AA2023-5

AIRCRAFT ACCIDENT INVESTIGATION REPORT

Nippon Cargo Airlines Co., Ltd.
J A 1 3 K Z

August 31, 2023

Japan Transport Safety Board

The objective of the investigation conducted by the Japan Transport Safety Board in accordance with the Act for Establishment of the Japan Transport Safety Board and with Annex 13 to the Convention on International Civil Aviation is to determine the causes of an accident and damage incidental to such an accident, thereby preventing future accidents and reducing damage. It is not the purpose of the investigation to apportion blame or liability.

TAKEDA Nobuo
Chairperson
Japan Transport Safety Board

Note:

This report is a translation of the Japanese original investigation report. The text in Japanese shall prevail in the interpretation of the report.

《Reference》

The terms used to describe the results of the analysis in "3. ANALYSIS" of this report are as follows.

i) In case of being able to determine, the term "certain" or "certainly" is used.
ii) In case of being unable to determine but being almost certain, the term "highly probable" or "most likely" is used.
iii) In case of higher possibility, the term "probable" or "more likely" is used.
iv) In a case that there is a possibility, the term "likely" or "possible" is used.

AIRCRAFT ACCIDENT INVESTIGATION REPORT

AIRCRAFT DAMAGE DUE TO TAIL STRIKE (LOWER AFT FUSELAGE CONTACT) AT THE TIME OF GO-AROUND
NIPPON CARGO AIRLINES CO., LTD.
BOEING 747-8F, JA13KZ
AT RUNWAY 16R of NARITA INTERNATIONAL AIRPORT
AT AROUND 18:51 JST, FEBRUARY 1, 2021

July 21, 2023
Adopted by the Japan Transport Safety Board

1. PROCESS AND PROGRESS OF THE AIRCRAFT ACCIDENT INVESTIGATION

1.1 Summary of the Accident	On February 1 (Monday), 2021, at around 18:51, a Boeing 747-8F, JA13KZ, operated by Nippon Cargo Airlines Co., Ltd., experienced a bounce and became unstable attitude when landing at Runway 16R of Narita International Airport. Therefore, the aircraft executed a go-around, but the lower aft fuselage contacted with the runway, which resulted in damage to the airframe. There were two persons on board, consisting of the PIC, one crewmember, but no one was injured.
1.2 Outline of the Accident Investigation	Japan Transport Safety Board (JTSB) designated an investigator-in-charge and two other investigators to investigate the accident on February 1, 2021. 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 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 pilot in command (hereinafter referred to as “the PIC”) and the First Officer (hereinafter referred to as “the FO"), records of the Flight Data Recorder (FDR), Quick Access Recorder (QAR), and Cockpit Voice Recorder (CVR) as well as ATC communication records, the history of the accident is summarized as follows. (1) Situation up to the Aircraft’s approach to Narita International Airport

At 15:34 Japan Standard Time (JST: UTC +9hrs, unless otherwise stated all times are indicated in JST on a 24-hour clock) on February 1 (Monday), 2021, a Boeing 747-8F, JA13KZ, operated by Nippon Cargo Airlines Co., Ltd., took off from Hong Kong International Airport as a scheduled flight 258 of the Company for Narita International Airport (hereinafter referred to as "the Airport"). In the cockpit of the Aircraft, the PIC sat in the left seat as PF*[1] and the FO in the right seat as PM*[1].

Figure 1: The Aircraft

The PIC and the FO had stayed overnight in the Republic of Singapore on the day before, but had no duties, had enough sleep, felt no fatigue and were physically fit before departure.

On the same day, prior to the scheduled flight, the same crew members on board the Aircraft had taken a flight from Singapore Changi International Airport to Hong Kong International Airport (Flight time: 3 hours 55 minutes).

(2) Situation from approach to touchdown

The information on the wind conditions at the Airport (180°/2 kt) was obtained from ATIS information*[2] for the Airport issued at 18:00, in which there was no information about turbulence and wind shear.

Before starting to descending to the Airport, the PIC carried out landing briefing that in the landing configuration, the flap 30° and autobrake 3 would be selected and the approach speed would be set to V_{ref}*[3]+5 KIAS*[4]. A briefing was conducted as usual, and there were no special notes.

The Aircraft was radar-vectored by a controller of Narita Arrival

*[1] "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.

*[2] "ATIS information" refers those on the approach type at the relevant airport, using runway, status of the airport, weather information and others, which is provided to aircraft taking off from or landing at the airport..

*[3] "V_{ref}" refers to an airspeed set as standard when an aircraft passes the runway threshold for landing.

*[4] "KIAS" refers to Knots indicated airspeed.

	Control of Tokyo Rader Approach Control Facility to the ILS*5 Y RWY16R Precision Segment*6 of the Airport. The Aircraft was using the autopilot and auto throttle. At 18:47:11, the Aircraft established communication with a controller in charge of tower control position of Narita Aerodrome Control Facility (hereinafter referred to as the "Narita Tower") and informed that it was approaching the PERCH, the start point on the precision segment of ILS RWY 16R approach. (See Figure 3). At 18:48:33, the pilot of the Aircraft during the final approach asked Narita Tower about the status of the surface wind, Narita Tower replied it was 200°/5 kt. At 18:49:21, Narita Tower issued the landing clearance to the Aircraft and reporting the surface wind (200°/4 kt), and the Aircraft responded it. The Aircraft was taking a crab*7 angle of about 10° to the right when approaching Runway 16R (Runway magnetic bearing: 157°, Runway threshold elevation: 130 ft, Runway length: 4,000 m). At 18:50:23, the Aircraft passed an altitude of 635 ft (altitude of 500 ft from runway threshold elevation, (500 ft Above Field Elevation (AFE)). The FO made a callout of "500 ft" and the PIC responded to it "STABILIZED". At 18:50:31, the Aircraft entered the Runway Alignment Mode (refer to 2.6 (4)) at an altitude of 545 ft (Altitude on the Radio Altimeter*8 (RA): 500 ft). The subsequent records on the FDR and QAR are as shown in Appended Figure 1 (from 18:50:30 to 18:51:45) and Appended Figure 2 (Enlarged view from 18:51:00 to 18:51:35). At 18:50:37, the PIC disengaged the autopilot at an altitude of 460 ft (RA 352 ft) and shifted to a manual control (See Appended Figure 1①). When the autopilot was disengaged, the wind conditions recorded on the FDR was 218°/22 kt, but the wind velocity began to decrease gradually

*5 ILS (Instrument Landing System) refers to a radio equipment, which is designed to provide an approach path for an aircraft on final approach to a runway by emitting the directional radio wave, and consists of a localizer (LOC) that indicates left/right deviation from the center of the approach course to the runway, a glide slope (GS) that indicates the appropriate approach angle and marker beacons, terminal DME or DME fix that indicate the distance to the runway.

A pilot can take the appropriate approach course following the course guidance on the system.

Horizontal distribution of the localizer signals ((two dots from far left to far right) indications between a full "fly-left" and a full "fly-right" on CDI) is adjusted so as to cover 210 m (700 ft) of far-left to far-right width at the landing threshold.

The GS beam is also transmitted in about 1.44° thickness vertically ((two dots from the top to bottom) indications between a full "fly-top" and a full "fly-bottom" on CDI)

*6 For the Precision Segment of ILS Y RWY16R at the Airport, the pilot passes PERCH at 2,800 ft and then descends on a heading of 157° with a path angle of 3.0°. The decision altitude for this approach type is 330 ft for a ILS. Category I

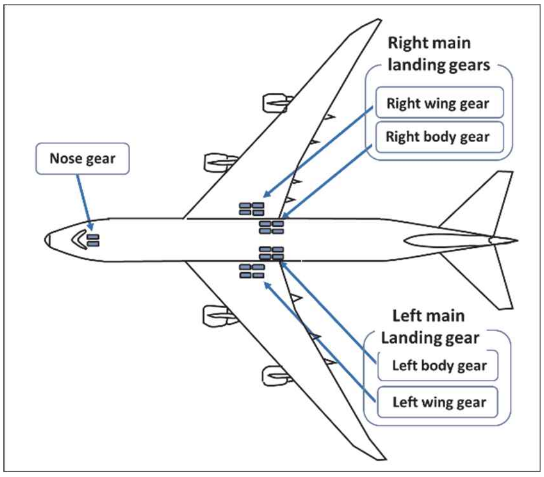
*7 "Crab" refers to an approach method in which the nose of the airplane is pointed into the wind a sufficient amount to counter a crosswind during crosswind landings.

*8 A radio altimeter is an altimeter that uses radio waves to directly measure altitude, unlike a pressure altimeter. It emits radio waves vertically downward to the ground from its own aircraft and measures the reflected waves from the ground.

	as the Aircraft descended. As the autopilot was disengaged, the Runway Alignment Mode was released. And the rudder, which had previously been turned to the left, returned to the neutral position (See Appended Figure 1②), and the heading of the Aircraft turned to the right (windward side). Therefore, the Aircraft began to veer to the right to the runway. When changing from the autopilot to the manual operation, the PIC did not make any rudder operation. At 18:50:39, the Aircraft descended through 100 ft (altitude of 430 ft) short of the decision altitude*[9]. The FO called out "APPROACHING MINIMUMS", and the PIC responded to it "CHECK" At 18:50:42, the PIC deactivated the auto-throttle. At 18:50:43, the PIC increased the engine rpm (N1*[10]), which had been about 66 % until then, to 75 to 77 %. The pitch angle of the Aircraft increased and the Aircraft began to veer to upward from a proper approach angle (on-glidepath) of the glide slope (GS). At 18:50:47, the Aircraft passed the decision altitude (altitude of 330 ft. The FO called out "MINIMUMS" and the PIC responded to it "LANDING" and then transitioned to outside visual cues. At 18:50:50, when the Aircraft passed 289 ft (154 ft AFE), the deviation from the GS on-glidepath was +1.02 dots (See Appended Figure 1③), and the deviation from the center of the approach course (on-course) of localizer (LOC) was 0.2 dots to the right. The PIC made the Aircraft roll to the left (roll angle of 4.2° left) and applied the left rudder pedal (8.8° to the left, and the maximum rudder pedal position of the Aircraft was 20°) in order to return the Aircraft to the runway centerline, which had deviated to the right from the runway centerline, and tried to make corrections. However, at 18:50:53, when the Aircraft passed 235 ft (100 ft AFE), the deviation from the LOC on-course was 0.28 dots to the right, and the deviation from the GS on-glidepath was +1.59 dots (See Appended Figure 1 ④), resulting in further enlarged deviation from a proper flight path. At 18:50:55, the PIC performed nose down operations and tried to make corrections for descending path by decreasing the N1 thrust up to about 65 %. At 18:50:56, the sink rate (V/S) increased and temporally reached 1,024 fpm (See Appended Figure 1⑤). The wind velocity recorded on the FDR began to increase after this. At 18:51:03, as the Aircraft passed the runway threshold, the PIC moved the forward thrust levers to the idle.

*9 "Decision Altitude" is the approach altitude limit, at which a pilot makes a decision to continue approach for landing or of a missed approach.

*10 N1 means the rotation speed of the fans, low-pressure compressor (LPC) and low-pressure turbines (LPT) of the engine, indicated with the number of rotations at 3,280 rpm which is close to the maximum engine thrust as 100 % for the event Aircraft.

	The Aircraft began to veer to the left from the runway centerline. The PIC applied the right rudder (11.5° to the right (See Appended Figure 1⑥)) in order to return the Aircraft to the runway centerline and made corrective operations. At 18:51:04, as the Aircraft returned to the runway centerline, the PIC released the right rudder pedal. The deviation from the LOC on-course was 0 dot (altitude of 128 ft (RA 6 ft)). At 18:51:05, at 132 ft (RA 3 ft, the crosswind from the right recorded on the FDR became at its maximum (240° /22 kt) (See Appended Figure 1⑦). The PIC made the Aircraft roll to the right and applied the right rudder pedal (7.2° right). In 11 seconds from 18:50:54 to 18:51:05, the wind changed from146°/02 kt to 240°/22 kt. The PIC was feeling that there was air current disturbance until just before touchdown. The FO was feeling that there was gusty condition at an altitude of 500 ft or less. (3) Situation from touchdown to the go-around While taking the roll angle to the right (4.2° right), the Aircraft touched down (see Attached Figure 2①) on the right main landing gear (right body gear and the right wing gear). The touchdown point was 520 m (90 m ahead the center (430 m) of aiming point marking) from the runway threshold. The heading (HDG) at the touchdown was 163° (See Appended Figure 2②). The PIC applied the left rudder pedal in order to align the HDG with the runway magnetic bearing.  Figure 2: Gear positions At 18:51:06, with the roll angle at 4.2° right, the left body gear touched down (See Appended Figure 2③), but bounded (see Appended Figure 2④). The Speedbrakes*[11] were extended but soon retracted (See Appended Figure 2⑥ for the Speedbrake operating status). At 18:51:08, with the roll angle at 3.9° right, the left body gear touched down again, and the left wing gear also touched down (See Appended Figure 2⑤). The Speedbrakes began to deploy again. In accordance with the

*11 The Boeing 747-8F has six spoilers on the upper surface of the wing (12 spoilers in total for two wings), which act as speed brakes. On the ground, when the speedbrake levers are in the arm position, the thrust levers 1 and 3 are near idle position, and at least one of right main landing gear and one of the left main gears (left body gear and left wing gear) touch down, the Speedbrake levers move to the up position and all spoilers deploy.

procedures (See 2.6 (11)), the FO called out “SPEED BREAK UP”. According to the normal landing roll procedure (See 2.6 (11)), the PIC raised the reverse thrust levers, and actuated the thrust reverser (See Appended Figure 2⑦). However, the PIC did not recognize the reverse thrust operation that the PIC had performed. The pitch angle began to decrease.

At 18:51:09, with the roll angle at 2.5° right, the right body gear, left body gear and left wing gear bounded (See Appended Figure 2⑧). The Speedbrakes were retracted once but soon extended. After that, the roll angle became almost horizontal, and all the gears except nose gear touched down. The pitch angle was 1.4°.

At 18:51:10, as thrust reversers were activated, the engine translating cowling (TC)*[12] began to deploy. The FO called “REVERSERS”. However, the FO did not recognize the call the FO had made. The pitch angle began to increase. In 3.5 seconds after this, the pitch angle changed from 1.4° to 9.8° (See Appended Figure 2⑨). The changes in the pitch angle were 2.4deg/ sec.

At 18:51:11, all the engine TCs deployed.

At 18:51:12, as the left and right wings were up and down alternately after the touchdown, which could not be contained even after that, and also feeling the Aircraft floating, the PIC decided to execute a go-around and made a call “GO-AROUND (GA)”, then moved the reverse thrust levers to the down position, moved the forward thrust levers to the position of the Maximum amount of control input (See Appended Figure 2⑩), and initiated a go-around. Concerned a hard landing, the PIC performed the go-around procedure with the flaps remained at 30° following not the normal go-around procedure but the procedure for escaping from the wind shear. As being concerned about the change in the Aircraft attitude, the PIC was not looking at the Aircraft speed.

At 18:51:13, the Pitch Augmentation Control System (PACS) (See 2.6 (13)) worked (See Appended Figure 2⑪ for PACS operating status), but the pitch angle was 9.8° (See Appended Figure 2⑫). The speed was reduced to 139 KIAS (See Appended Figure 2⑬). The TCs started to move toward the retract position.

At 18:51:15, all the engine TCs were closed completely (See Appended Figure 2⑭ for TC operation status). The N1 gradually started to rise from the engines whose TCs were completely closed (See Appended Figure 2⑮). The flight crew members felt that the increase in the engine rpm was slow, but they thought that it was because the N1 had been reduced to the minimum idle.

At 18:51:21, the speed was 123 KIAS (See Appended Figure 2⑯), which

*12 “Translating Cowl (TC) refers to the part of the cowling that plays a role to inject the forward thrust from the engines backward and slides backward after landing in order to slow the aircraft, damming the jet of forward thrust and injecting that jet diagonally forward.

TC can be deployed backward by pulling the reverse thrust levers. When TC is deployed, even if the Forward thrust levers are moved to the maximum control input position, the engine thrust does not increase due to engine control until TC is retracted completely.

was the lowest value during the landing roll. After that, the speed started to increase.

At 18:51:25, the N1 of all the engines exceeded 90 % (See Appended Figure 2⑰). PACS worked (See Appended Figure 2⑱ for PACS operating status), but for three seconds after that, the pitch angle became 9.8° (See Appended Figure 2⑲). The speed changed from 132 KIAS to 134 KIAS. The Aircraft made a landing roll without the nose gear touching down. As being concerned about the change in the Aircraft attitude and the runway-remaining-distance even during the lading roll, the PIC was not looking at the Aircraft speed. At 18:51:26, the roll angle was 2.5° left, and the right wing gear became airborne (See Appended Figure 2⑳).

At 18:51:31, the Aircraft executed a go-around. The pitch angle was 10.2° (See Appended Figure 2㉑) and the speed was 143 KIAS, the roll angle was 2.8 to the left. The runway-remaining-distance was 1,619 m.

(4) Situation after the go-around

For two seconds after the go-around, the stall warning system was activated (See Appended Figure 2㉒). The FO called out “PUSH NOSE DOWN”, and urged the PIC to lower the pitch angle.

At 18:51:40, the Aircraft reported to Narita Tower that it had executed a go-around.

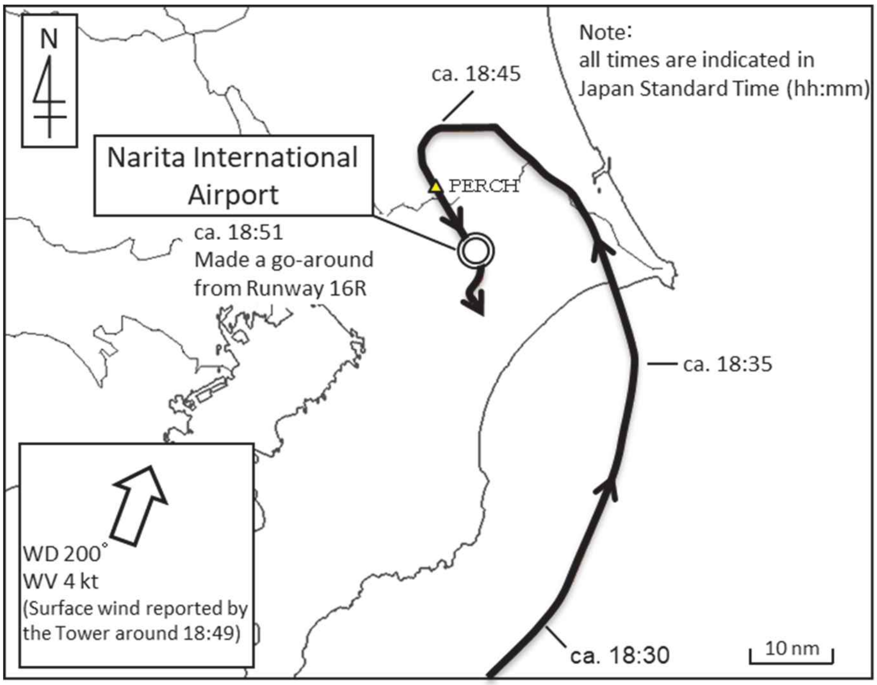
At 18:52:07, Narita Tower instructed the Aircraft to transfer to the Narita Departure Control. At that time, asked about the reason for the go-around from Narita Tower, the flight crew member answered, “Because of wind shear”.

Taking into consideration the air current disturbance, for the second approach, the Aircraft made it at an approach speed of V_{ref}+8 KIAS in its landing configuration with flap 25°.

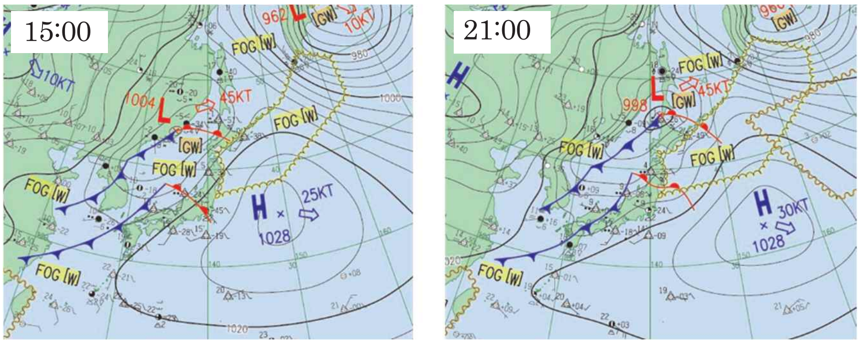
The preceding arrival aircraft reported to the Tower that it encountered wind shear immediately before the touchdown.

At 19:08:12, the Aircraft landed on Runway 16R.

After the spot in, a mechanic who made the external inspection of the Aircraft, found scratch marks on the lower aft fuselage. The flight crew members did not notice its tail strike until they received the report from the

	mechanics.  Figure 3: Estimated flight route This accident occurred about 18:51, on February 1, 2021, on Runway 16R of Narita International Airport (Latitude 35°45' 19" N and Longitude 140°22' 56" E).
2.2 Damage to the Aircraft	Extent of damage: Substantial Damage and deformation of outer panel and structural components of the lower aft fuselage
2.3 Personnel Information	(1) PIC: Age 61 Airline transport pilot certificate (Airplane) November 8, 2001 Type rating for Boeing 747-400 *13 May 17, 2007 Class 1 aviation medical certificate Validity May 11, 2021 Total flight time 19,626 hours 09 minutes Flight time in the last 30 days 46 hours 45 minutes Flight time on the type of the aircraft 6,670 hours 29 minutes Flight time in the last 30 days 46 hours 45 minutes (2) FO: Age 36 Airline transport pilot certificate (Airplane) May 26, 2016 Type rating for Boeing 747-400 May 26, 2016 Class 1 aviation medical certificate Validity July 6, 2021 Total flight time 7,052 hours 56 minutes Flight time in the last 30 day 62 hours 00 minute

*13 Boeing 747-400 and Boeing 747-8F are in the same type rating according to the competence certification of the provisions of Article 25 of Civil Aeronautics Act and Article 53 and 54 of Ordinance for Enforcement of the Civil Aeronautics Act.

	Flight time on the type of the aircraft 2,154 hours 38 minutes Flight time in the last 30 days 62 hours 00 minute
2.4 Aircraft Information	Aircraft Type Boeing 747-8F Serial Number 36138 Date of manufacture February 3, 2011 Certificate of airworthiness Toh-2020-121 Validity: Term of validity Period during which the Maintenance Manual (Nippon Cargo Airlines Co., Ltd.) was effective. Category of airworthiness Airplane Transport T Total flight time 32,305 hours 37 minutes The weight and the position of the center of gravity of the Aircraft were within the allowable range at the time of the accident.
2.5 Meteorological Information	(1) Aerodrome weather commentary on the Airport According to the aerodrome weather commentary on the Airport issued at 16:00, February 1, 2021, by Narita Aviation Weather Service Center, as for the general weather outlook for Kanto and Chubu regions, it was announced that as of 09:00 on February 1, 2021, a front was extending from the East China Sea to western Japan, while a low-pressure system accompanied by a front in Primorskii was moving northeast. As a commentary on the Airport, it was announced that around 18:00 on February 1, 2021, they were expected to deliver the aerodrome meteorological information about wind shear.  Figure 4: Extract from Asia Pacific Surface Analysis Chart on February 1, 2021 (for reference) (2) The aerodrome routine meteorological reports (METAR) and landing forecast for the Airport 18:00 Wind direction 180°, Wind velocity 2 kt, Visibility 10 km or more Cloud: Amount 1/8, Type Cumulus, Cloud base 2,000 ft Amount 3/8, Type Altocumulus, Cloud base 14,000 ft Temperature 7 °C, Dew point 6°C Altimeter setting (QNH) 30.08 inHg No significant changes 18:30 Wind direction 160°, Wind velocity 6 kt, Wind direction fluctuation 140° to 200°, Visibility 10 km or more

Cloud: Amount 1/8, Type Cumulus, Cloud base 2,000 ft
Amount 3/8, Type Altocumulus, Cloud base 13,000 ft
Temperature 9 °C, Dew point 6°C
Altimeter setting (QNH) 30.06 inHg
No significant changes

19:00 Wind direction 210°, Wind velocity 9 kt, Visibility 10 km or more
Cloud: Amount 1/8, Type Cumulus, Cloud base 2,500 ft
Temperature 10 °C, Dew point 6°C
Altimeter setting (QNH) 30.05 inHg
No significant changes

(3) The Airport Low-level Wind Information (ALWIN) for Runway 16R at the Airport around the time of the accident was as follows:

Table 1: Airport Low-level Wind Information (ALWIN) for Runway 16R

Time of Observation	18:48	18:50	18:53
Altitude (ft)	WD (°) / WV (kt)	WD (°) / WV (kt)	WD (°) / WV (kt)
1,000	230 / 37	230 / 31	230 / 28
750	210 / 28	220 / 30	220 / 30
500	200 / 20	210 / 24	220 / 26
400	200 / 18	210 / 21	220 / 24
300	210 / 15	210 / 17	210 / 20
200	210 / 13	210 / 14	200 / 16
100	220 / 10	220 / 12	210 / 12
50	220 / 08	220 / 09	210 / 10
Ground	200 / 04	220 / 05	220 / 06

2.6 Additional Information

(1) Aircraft damage

Scratches were found in an area a total length about 3.0 meters and a maximum about 0.9 meter wide on the outer panel of the lower aft fuselage, and the internal structural components were deformed.

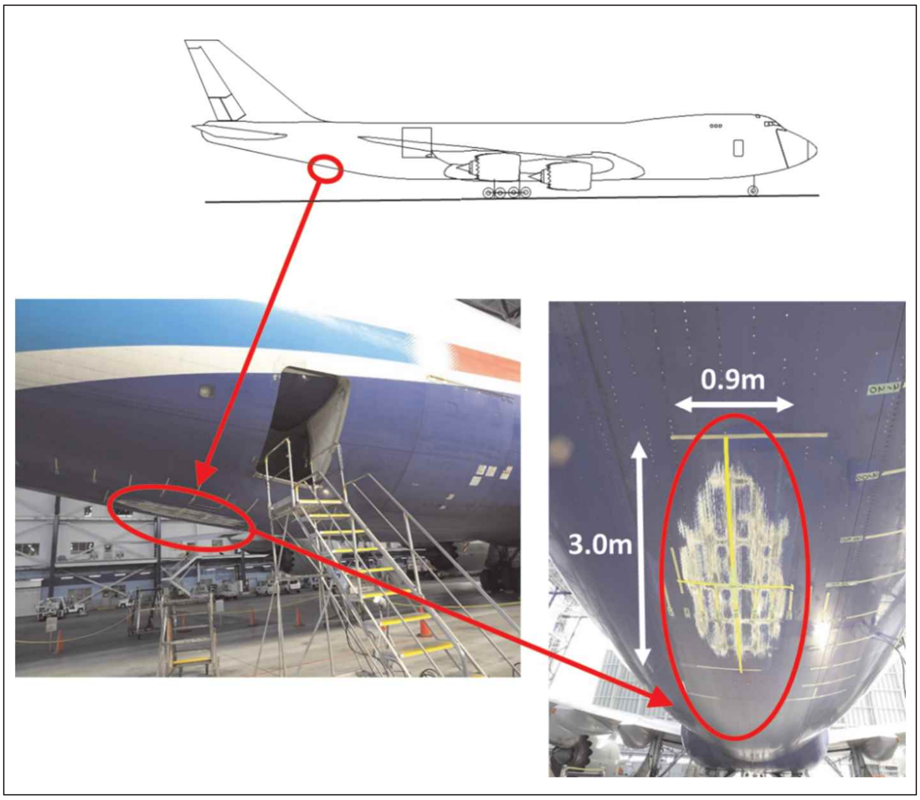


Figure 5: Conditions of damaged airframe

(2) Video recording

At Sakura-no-Yama Park in Narita City, there was a witness who was shooting a video of the aircraft landing at the Airport. The captured video recorded after touching down and bouncing, the Aircraft which raised its nose substantially.

(3) Runway check

In response to this event, the Narita International Airport Corporation (NAA) conducted a runway check after the Aircraft landed, but could not confirm the scratch marks on the runway related to the tail strike of the Aircraft.

(4) Runway Alignment Mode

The Aircraft's Automatic Flight System is equipped with a Runway Alignment Mode.

The “Runway Alignment Mode” refers to a function that allows the aircraft to approach straight toward the landing runway using both the crab and sideslip methods, such that the aircraft can fly taking a crab angle on the normal autopilot in crosswind conditions, and then lowering the upwind wing (sideslip).

When disengaging the autopilot while the rudder control is activated by the autopilot, the rudder position returns to the neutral (to the trim position, when trimmed), and thus the heading will change to the upwind side. Therefore, the pilot needs to keep balance of the aircraft by the rudder operation in order to shift smoothly to manual controls.

	(5) Provisions concerning Stabilized Approach The Company's Airplane Operations Manual (AOM*[14]) includes the following descriptions regarding the Stabilized Approach. (Excerpt) *A stabilized approach is a concept whereby an approach and landing is carried out following the establishment of a stabilized condition by 1,000 ft AFE. If a stabilized condition can not be established by 1,000 ft AFE, or a stabilized condition can not be maintained constantly below 1,000 ft AFE, the flight crew shall initiate a go-around without hesitation.* *An approach is considered as stabilized, when all of the following criteria are met:* (Omitted) *・The airplane is on the correct flight path.* *・Only small changes in heading/pitch are required to maintain the correct flight path.* (Omitted) *・The sink rate is no greater than 1,000 fpm. (Except when a heavy landing weight and/or weather conditions etc. require a sink rate greater than 1,000 fpm. In this case, the appropriate sink rate should be confirmed before commencing the approach.)* (Omitted) *・ILS approaches are flown within one dot of the GS and LOC or within the expanded scale.* (6) Regulations on the flight when encountering wind shear The Company's AOM includes the following contents regarding the flight when encountering wind shear. A Windshear Escape Maneuver (operations to escape from wind shear) shall be performed when wind shear is encountered during flight. With manual control, the PF shall disengage the autopilot and immediately set the maximum thrust. The PM shall confirm that the maximum thrust is set. The flap position or gear position shall not be changed until there would be no danger of wind shear. (7) Regulations on the callout The Company's AOM includes the following contents regarding the callout when the PM perceives a deviation from the intended flight path at or below 1,000 ft AFE. When a V/S becomes greater than 1,000 fpm, the PM shall call out "SINK RATE".

*[14] The "AOM" is a set of regulations concerning the aircraft performance, aircraft operations, and operation procedures for crew, which is provided for each type of aircraft and issued by airlines after review based on manuals issued by aircraft manufacturers. The AOM specifies operating limitation, normal operations, emergency response procedures / procedures in case of malfunction, various systems and the system operations, performance, special operations, weight and balance and others.

	When the deviation from the GS on-glidepath exceeds one dot, the PM shall call out "GLIDE SLOPE". (8) Regulations on go-around The Company's Operations Manual (OM*15) SUPPLEMENT includes the following contents regarding the go-around. When judging that the stabilized approach specified in the AOM cannot be established, or when the requirements for the stabilized approach cannot be met continuously, a go-around shall be executed. (9) Regulations on go-around procedures The Company's AOM includes the following contents regarding the go-around procedures. ・The PF calls "GO AROUND", at the same time, pushes the TO/GA switch*16, and calls "FLAP 20". ・The PM sets the flap lever to 20° following the instructions from the PF. (10) Tail strike The Company's Flight Crew Training Manual (FCTM*17) includes the following descriptions regarding the factors of tail strike at landing. (Excerpt) *Landing risk factors* ・*Unstabilized approach* *Flight recorder data shows that flight crews who continue with an unstabilized condition below 500 feet seldom stabilize the approach.* (Omitted) *If the pitch is increased rapidly when touchdown occurs as ground spoilers deploy, the spoilers (speedbrakes) add additional nose up pitch force, reducing pitch authority, which increases the possibility of a tail strike.* (Omitted) ・*Over-rotation during go-around* *Go-arounds initiated very late in the approach, such as during the landing flare or after touching down, are a common cause of tail strikes.* (Omitted) *If the pilot flying abruptly rotates up to the pitch command bar, a tail strike can occur before the airplane responds and begins climbing. During a go-around, an increase in thrust as well as a positive pitch attitude is needed. If the thrust increase is not adequate for the increased pitch attitude, the resulting speed decay will likely result in a tail strike。*

*15 The "OM" provides basic policies, implementation outline, and regulations regarding air transportation operations and services, and is established based on airlines' policies and consists of operation control, flight operation standard, ground crew members, flight crew members, weather minimum, emergency responses, and others.
*16 "TO/GA switch" refers to the switch related to the auto throttle on the thrust levers. On take-off, to push this switch makes an auto throttle advance the thrust levers to the take-off thrust, and during approach, to push this switch makes an auto throttle advance those levers to the go-around thrust.
*17 "FCTM" refers to a manual to provide pilots with practical information on how to fly the same aircraft type.

(11) Regulations on landing roll

The Company's AOM includes the following descriptions regarding landing roll. (Excerpt)

Landing Roll Procedure

PF	*PM*
Verify the thrust levers are closed. *Verify the SPEEDBRAKE lever is UP.*	*Verify the SPEEDBRAKE lever is UP.* *Call "SPEEDBRAKES UP."* (Omitted)
Monitor the rollout progress.	
(Omitted)	
WARNING: After the reverse thrust levers are moved, a full stop landing must be made. *If an engine stays in reverse, safe flight is not possible.*	
Without delay, move the reverse thrust levers to the interlocks and hold light pressure until the interlocks release. *Apply reverse thrust as needed.*	*Verify that the forward thrust levers are closed.* *When all REV indications are green, call "REVERSERS NORMAL."* (Omitted)

(12) Thrust levers

① The Company's AOM includes the following descriptions regarding the thrust levers. (Excerpt)

a *Reverse thrust levers (Figure 6 ①)*

Control engine reverse thrust.

Reverse thrust can only be selected when Forward Thrust levers are closed.

Actuates automatic speedbrakes.

b *Forward thrust levers (Figure 6 ②)*

Control engine forward thrust.

Thrust levers can only be advanced when Reverse Thrust levers are down.

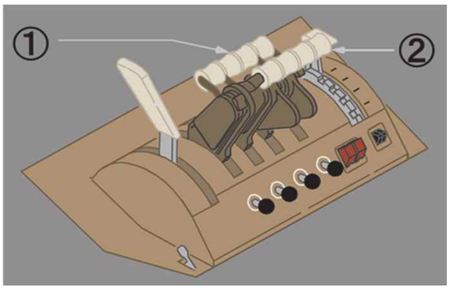
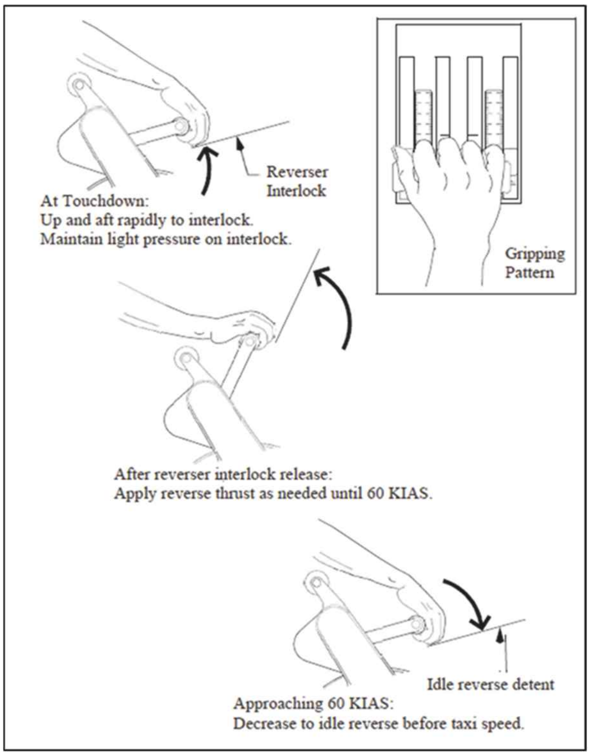


Figure 6: Thrust levers

② The Company's FCTM includes the following descriptions

	regarding the reverse thrust operations (Figure 7).  Figure 7: Reverse thrust operations (13) PACS The Company's AOM includes the following descriptions regarding the PACS. (Excerpt)) *The pitch augmentation control system (PACS) assists with pitch stability and landing flare.* *PACS has limited elevator authority and does not move the control column.* *PACS performs the following functions:* ・*High angle of attack ・・・・PACS provides nose-down elevator when the angle of attack sensed by redundant AOA*[18] *vanes exceeds a calculated threshold.* (Omitted) ・ *Tail strike protection ・・・・During takeoff and landing, PACS calculates whether a tail strike is imminent and provides nose-down elevator deflection, if required, to reduce the potential for tail-to-ground contact.* (14) Ground contact during normal landing The Company's FCTM includes the following descriptions regarding the ground contact during normal landing.

*18 The "AOA" refers to the angle of attack, which is the angle that is formed between the airflow direction and the chord line of the airfoil when the wings are placed in a uniform airstream.

A contact between body gears and tail is possible when exceeding the line segment (Figure 8 Red line) connecting from a roll angle of 0° / a pitch angle of 10.2° to a roll angle of 5.4° / a pitch angle of 10.8°.

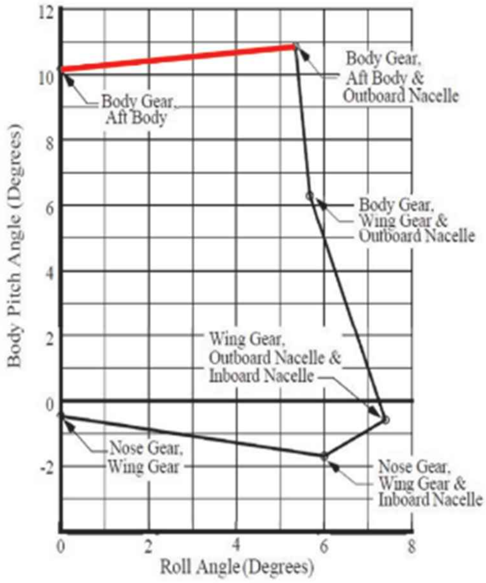


Figure 8: Ground contact angle (During normal landing)

(15) Crew assignment and alcohol testing for flight crew members

The Company's OM includes the following descriptions regarding the standard of the crew assignment. (Excerpt)

	Flight crew formation	*In continuous 24-hour period*			*Flight duty time (FDT)*		
		FDH	*WDH*	*No. of landings*	*1 CM*	*3 CM*	*1 CY*
Int'l flight operation	*1 PIC* *1 PIC or 1 FO*	*12 hr*	*15 hr*	*5 times*	*95 hr*	*250 hr*	*940 hr*

The PIC and the FO were had a flight duty hours (FDH) of 8 hours and 53 minutes and a working duty hours (WDH) of 14 hours and 10 minutes in a continuous 24-hour period, and they were conducting their duties in accordance with the standard of the crew assignment.

The result of the alcohol testing conducted before the departure from Singapore Changi International Airport and after the arrival at Narita International Airport revealed that the alcohol content of both the PIC and the FO was 0.00 mg/L.

(16) Education, training and examination taken by the PIC and the FO

They had taken trainings and examinations regularly until the occurrence of this accident, and there were no problems in the general assessment about the management, monitoring work, LOFT *19 training,

*19 "LOFT" stands for Line Oriented Flight Training, consists usual flight crew, by using Full Flight Simulator, a training under a line operation of the normal and possible abnormal and emergency condition, which is designated by Minister of Land Infrastructure Transport and Tourism, the training for the improvement of the ability to practice CRM.

	and the Crew Resource Management (CRM)/Threat and Error Management (TEM), etc., which are conducted every fiscal year with skill themes. (17) CRM/TEM ① TEM Human Factors Training such as CRM/LOFT has been traditionally introduced to flight crew members training in order to prevent the aviation accident caused by human error. Nowadays, based on the belief that human error will always occur, the TEM concept is included in the requirements for flight crew members training. Threats here are various factors that complicate operations and induce errors, which reduce safety margins if not properly dealt with. "Errors" are defined actions or inactions by the flight crew members that lead to a deviation from the intent or expectations of the organization or flight crew member. In order to practice TEM, flight crew members are required to demonstrate their CRM skills. ② CRM skills The Crew Resource Management: An Introductory Handbook (CRM HDBK) issued by the Federal Aviation Administration (FAA) states that CRM skills are classified into communication, decision making, team building & maintenance, workload management, and situation awareness management. Among these skills, FAA Advisory Circular (AC) has the following description regarding Monitoring. (Extract) *Several studies of crew performance, incidents, and accidents have identified inadequate monitoring and cross-checking as vulnerabilities for aviation safety. Effective monitoring and cross-checking can be the last barrier or line of defense against accidents because detecting an error or unsafe situation may break the chain of events leading to an accident.* (omitted) *Flightcrews must use monitoring to help them identify, prevent, and mitigate events that may impact safety margins.* Regarding communication, "CRM HDBK" created by FAA has remarks to point out that it is important to exchange information within a cockpit and to express ones' concern and advice, positively and explicitly for effective communications. (18) Aircraft accidents involving wind shear at the Airport There are similar accidents involving wind shear occurred at the Airport as follows: The one occurred on March 24, 1990 at about 14:12, when the aircraft made a hard landing on Runway 16 (currently Runway 16R), in which the rear spar of the wing root and its vicinity of the left wing were damaged and the fuel flowed out from the No.1 fuel tank (https://www.mlit.go.jp/jtsb/aircraft/rep-acci/92-2B-VR-HOC.pdf), and the other occurred on June 20, 2012 at about 13:23, when the aircraft experienced a bounce at the time of attempting to land at Runway 16 R and had a damage to the airframe by a strong impact (https://www.mlit.go.jp/jtsb/aircraft/rep-acci/AA2016-6-2-JA610A.pdf).

3. ANALYSIS

(1) Meteorological Conditions

The JTSB concludes that according to the wind conditions recorded on the FDR and the statements of flight crew members, there was most likely a strong crosswind at 500 ft and below, and likely have been subject to airflow turbulence.

The flight crew members should have considered the responses (go-around) to turbulence including crosswinds and shared them among flight crew members at approach briefing and others because the crosswind speed exceeded 20 kt in the air, although the reported wind speed on the ground was less than 5kt.

(2) Situation upon approach status and decision on landing

The JTSB concludes that based on the records on FDR and QAR, the Aircraft certainly made a stable approach up until the autopilot was disengaged.

The PIC disengaged the autopilot at an altitude of 460 ft (RA 352 ft). As the autopilot was disengaged, the Runway Alignment Mode was released. And the rudder, which had previously been turned to the left, returned to the neutral position (trim position), and the heading of the Aircraft started to turn to the windward side. It is probable that as the PIC was unable to deal with the Aircraft's movement, the Aircraft began to veer to the right and deviated to the right from the runway centerline,

It is probable that the PIC was unable to perform an appropriate operation because the PIC had not been able to recognize the disengagement of the autopilot at low altitudes as threat.

After that the PIC deactivated the auto-throttle to increase the thrust. Due to the thrust increase, the pitch angle increased, which more likely resulted in the Aircraft deviation from the GS on-glidepath.

The quantity of deviation from the GS on-glidepath exceeded the criteria for the stabilized approach specified by the Company, but the PIC more likely continued approaching judging that corrections should be possible. It is probable that the deviation from the LOC on-course was corrected by the rudder operations made by the PIC immediately before the touchdown, but the Aircraft was unable to maintain a stabilized approach, therefore the PIC should have executed a go-around earlier. In addition, when the quantity of deviation from the GS on-glidepath and the V/S exceeded the criteria specified by the Company, the FO should have called out to caution the PIC to execute a go-around immediately.

(3) Situation at the time of touchdown

The JTSB concludes that while taking a roll angle of 4.2° right, the Aircraft touched down on the right main landing gear first with a HDG of 6.0° right from the runway magnetic bearing. After the touchdown, the PIC applied the left rudder pedal in order to adjust the Aircraft's HDG to the runway magnetic bearing. The left body gear touched down but bounced, thus, the left wing gear did not touch down. At this time, probably the PIC was required to reduce the roll speed to the left by applying the ailerons to lower the right wing against the crosswind from the right. The speedbrakes were extended but soon retracted.

Three seconds after the touchdown, all main gears touched down and all speedbrakes started to deploy. It is probable that the PIC listened to the FO's call "SPEEDBRAKES UP" and reflexively moved the reverse thrust levers. As the reverse thrust levers were moved, the thrust reverser was actuated, and the FO called "REVERSERS", which was believed to be probably an attempt for the FO to say "REVERSERS NORMAL" that is the call to be made when the thrust reversers are actuated. However, the PIC and the FO did not remember having actuated the thrust reversers. It is probable that the PIC and the FO did not remember having actuated the thrust reversers is because both the PIC's operation and the FO's call were reflexive responses, and because they were distracted by the change in movement of the Aircraft as the Aircraft movement was unstable after landing.

The reverse thrust levers should be operated after not confirming the touchdown with only one element (for example, call, "SPEEDBRAKES UP", etc.) but consciously confirming the secure touchdown of the main landing gears and the operation of the autobrakes.

It is probable that the pitch angle, which had been temporarily reduced to 1.4°, started to increase to the direction of nose up due to the effect of nose-up force generated by the speedbrakes starting to be deployed.

(4) The PIC's decision to execute a go-around

The JTSB concludes that after the touchdown, the Aircraft repeated bouncing with unstable attitude, and the PIC more likely decided to execute a go-around as feeling the Aircraft floating according to the increase in pitch angle to the direction of nose up.

However, when the PIC decided to execute a go-around, the thrust reversers had been already actuated, which would go against the rules in the AOM, therefore, the go-around from this phase was probably inappropriate. The PIC should have made the landing roll while maintaining the direction after lowering its nose and letting the nose gear touch down early, and made a full stop. The decision on go-around should be made after Accurately grasping the condition of the aircraft.

(5) Operation of go-around

The JTSB concludes that the PIC called "GO AROUND (GA)", then moved the reverse thrust levers to down position and the forward thrust levers to the maximum amount of control input, and initiated a go-around, however, as the PIC had already actuated the thrust reversers, the engine thrust did not increase until TCs were closed completely, which probably resulted in taking time for the speed to increase. When executing a go-around, as being anxious about the change in the Aircraft attitude and the runway-remaining-distance, the PIC was not looking at the Aircraft speed. It is probable that the PIC performed the operation to continue the excessive nose-up attitude while the Aircraft was unable to attain the speed required to be airborne.

The PIC performed the operation to continue the excessive nose-up attitude is more likely because the PIC judged the Aircraft became airborne, and tried to get off the ground as quickly as possible being afraid that the Aircraft would make a hard landing due to the effect of wind shear.

The reason why the PIC judged the Aircraft became airborne is because the Aircraft bounced, in addition, as it was at night, it was likely difficult to recognize the runway and its surrounding ground objects and determine altitude and attitude.

(6) The Aircraft condition at the time of go-around

The JTSB concludes that at the time of the go-around, PACS worked and provided nose-down elevator deflection to prevent a tail strike, but at 18:51:13, the pitch angle of the Aircraft was 9.8°, and at this time, the speed was 139 KIAS.

Furthermore, during the ground roll for the subsequent go-around, PACS worked and provided nose-down elevator deflection to prevent a tail strike, but in three seconds from 18:51:25, the pitch angle was 9.8°. The speed changed from 130 KIAS to 136 KIAS.

When the Aircraft became airborne, the pitch angle was 10.2°, the bank angle 2.8° left, and the speed was 143 KIAS.

(7) Occurrence of a tail strike

It could not be determined when a tail strike occurred since any trace was not found on the runway, however, according to the analyzation with reference to the image recordings, the Aircraft condition (in 3.5 seconds, the pitch angle changed significantly from 1.4° to 9.8°, the speed was reduced up to 139 KIAS, the spoilers deployed, and PACS worked), and 2.6 (14), it most likely occurred at the time of the go-around (18:51:13).

Furthermore, the condition of the aircraft during the ground roll from 18:51:25 to 18:51:28 (pitch angle was 9.8° for 3 seconds, speed was low from 132 KIAS to 134 KIAS, and PACS worked) and during becoming airborne (18:51:31) (pitch angle was 10.2°, speed was 143 KIAS, bank angle was 2.8° to the left) were analyszed, it was likely that a tail strike may have occurred at that time as well.

(8) The Aircraft condition immediately after airborne

The JTSB concludes that immediately after lift-off, the stall warning system was activated for two seconds, which would be evidence that when lifting off, the Aircraft speed was close to the stall speeds, and the Aircraft was more likely in danger of stalling, however, this situation was avoided due to the assertion made by the FO.

Effective monitoring and cross-checking are very important because detecting errors and unsafe conditions would break the chain of events leading up to the accident.

(9) CRM/TEM education/training in the Company

The JTSB concludes that the Company has been more likely working on the CRM/TEM education/training for the flight crew members by regularly providing LOFT training and the classroom lectures in CRM/TEM training, which are conducted every fiscal year with skill themes. However, as described in 3 (2), when considering the pilot operations conducted by the PIC and the FO at the time of the occurrence of the accident, there was more likely room for improvement in their practice of CRM/TEM. It is important for the Company to try to ensure that the flight crew members have sufficient CRM/TEM skills by continuing and enhancing the CRM/TEM education/training for the flight crew members.

4. PROBABLE CAUSES

The JTSB concludes that the probable cause of this accident was that when the Aircraft made a go-around while becoming unstable attitude after touching down and bouncing, the pitch angle became excessively large with an inadequate aircraft speed, which more likely resulted in the lower aft fuselage contacting with the runway.

The Aircraft bounced after the touchdown is because it was likely insufficient to deal with the crosswind.

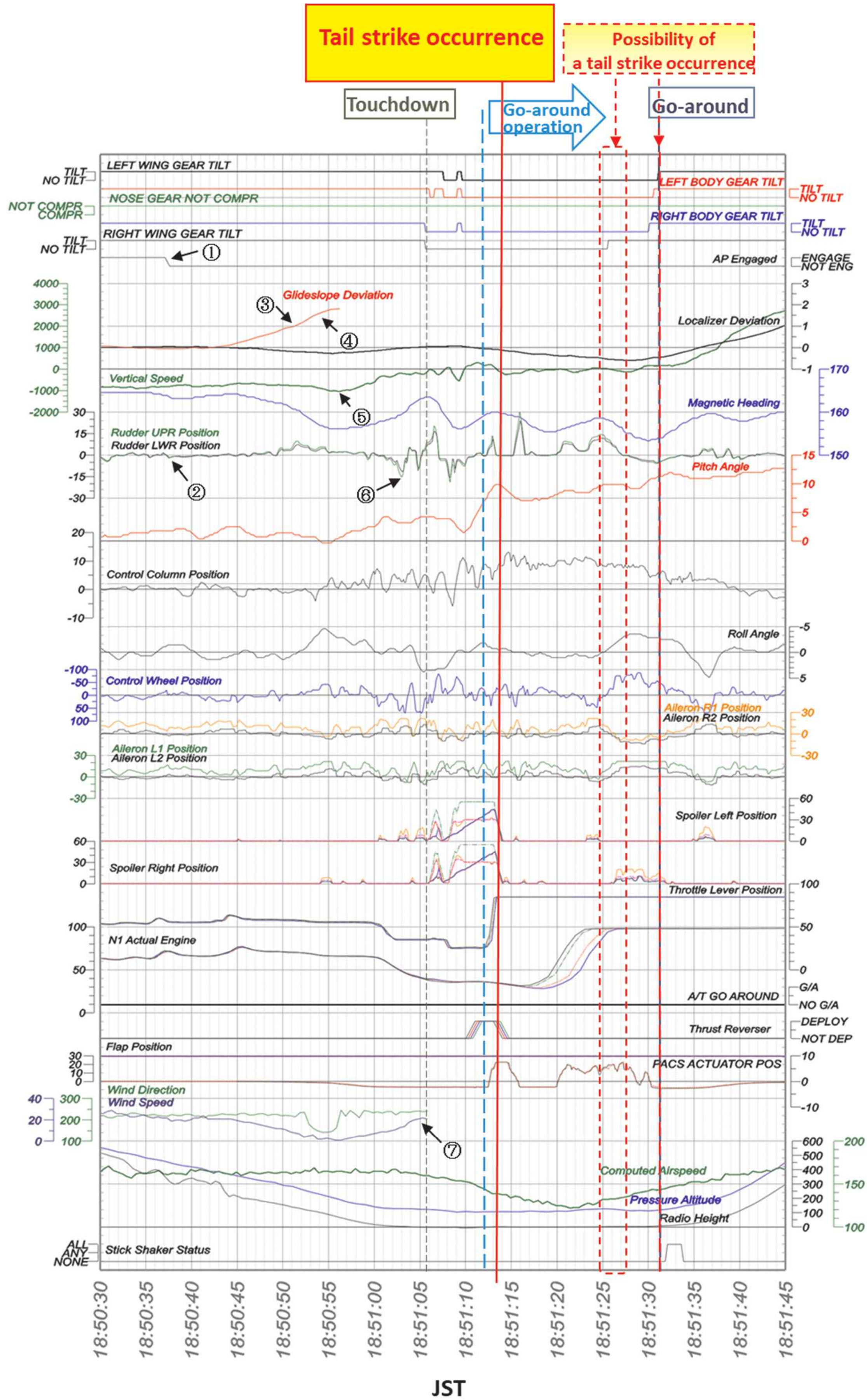
The pitch angle became excessively large with an inadequate aircraft speed is probably because the PIC reflexively moved the reverse thrust levers after the touchdown, therefore, in the situation where it took time for the aircraft speed to increase due to the go-around operation, while being anxious about the runway-remaining length and others and trying to get off the ground as quickly as possible, the PIC performed the nose-up operation without checking the aircraft speed.

5. SAFETY ACTIONS

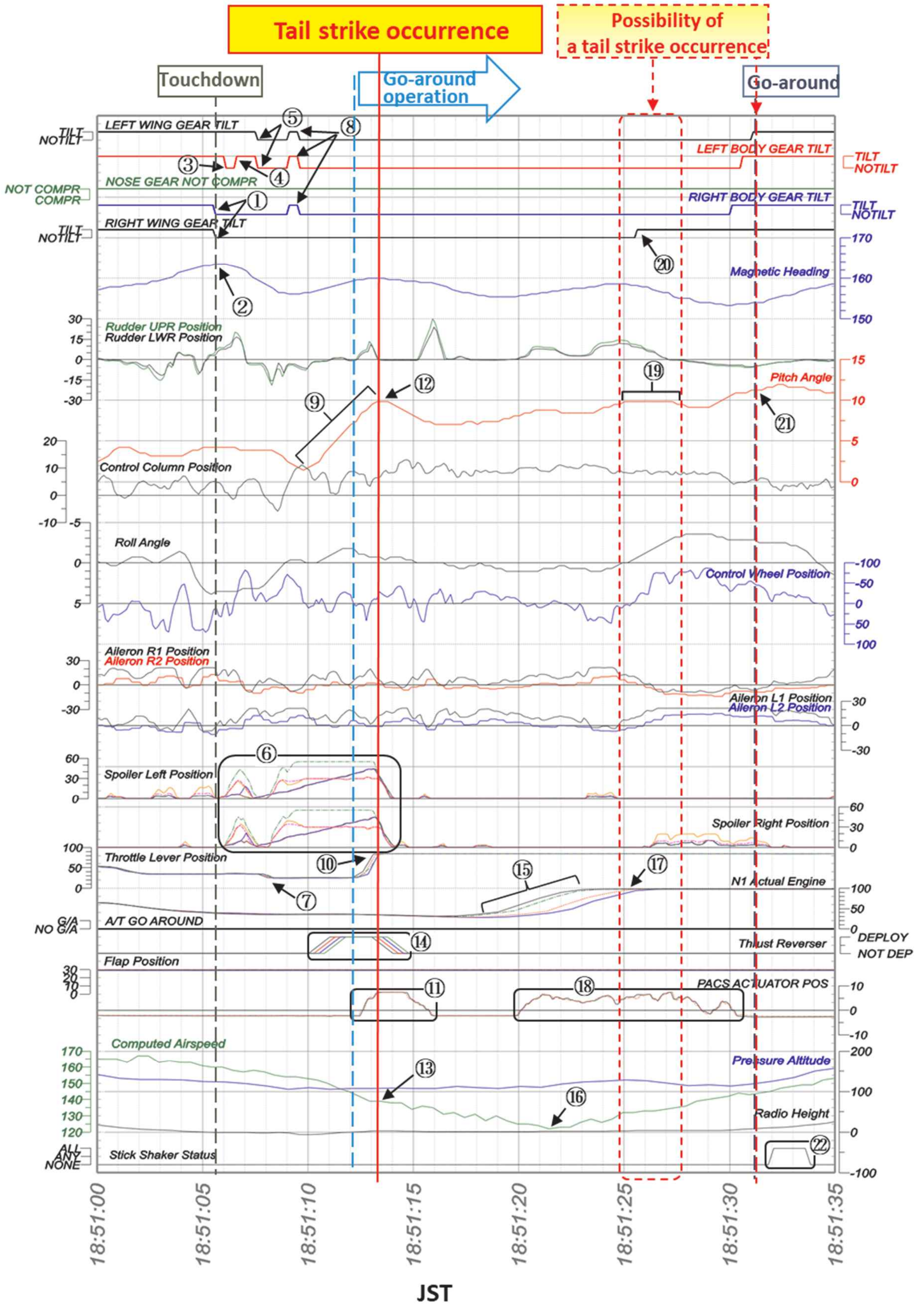
5.1 Safety Actions	Regarding the procedures for stabilized approach and go-around, it is

Required	probably necessary for the Company to have the flight crew members comply with the rules in the AOM. In addition, it is required for the Company to enhance the Company's CRM/TEM education/training by studying this accident and reflecting it in the contents of CRM/TEM education/training so that the flight crew members would be able to demonstrate the CRM skills appropriately and practice the TEM.
5.2 Safety Actions Taken after the Accident	After this accident, the Company took the following safety actions. (1) Measures taken for the relevant flight crew members ① PIC a The knowledge of the following items was reconfirmed in ground school trainings. ・Regarding the concept of go-around, the stabilized approach, andgeneral pilot operations / general auto-pilot operations, the relevant rules were reconfirmed. ・CRM/TEM and the competencies required for the Company's flight crew members were reconfirmed. b Regarding the pilot operation for Boeing 747-8F, the knowledge of the following items was reconfirmed, and simulator trainings were conducted. ・Basic pilot training using a simulator ・Situation awareness management trainings and judgment training using a simulator ・Training and effectiveness measurement by setting up specific scenarios using a simulator ② FO a The knowledge of the following items was reconfirmed in ground school trainings. ・Safety management manual, duties of flight crew member in the OM, concept of go-around and AOM standard call-out training ・CRM/TEM training b Simulator training was conducted to confirm the improvement of knowledge and skills after the above-mentioned ground school trainings. (2) Measures taken for all flight crew members ① The knowledge of the following items was reconfirmed in ground school trainings. a The stabilized approach and the concept of go-around were made known thoroughly. b Reminder for the reverse trust lever operation after the call "SPEEDBRAKES UP" was reconfirmed. c Regarding the Approach Landing Logic of Autopilot Flight Director System (AFDS) (including points to note when executing a go-around after touchdown), education was provided and the

	degree of proper understanding was confirmed by means of oral examination in the periodic examinations. ② The following additional training was conducted by using a simulator. a "Shallow Bounce ⇒ Landing or Go Around" was added in the additional training, and it was conducted.



Appended Figure 1: FDR and QAR records (18:50:30 to 18:51:45)



Appended Figure 2: FDR and QAR records (zoom in from 18:51:00 to 18:51:35)