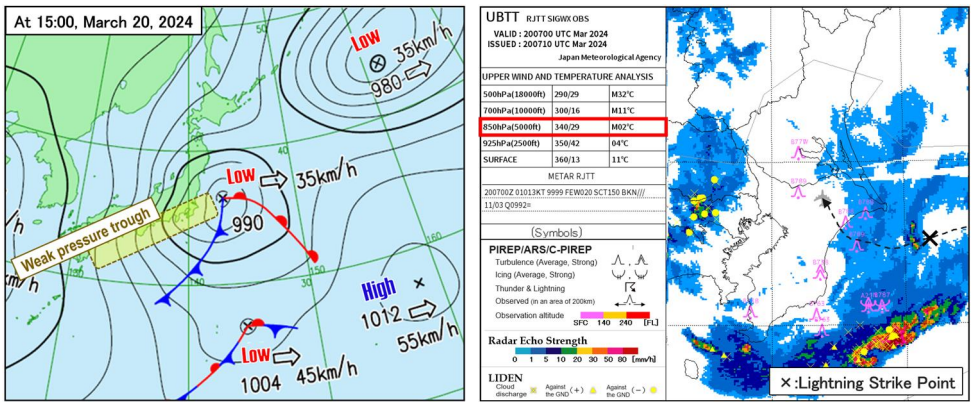
＊3 "PF" and "PM" is a term for identifying a pilot from role sharing in an Aircraft controlled by two people, PF (Pilot Flying) mainly manipulates the Aircraft and PM (Pilot Monitoring) Mainly performs monitoring of flight condition of the Aircraft, and makes cross check of operation of PF and operations other than maneuvering.

＊4 "Echo" refers to the reflected waves captured on the radar as radio waves emitted from a metrological radar are reflected by raindrops and ice particles, etc. The reflective waves allow to observe the distribution of precipitation area and the intensity, and this precipitation area may be also called “Echo”.

	the aircraft's approach path and a strong echo off the Boso Peninsula, but no significant echoes were confirmed on the aircraft's approach path. In addition, the information received by ACARS*5 confirmed the echoes which were moving to the northeast, but there was no information about other aircraft being struck by lightning, thus, the flight crew members judged that it should not affect the continuing flight (see "2.6 Meteorological Information" below). During the descent, the flight crew members confirmed the echo areas, including strong echoes on the south side of the approach path, on the airborne weather radar unit (hereinafter referred to as "the Airborne Radar"). And they flew the aircraft, selecting different sensitivities in the left and right pilot seats for the Airborne Radar settings to respond to suddenly formed clouds. In order to avoid the weak echo areas observed on the Airborne Radar, the aircraft continued its descent while changing the heading in sequence from 250° to 220° after receiving ATC clearance, and when sighting the sea surface, the flight crew members reported that they had passed through the areas required for the avoidance maneuver (clear of weather) and then flew the aircraft in accordance with ATC instruction. Having received the ATC instruction to change heading (260° →270°), the aircraft was flying at an altitude of approximately 1,500 m, about 77 km east-southeast of Narita International Airport, in thin clouds with the ground surface visible near the cloud base, when the aircraft was suddenly struck by lightning at about 16:15. Immediately after the lightning strike, the message "WXR RADAR SYSTEM L" (the Airborne Radar on the left) was displayed, but the echoes on the Airborne Radar screen were displayed correctly, and other instruments were in normal condition. In addition, the burning smell also occurred briefly, but after that there was no anomaly, and the aircraft landed at Narita International Airport at 16:29. During the inspection after landing, lightning damage was found to the outer skin of the forward right side fuselage and to the radome. No crew members and passengers were injured. This accident occurred at about 16:15, on March 20, 2024, at an altitude of approximately 1,500 m, about 77 km east-southeast of Narita International Airport (35° 30' 00" N, 141° 10' 30" E).
2.2 Injuries to Persons	None
2.3 Damage to the Aircraft	Extent of Aircraft Damage: Substantial damage ・Delamination on the outer skin of the forward right side fuselage (Area requiring major repairs): Two locations (Figure 2)

＊5 "ACARS " stands for Aircraft Communications Addressing and Reporting System. It is equipment for providing the information necessary for an aircraft's operation from the ground to the aircraft and vice versa, via digital data communication.

	・Burn marks on the upper and rear of the above: 10 locations (Figure 3, left) ・Burn marks on the radome: Two locations (Figure 3, right)  Figure 2: Damage to Forward Right Side Fuselage and Enlarged View  Figure 3: Damage to Parts other than those Requiring Major Repairs
2.4 Personnel Information	(1) PIC: Age 60 Airline transport pilot certificate (Airplane) April 5, 2002 Type rating for Boeing 787 February 3, 2014 Class 1 aviation medical certificate Validity: August 27, 2025 Total flight time 17,508 hours 46 minutes Total flight time on the type of the aircraft 6,617 hours 46 minutes (2) Acting PIC: Age 58 Airline transport pilot certificate (Airplane) October 19, 2000 Type rating for Boeing 787 June 29, 2021 Class 1 aviation medical certificate Validity: July 12, 2024 Total flight time 13,225 hours 30 minutes Total flight time on the type of the aircraft 779 hours 23 minutes (3) Co-pilot: Age 43 Airline transport pilot certificate (Airplane) July 28, 2017 Type rating for Boeing 787 October 24, 2012 Class 1 aviation medical certificate Validity: May 1, 2024

	Total flight time 8,704hours 09 minutes Total flight time on the type of the aircraft 6,234 hours 57 minutes
2.5 Aircraft Information	Aircraft type: Boeing 787-9 Serial number: 40751 Date of manufacture: March 29, 2017 Airworthiness certificate: No. 2017-011 Validity: Period starting from April 18, 2017, during which the Maintenance Management Manuals (All Nippon Airways Co., Ltd.) are applied. Total flight time 29,826 hours 06 minutes (2) There was no record indicating vibration, impact and other anomalies related to the accident in the EAFR flight records. Besides, the voice records of the EAFR (with a maximum recording period of two hours) did not retain any voice records during the flight since they had been overwritten during the period until the extent of the damage was decided as requiring major repairs. (3) When the accident occurred, the weight (402,700 lb) and the position of the center of gravity (1,214 in) of the aircraft were within the allowable range.
2.6 Meteorological Information	(1) General Weather Conditions According to the Weather Observation Chart announced by the Japan Meteorological Agency at 15:00 on March 20, 2024, a low-pressure system accompanied by fronts was moving eastwards off the Kanto coast while developing. In addition, it was analyzed that a weak pressure trough was located the south of the Kanto region from the low pressure (Figure 4, left). According to the Narrow Area Significant Weather Observation Chart (UBTT) at 16:00 on March 20, 2024, there was a line with active cumulonimbus clouds accompanied by lightning off the Boso Peninsula where it was far from the approach path of the aircraft. In addition, the temperature at the altitude (1,500 m) where the aircraft was struck by lightning was minus 2°C (Figure 4, right).  Figure 4: Weather Observation Chart and Narrow Area Significant Weather Observation Chart

(2) Changes in Lightning Activity

According to the analysis chart of the thunder nowcasts*6, from 15:30 to 16:10, the degree of lightning activity increased in the vicinity of the aircraft's lightning strike point (Figure 5).

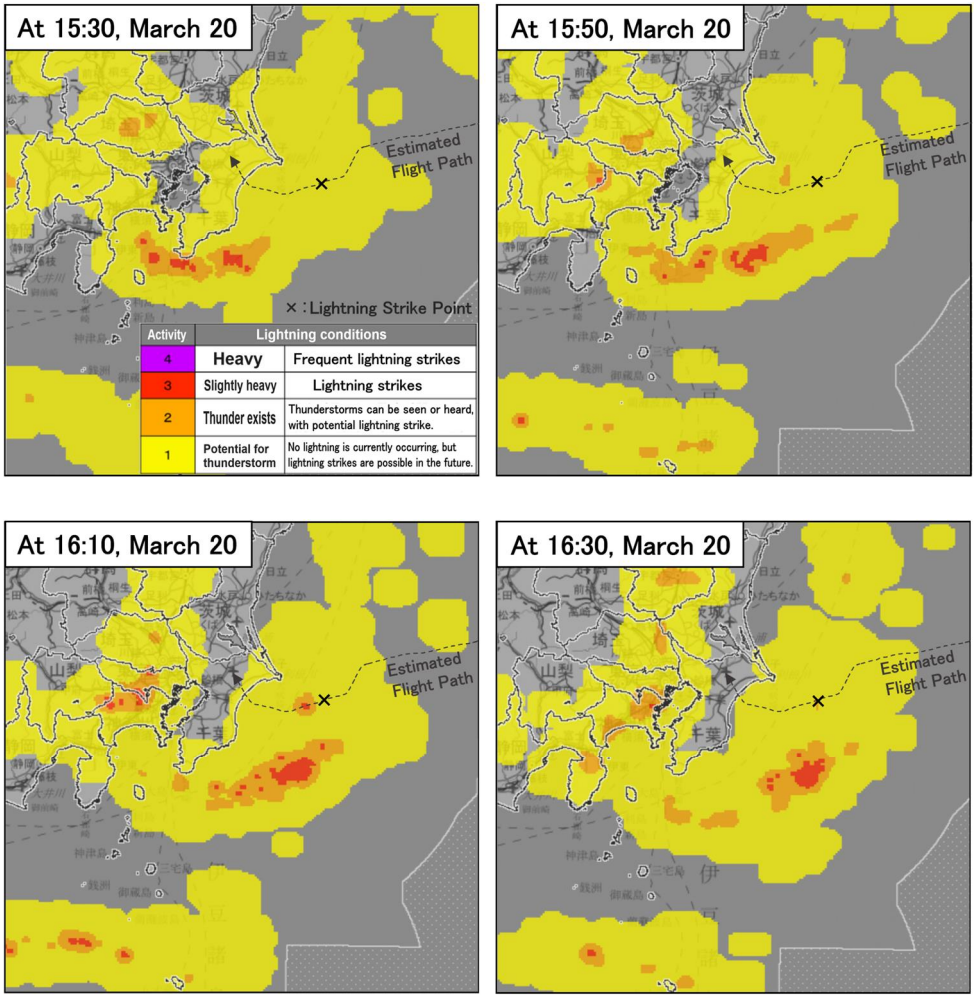


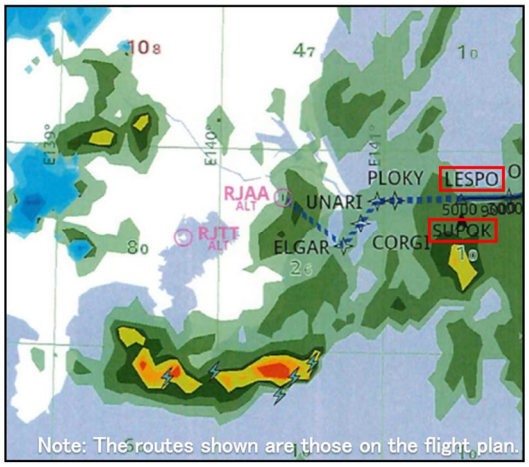
Figure 5: Thunder Nowcasts Analysis Chart

(3) Information Obtained by Flight Crew Members in Flight

According to the information confirmed by the flight crew members at about 15:40 using the application on the tablet provided by the company, there was a slightly strong echo to the south of the waypoint (LESPO, SUPOK) located on the aircraft's approach path and a strong echo off the Boso Peninsula (Figure 6, left).

According to the information obtained by the flight crew members by ACARS at 15:52, a weak echo located 20 to 60 nm east to south of Narita International Airport and a moderate echo located south to southwest of the airport, both moving northeast (Figure 6, right).

＊6 "Thunder nowcasts" is one of the forecast services provided by the Japan Meteorological Agency, which analyzes a severity and a possibility of the thunder based on the data detected by the thunder monitoring system. The degree of lightning activity is expressed from Activity 1 to 4, indicating that the higher the number of lightning discharges detected, the more severe the thunder is (higher activity: 2 to 4).



TIME/Z 2024/03/20 06:52

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RJAA OBS 0641/20Z SR2041Z/SS0851Z
USING RWY :
T/O 34L FREQ 124.2
L/D 34R ILS Z
L/D 34L ILS
//WIND CAUTION FM 2340Z//
1. RWY COND : W E T
2. SFC WIND : 34L:040/05-07KT
              34R:000/00-01KT
3. FNL COND : SLIGHTLY ROUGH-ROUGH
 //ALWIN//  3000 340/23
           2000 340/20
           1000 010/09
            500 050/07        (0640Z
   //WSA// 34L NIL SO FAR       (++++Z
          34R -27KT OVER RWY    (0615Z
4. ECHO    : 1)WEEK ECHO 20-60NM E-S
             MV TO NE
           2)MOD ECHO 60NM S-SW
             MV TO NE
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Figure 6: Information Obtained during Flight

2.7 Additional Information

(1) Airframe Material and Damage

Unlike conventional aircraft where most parts are made of lightweight metals such as aluminum alloys and others, the aircraft's fuselage outer skin is made of carbon fiber reinforced plastic (CFRP).

CFRP is manufactured by using intermediate material CFRP prepreg sheets, with a thickness of around 150 μm, where unidirectionally oriented fibers are impregnated with uncured toughened epoxy resin containing thermoplastic resin particles. Then unidirectional CFRP prepreg sheets are stacked in a quasi-isotropic lay-up, and cured in an autoclave by applying heat and pressure. It should be noted that separate toughened epoxy resin layers are interleaved between each CFRP sheet to prevent delamination (separation between CFRP sheets).

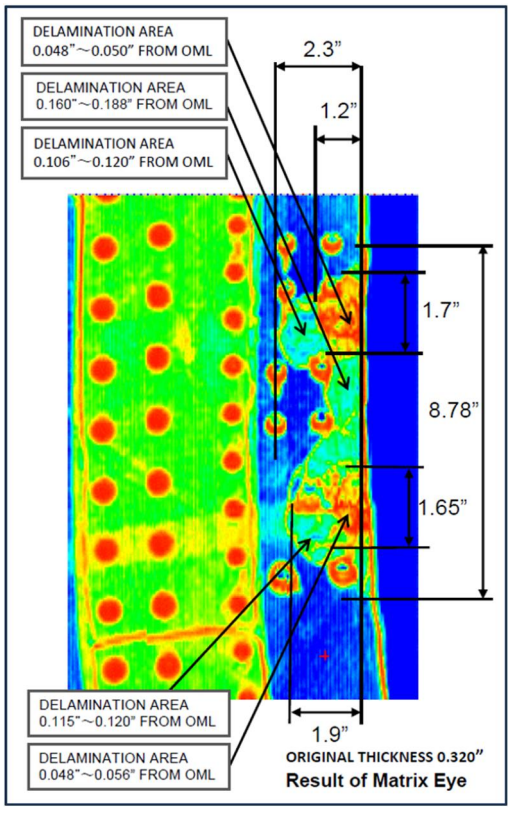

Figure 7: 3D Ultrasound Image

Compared to conventional aircraft fuselage skins, CFRP skins have a high strength and rigidity to weight ratio but may be subject to delamination in the event of a severe external impact.

In this accident, it was determined that the damage required major repairs because the delamination of the outer skin of the forward right side fuselage had propagated across all layers.

	The multi-layered delamination was repaired by the company according to the repair method obtained from the design and manufacturing company, as the 3D ultrasound image was available at the company. It is desirable that non-destructive testing shall be conducted periodically on the repaired parts to confirm that there is no propagation of the delamination (Figure 7). (2) The Company's Measures against Lightning Strikes The company has taken the following measures against lightning strikes: ・Winter: Establishment of avoidance routes at airports on the Sea of Japan side (Toyama Airport, Akita Airport) ・Spring and Summer: Provision of lightning information to flight crews via ACARS at Tokyo International Airport and Narita International Airport. ・A 3D aviation weather application development in collaboration with the Japan Aerospace Exploration Agency (JAXA) and MTI Co. Ltd. and promotion of the information provision by ground operating staff through its introduction. (3) Temperature Zones with High Risk of Lightning Strike Aeronautical Information Manual Japan (AIM-J) No. 80 (Late 2024 Edition. Sections 851), (Published by Japan Aircraft Pilot Association) states as follows; (excerpts) *f. Flight operation in a thunderstorm area* *a) Horizontal avoidance: When avoiding a cumulonimbus, detouring is the easiest and safest choice. A pilot should avoid any thunderstorm regarded as SEVERE or strong radar echoes at least by 20 nm.* (Omitted) *c) Flight proximity to a thunderstorm* *(When required to operate within the area described in a))* 1) to 3) (Omitted) *4) Avoid a 0 °C altitude with enough margin. Strong turbulence, strong icing and electric discharge are often encountered at that altitude. Statistically, -8°C ~ +8°C of this level, a thunderstorm may be experienced with 90% possibility. It is recommended to avoid the freezing level by 5,000 feet above or below.* (Omitted)

3. ANALYSIS

(1) Damage Status

The JTSB concludes that it is certain that in this accident, the aircraft was struck by lightning in flight, resulting in damage to the forward right side fuselage.

(2) Meteorological Conditions

The JTSB concludes as follows:

Although there was a cloud line with an active cumulonimbus accompanied by lightning off the Boso Peninsula, it was far from the aircraft's approach path (see Figure 4, right). Nevertheless, the aircraft was struck by lightning because the temperature of the altitude where the aircraft was

struck was within the temperature zones with a high risk of lightning strikes, and according to the analysis chart of the thunder nowcasts from 15:30 to 16:10, the lightning activity level increased in the vicinity of the aircraft's lightning strike point, making it most likely that the possibility of a lightning strike was rapidly increasing (see Figure 5).

(3) Response of Flight Crew Members

The JTSB concludes as follows:

Although there was no information about the lightning strike during the pre-flight briefing or during the flight, the flight crew members flew reacted to the suddenly formed clouds by changing the Airborne Radar settings one after another and changing the heading one by one to avoid even weak echo areas. It is highly probable that it would have been difficult for the flight crew members to predict and avoid the lightning strike, as it is most likely that in this accident, the possibility of a lightning strike was rapidly increasing.

4. PROBABLE CAUSES

The JTSB concludes that it is certain that in this accident, the aircraft was struck by lightning in flight, resulting in damage to the forward right side fuselage.

Regarding the Aircraft being struck by lightning, it is highly probable that it would have been difficult for the flight crew members to predict in advance that the possibility of a lightning strike was rapidly increasing at the lightning strike point and to avoid it.

5. SAFETY ACTIONS

5.1 Safety Actions Required	It is desirable to take further measures to prevent lightning strikes, such as avoiding the risk of lightning strikes based on more accurate lightning strike prediction information.
5.2 Safety Actions Taken after the Accident	In addition to the lightning protection measures already in place, the company has taken the following measures. ・Promote awareness-raising activities and incorporate them into various education and training programs to raise awareness of flight crew and ground operation staff regarding lightning prevention for aircraft. ・Improve operational methods, such as promoting flight methods that avoid flying in temperature zones with a high risk of lightning strikes. ・Further improve lightning strike prediction tools such as 3D aviation weather applications.