AA2013-7

AIRCRAFT ACCIDENT INVESTIGATION REPORT

AIR NIPPON CO., LTD.

J A 8 3 8 4

September 27, 2013

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.

Norihiro Goto
Chairman,
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.

AIRCRAFT ACCIDENT INVESTIGATION REPORT

AIR NIPPON CO., LTD.
AIRBUS INDUSTRY A320-200, JA8384
DAMAGE DUE TO TAILSTRIKE
ON THE RUNWAY 27 OF SENDAI AIRPORT, JAPAN
AT ABOUT 09:03 JST, FEBRUARY 5, 2012

September 13, 2013
Adopted by the Japan Transport Safety Board

SYNOPSIS

＜Summary of the Accident＞

On Sunday, February 5, 2012, an Airbus A320-200, registered JA8384, which was operated by Air Nippon Co., Ltd., took off from Osaka International Airport, flew to Sendai, and approached Runway 27 of Sendai Airport. It was the scheduled Flight 731, jointly operated with All Nippon Airways Co., Ltd. At around 09:03 Japan Standard Time (JST: UTC +9 h, unless otherwise stated all times are indicated in JST on a 24-hour clock), when the Aircraft rejected the landing above the runway, the lower part of its rear fuselage contacted with the runway, damaging the airframe. Later, the Aircraft landed Sendai Airport at around 09:27.

A total of 166 persons consisting of a captain, five crew members and 160 passengers were on board the aircraft, but nobody sustained injuries.

＜Probable Causes＞

In this accident, it is highly probable that when the Aircraft rejected the landing after touching Runway 27, its nose was raised sharply, causing the lower part of the rear fuselage to contact with the runway and be damaged.

It is highly probable that the substantial pitch-up moment caused the quick Aircraft nose-up with the following reasons: The captain decided to reject the landing under the circumstance where he could not recognize the touchdown of main landing gears due to the soft landing; Balanced pitching moment was disrupted by the captain's nose-up elevator input as his go-around was initiated from the full-aft sidestick position.

Abbreviations used in this report are as follows:

ADIRS:	Air Data Inertial Reference System
AGL:	Above Ground Level
AOM:	Airplane Operations Manual
AOR:	Airplane Operations Reference
ASAP:	As Soon As Possible
A/P:	Auto Pilot
A/T:	Auto Thrust
BRK:	Brake
CAT-I:	Category-One
CG:	Center of Gravity
C'K:	Check
CVR:	Cockpit Voice Recorder
DECEL:	Deceleration
DFDR:	Digital Flight Data Recorder
ECAM:	Electronic Centralized Aircraft Monitor
ELAC:	Elevator Aileron Computer
ENG:	Engine
FCOM:	Flight Crew Operating Manual
FL:	Flight Level
FMGC:	Flight Management Guidance Envelope Computer
FOBN:	Flight Operations Briefing Notes
F/CTL:	Flight Control
GS:	Glide Slope
ILS:	Instrument Landing System
LDG:	Landing
LO:	Low
MAX:	Maximum
MAC:	Mean Aerodynamic Chord
MCDU:	Multipurpose Control and Display Unit
MED:	Medium
MSA:	Minimum Safe Altitude
PACK:	Pressurization and Air Conditioning Kit
PAPI:	Precision Approach Path Indicator
pb:	Push Button
PF:	Pilot Flying
PFD:	Primary Flight Display
PIC:	Pilot-In-Command
PM:	Pilot Monitoring
QAR:	Quick Access Recorder
RA:	Radio Altitude
REV:	Reverse
RNAV:	Area Navigation
SPD:	Speed

SRS:	Speed Reference System
THS:	Trimmable Horizontal Stabilizer
TO/GA:	Take Off / Go Around
VHF:	Very High Frequency

Unit Conversion Table

1 ft:	0.3048 m
1 kt:	1.852 km/h (0.5144 m/s)
1 nm:	1,852 m
1 lb:	0.4536 kg

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1 PROCESS AND PROGRESS OF THE AIRCRAFT ACCIDENT INVESTIGATION

1.1 Summary of the Accident

On Sunday, February 5, 2012, an Airbus A320-200, registered JA8384, which was operated by Air Nippon Co., Ltd., took off from Osaka International Airport, flew to Sendai, and approached Runway 27 of Sendai Airport. It was the scheduled Flight 731, jointly operated with All Nippon Airways Co., Ltd. At around 09:03 Japan Standard Time (JST: UTC +9 h, unless otherwise stated all times are indicated in JST on a 24-hour clock), when the Aircraft rejected the landing above the runway, the lower part of its rear fuselage contacted with the runway, damaging the airframe. Later, the Aircraft landed Sendai Airport at around 09:27.

A total of 166 persons consisting of a captain, five crew members and 160 passengers were on board the aircraft, but nobody sustained injuries.

1.2 Outline of the Accident Investigation

1.2.1 Investigation Organization

On February 5, 2012, the Japan Transport Safety Board (JTSB) designated an investigator-in-charge and two investigators to investigate this accident.

1.2.2 Representatives of the Relevant State

An accredited representative from France, as the State of Design and Manufacture of the aircraft involved in this accident, participated in the investigation.

1.2.3 Implementation of the Investigation

February 5, 2012	Interviews
February 6, 2012	Interviews, airframe examination and on-site investigation
February 7, 2012	On-site investigation
February 14, 2012	Interviews
March 8, 2012	Interviews
March 26, 2012	Interviews
April 13, 2012	Interviews

1.2.4 Comments from the Parties Relevant to the Cause of the Accident

Comments were invited from parties relevant to the cause of the accident.

1.2.5 Comments from the Relevant State

Comments were invited from the relevant State.

2 FACTUAL INFORMATION

2.1 History of the Flight

On February 5, 2012, an Airbus A320-200, registered JA8384 (hereinafter referred to as the

“Aircraft”), which was operated by Air Nippon Co., Ltd. (hereinafter referred to as the “Company”; current All Nippon Airways Co., Ltd.), took off from Osaka International Airport, flew to Sendai, and approached Runway 27 of Sendai Airport. It was the scheduled Flight 731, jointly operated with All Nippon Airways Co., Ltd.

The flight plan for the Aircraft was as follows:

Flight rules:	Instrument flight rules (IFR)
Departure aerodrome:	Osaka International Airport
Estimated off-block time:	08:05
Cruising speed:	456 kt
Cruising altitude:	Flight Level (FL) 350
Route:	(Omitted) – Y15 (RNAV Route) – OWLET (waypoint)
Destination aerodrome:	Sendai Airport
Total estimated elapsed time:	0 hr and 51 min
Fuel load expressed in endurance:	4 hrs and 01min
Alternate aerodrome:	Tokyo International Airport

When the accident occurred, the captain was in the left seat in the cockpit of the Aircraft as the PF (Pilot Flying: pilot mainly in charge of flying) and the first officer was in the right as the PM (Pilot Monitoring: pilot mainly in charge of duties other than flying).

Based on the records from the digital flight data recorder (DFDR) and the cockpit voice recorder (CVR), records of communication with air traffic controllers, and the statements of crew members, history of the flight for the Aircraft up to the time of the accident is summarized as follows:

2.1.1 History of the Flight based on the DFDR, CVR Records and Records of ATC Communications

8:58:30	The Aircraft began to communicate with the Sendai Air Traffic Control Tower (hereinafter referred to as the “Tower”) and notified it that it would make a visual approach to Runway 27.
8:58:38	The Tower instructed the Aircraft to continue its approach.
9:00:19	The Tower issued a landing clearance for Runway 27 to the Aircraft and informed that the wind was 160 degrees and at 2 kt. The Aircraft read back the landing clearance.
9:00:51	The Tower informed the Aircraft of a change in QNH (barometric pressure adjusted to sea level) and wind information (160 degrees at 2 kt).
9:01:05	The landing gear handle was locked in the DOWN position.
9:01:10	The auto pilot (A/P) was disengaged.
9:01:41	The flaps were extended the FULL DOWN position (flaps: 35 degrees; slats: 27 degrees). The landing checklist was completed.

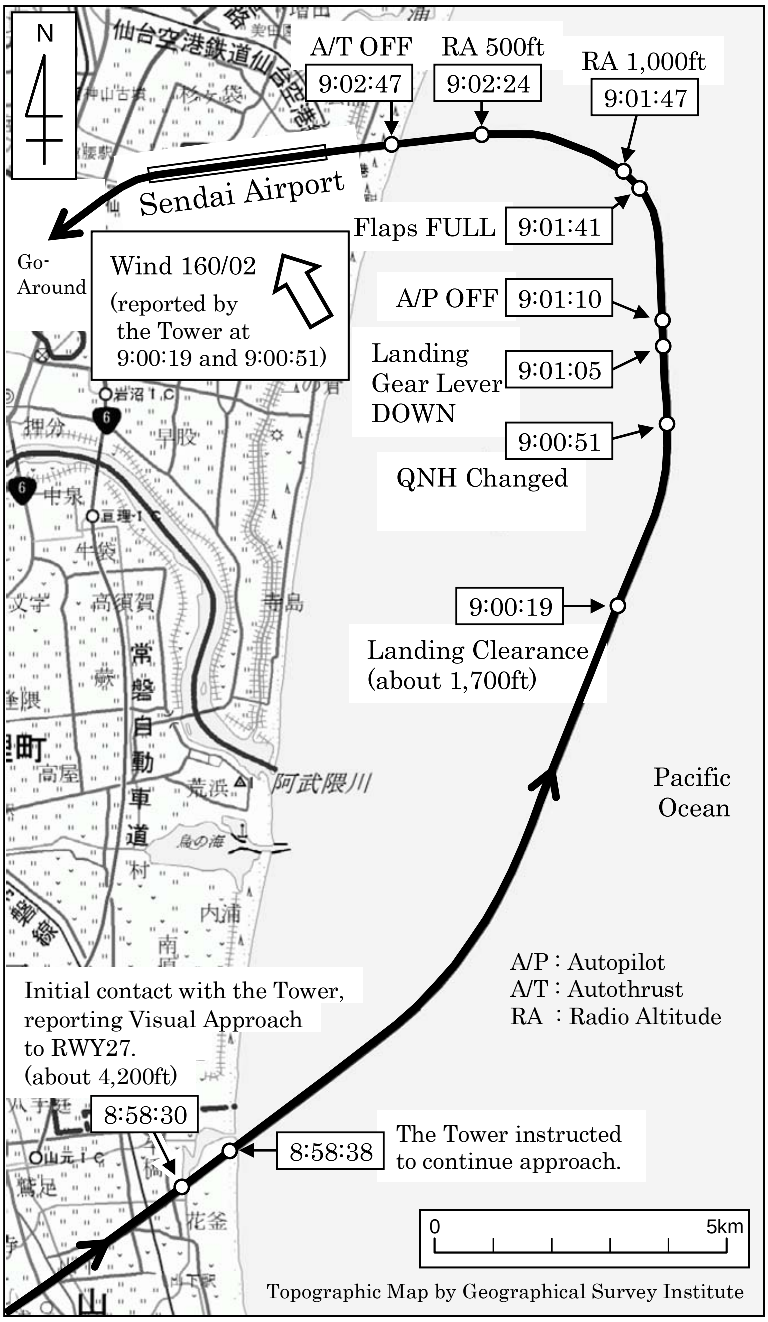


Figure A: Estimated Approach Route

9:01:47	The radio altitude for the Aircraft was 1,000 ft.
9:02:24	The radio altitude was lowered to 500 ft, prompting the first officer to call, “Five hundred.” The captain replied, “Stabilized.”
Around 9:02:35-50	The Aircraft’s approach angle declined temporarily.

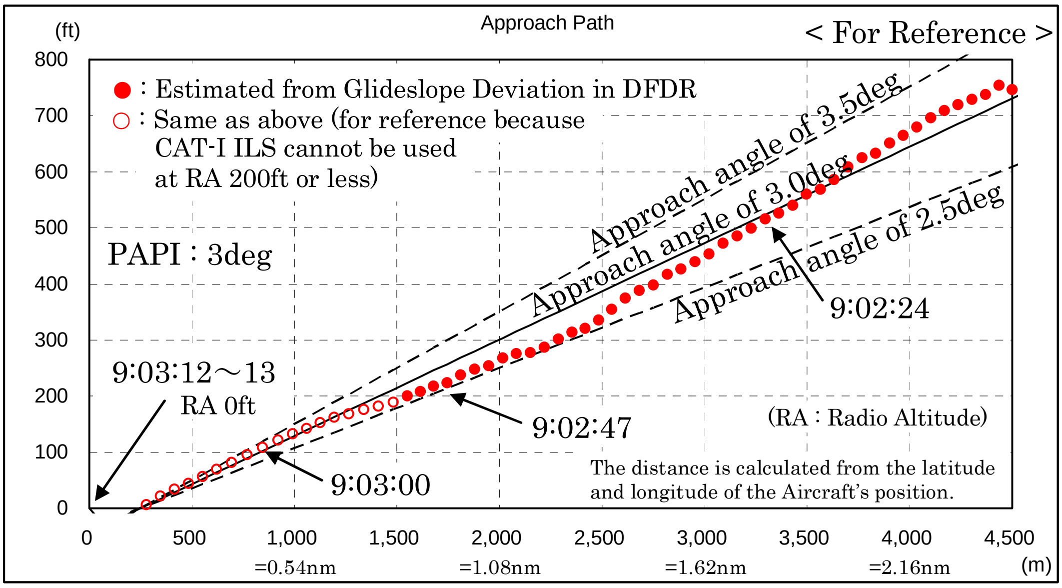


Figure B : Estimated Final Approach Angle

(For Reference because the Aircraft made a Visual Approach.)

9:02:47	The auto thrust (A/T) was disengaged.
9:03:00	The automatic voice called out (hereinafter referred to as "Auto Callout"), "One hundred (100 ft RA)."
9:03:02	The movement of the trimmable horizontal stabilizers (THSs) stopped.
9:03:04	The Aircraft passed the Runway 27 threshold at about 50 ft RA, at an airspeed of 138 kt, and at a pitch angle of 3.2 degrees, followed by the "Fifty (50 ft RA)" Auto Callout.
Around 9:03:05-08	Three Auto Callouts were annunciated: "Thirty (30 ft RA)," "Twenty (20 ft)," and "Retard (returning the thrust lever to the IDLE position)."
9:03:08	The thrust levers were moved to the IDLE position.
Around 9:03:08-10	The second and third "Retard" Auto Callouts were annunciated.

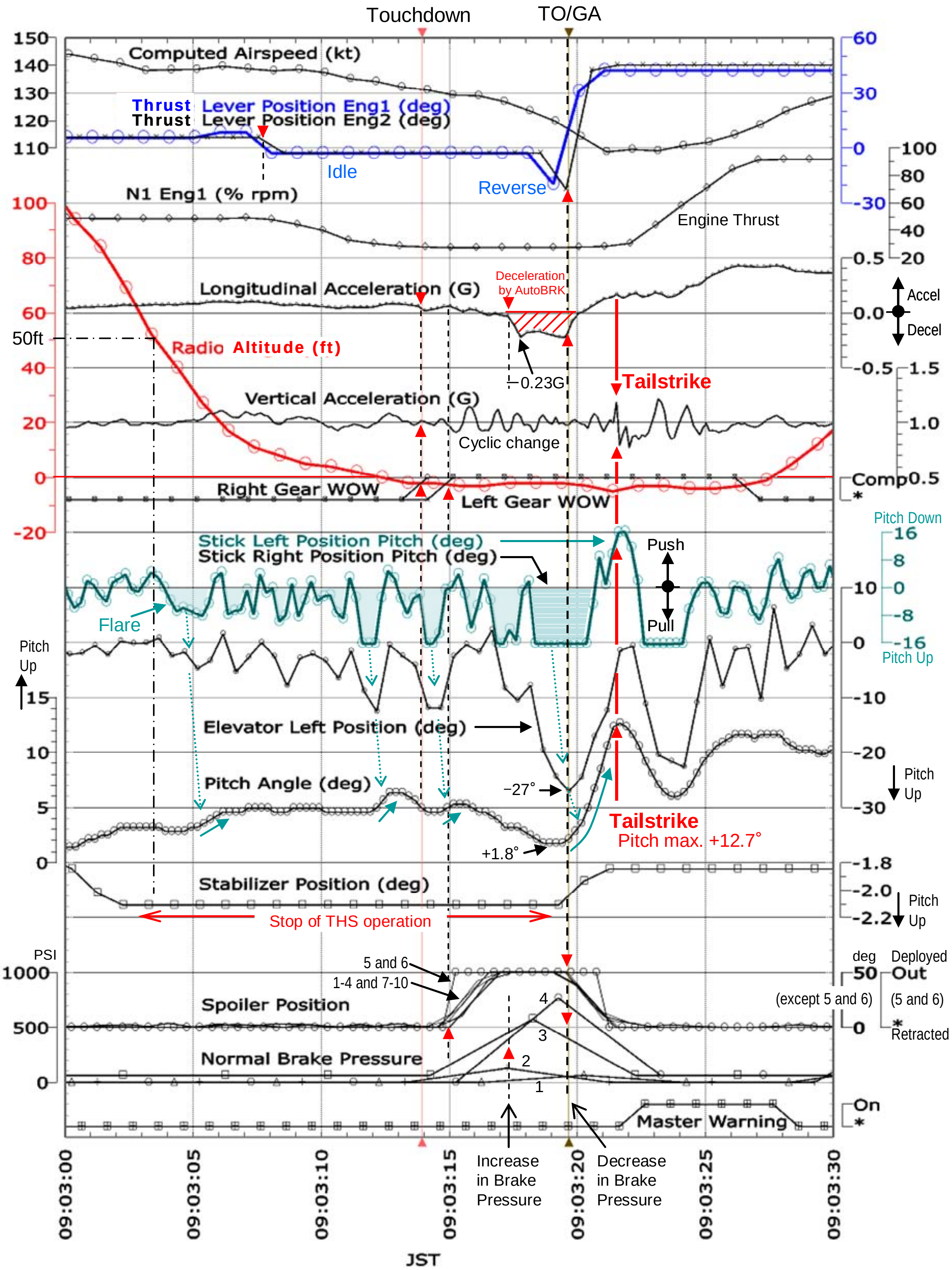


Figure C : DFDR Records

Around 9:03:14-15 The Aircraft's right main landing gear touched the runway, followed by the left one. The CVR records are unable to confirm the sounds of the main landing gears' touchdown, those of landing runs, and so forth. At this time, the airspeed was 130 kt, and the changes in vertical acceleration ranged between 0.98 and 1.04 G.

	At the same time that both the main landing gears touched the ground, the spoilers started to deploy. The captain said, "Oh, no good."
Around 9:03:15-18	The vertical acceleration changed cyclically, fluctuating between 0.91 and 1.15 G.
9:03:17	All spoilers extended completely. The longitudinal acceleration decreased to –0.23 G. At this time, as recorded in CVR, what sounded like the noise of running main landing gears and the vibrations of the airframe started to become louder.
Around 9:03:18-20	The sidestick by the left seat (captain) was made full aft input (pitch-up direction, –16 degrees), and this position was maintained for about two seconds.
9:03:19	The thrust levers were momentarily moved to the REVERSE positions. Later, the captain called, "Go around."
9:03:20	The elevator angle was deflected to –27 degrees (maximum: –30 degrees; a negative value indicates pitch-up). The thrust levers were moved to the TO/GA positions, and the spoilers started to be retracted. The longitudinal acceleration became almost zero, and then it stopped decelerating. THSs began to move in a pitch-down direction.
9:03:22	The pitch angle reached +12.7 degrees, the largest during this phase of flight, changing the vertical acceleration sharply.
9:03:23	A master warning (continuously repeated chime) was issued.
9:03:27	Both main landing gears left the runway. The nose landing gear did not touch the ground while the main landing gears did so.
9:03:30	The flap lever was raised by one level from the FULL DOWN position.
9:03:32	The landing gear handle was set to the UP position.
9:03:40	The first officer reported to the Tower that the Aircraft would go around.
9:06:31	The chief purser reported to the first officer that an unusual sound had been heard at the back of the Aircraft, and that there was a possibility that a tail strike had occurred.
9:07:10	The first officer reported to the Tower that an unusual sound had been heard in the cabin during the go-around, indicating a possibility that a tail strike had occurred, and requested the runway inspection. In its left turn to the final approach path for Runway 27, the Aircraft went up again.
Around 9:08	The Aircraft was holding at an altitude of about 1,500 ft near the south downwind leg.
9:14:43	The Tower notified the Aircraft that there was a white contact mark on the runway.
Around 9:27	The Aircraft landed on Runway 27 of Sendai Airport.

2.1.2 Statements of Crew Members

(1) Captain

On the morning of February 5, the captain arrived at Osaka International Airport earlier than usual.

Flight 731 was the first flight of which he took charge on the day, and he was mainly in charge of flying on the left seat. He thought that at Sendai Airport, winds would pose no problem when the Aircraft landed there though they were somewhat behind the Aircraft. Since the airport was visible when he communicated with Sendai Approach (Sendai Radar Approach Control), he requested a visual approach to Runway 27. He made descent and continued to fly for a final approach.

The Aircraft was slightly heavier because it was carrying fuel for a return flight. It approached at a managed speed (described later, in 2.9.4 (2) and 2.9.8 (2)), and remained stable though the airspeed slightly swung because of wind waves on the final approach course due to minor changes in wind velocity. The flaps were deployed the FULL DOWN position with the autobrakes in MED mode, the middle of the three levels of deceleration (MAX/MED/LO; MAX must not be used for landing).

Near the threshold, the precision approach path indicator (PAPI) was in “two reds and two whites,” which meant an appropriate angle of approach. Since he heard the “Fifty” Auto Callout, he determined that the Aircraft was almost “on path” (normal angle of approach). Probably due to the turn of winds, however, the captain, feeling that a minor upwash had raised the airframe slightly, thought that he had used a deeper pitch angle (pitch-down). Accordingly, this slightly gained speed, and he retarded the thrust levers. He thought that he had performed a normal flare just before the Aircraft touched the ground, but probably because he did so a little earlier, the Aircraft floated (which means a condition in which it did not touch the ground but continued to fly above the runway at a low altitude without intending to) and ran longer than intended, passing the touchdown zone markings.

He did not feel the impact of touchdown, but based on the surrounding circumstances he saw, he assumed that the Aircraft had touched down and pulled the reverse levers. Almost at the same time, he felt some vibrations from the airframe like stall buffeting and thought that it was not a normal landing. Determining that the Aircraft was still in the air, the captain decided to go around, shifting the thrust levers to TO/GA positions.

In the course of the go-around operation, the right main landing gear probably touched down, but the Aircraft continued to go up without slowing down. During the go-around, with the threshold of the runway still in view, the captain did not need to look at the panels, and therefore, he did not remember what the pitch angle actually was. That was exactly the same as the ordinary go-around operation.

At an early stage of the go-around, one of the flight attendants called the captain, but he deferred making a reply for some time because it was dangerous to respond while maneuvering the Aircraft. He was trying to land again after going through the normal traffic pattern when the flight attendant called him again, saying that a loud sound had been heard at the back of the Aircraft, and therefore, the captain postponed the landing and performed a go-around again. With the possibility of a tailstrike in mind, he requested the Tower to inspect the runway.

After the runway inspection was completed, the captain, informed that there were white contact marks left on the runway, determined that the possibility of a tailstrike was extremely high. With no particular body vibrations and other irregularities, he decided to land at Sendai Airport as planned. After its third approach, the Aircraft landed on the airport.

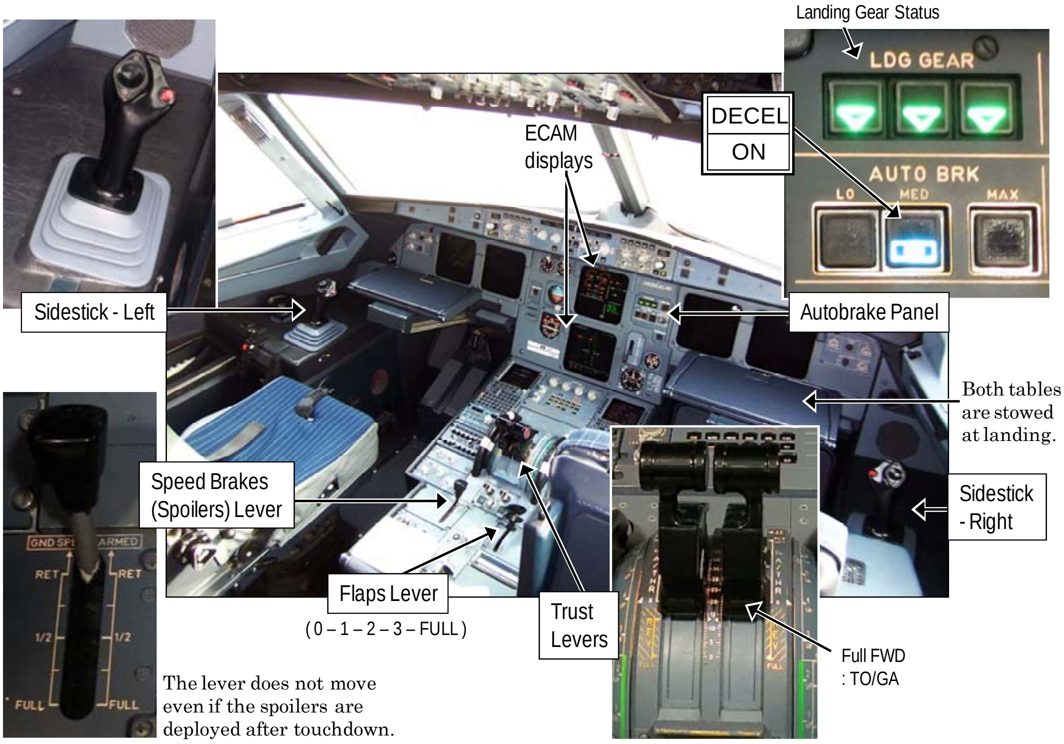


Photo A : Cockpit

The captain usually feels the Aircraft pitch up naturally when the spoilers are extended after landing, but he did not particularly have that feeling during the first attempt at approaching and landing.

Since floating usually occurs when there is extra energy such as strong winds, cockpit crew is not concerned much about the phenomenon because the Aircraft has a sufficient airspeed. But at that time, the Aircraft was floated though the wind was weak and there was little extra energy, and that was why the captain felt that the Aircraft was in a strained situation given the passage of time experienced during the floating.

Usually, even if the captain supports the nose of the Aircraft by performing the flare and pulling the sidestick, the main landing gears touch the ground as the Aircraft gradually goes down, but at that time, he did not have a feeling of touchdown and determined that floating was taking place. If such a situation continues, he gradually starts to think when he should go around. An extended time for touchdown is a delicate moment when he assesses the altitude of the Aircraft, and he performed a go-around thinking that he should be on a safer side if he was doubtful. That was a question with two choices—whether to go around or land—and the captain believed that it was safer to go around. He decided that since he felt the Aircraft stalled right after vibrations were felt, the landing must be cancelled even if there was a sufficient distance left on the runway. He makes it a rule to go around without hesitation if he feels dangerous.

Never in his career as a pilot had he experienced a landing in which he did not feel impact when the Aircraft touched the ground.

(2) First Officer

The weather was fine, and the flight went on as usual. Since the weather in Sendai was also fine, the first officer requested a visual approach to Runway 27.

During the approach, the Aircraft experienced some disturbances in the air current, and all four PAPI lights temporarily turned red, indicating that the angle of approach was low. But the captain performed a corrective operation prior to the first officer's deviation call (to attract the captain's attention if the Aircraft deviated substantially from the standard approach path), and the first officer did not think that the Aircraft was unstable.

The captain performed the flare as usual. Due to slight wind changes, the first officer more or less expected a long touch (which means touching the ground farther ahead), but being not aware of any extreme danger, he believed that the Aircraft would touch down within the range of standard operation and complete the landing as usual.

The first officer was expecting the main landing gears to touch the ground soon when he heard the captain's go-around call. Almost at the same time, the main landing gears touched the ground in a somewhat hard way, and the master warning was sounded for an instant. Then the captain shifted to a go-around operation. The first officer was not aware that the Aircraft had had part of its body scratched. With the end of the runway in view, he did not feel that the Aircraft was raised abruptly.

The first officer is supposed to confirm the deployment of spoilers on the screen of the electronic centralized aircraft monitor (ECAM) after touchdown and call, "No spoilers," if they are not extended properly. At that time, the first officer had not yet turned his eyes to the ECAM Wheel Page because he was not yet aware that the Aircraft had touched the ground (see 2.9.2).

After the go-around, near the base turn, the chief purser informed the cockpit that a tailstrike might have occurred because a loud unusual sound was heard. The first officer thought that there might be some debris left on the runway if the Aircraft had its tail scratched, and sharing the thought with the captain, he requested the Tower to inspect the runway.

Never in his career as a first officer had he experienced a landing in which he did not realize at landing that the Aircraft had touched the ground.

(3) Chief purser (L1: front left)

During the approach, she had no unusual feelings, nor did she feel any abnormality. When it was going to land soon, the Aircraft aborted the landing and went around. During the go-around, the chief purser heard a sound and felt an impact, those of which were different from ordinary ones, feeling that the Aircraft might have hit some obstacle or other. After she made an in-flight announcement, a rear flight attendant informed her that an unusual sound had been heard.

The chief purser told the cockpit crew via intercom that an unusual sound had been heard, and that there was a possibility of a tailstrike. The cockpit crew said that the reason for the go-around was winds, and that the unusual sound was attributed to the wheels touching the ground at the go-around.

(4) Rear flight attendants (L2: back left; seated with her face toward the back of the cabin, R2: back right; seated with her face toward the front of the cabin)

Flight attendant L2 did not have feelings such as strong winds and thought that the

Aircraft approached the runway as usual. When the Aircraft was going to touch the ground soon, she thought that its angle against the ground was different from the usual one. The moment she felt that the Aircraft had raised its nose, a loud sound was heard, and the flight attendant thought that the Aircraft had dragged its rear end on the runway.

When the terminal building came into view and she felt that the Aircraft raised its nose, Flight attendant R2 heard a sound of something being dragged and scratched come from beneath the rear galley. After the chief purser made an announcement in the cabin, Flight attendant L2 informed the chief purser of the situation.

The accident occurred at a location about 1,140 m from the Runway 27 threshold of Sendai Airport (38° 08' 27" N, 140° 55' 11" E) at around 09:03.

(See Figure 1 "Estimated Flight Route" and Figure 3 "Condition of Touchdown Based on DFDR and CVR Data")

2.2 Damage to the Aircraft

2.2.1 Extent of Damage

Substantial

2.2.2 Damage to the Aircraft Components

On the external plates for the lower part of the rear fuselage was an abrasion of about three meters in length and about 40 centimeters in width, and two of the drain masts were damaged. The lower portion of the rear pressure bulkhead was slightly deformed, and the frame of the bulkhead close to the portion was also damaged.

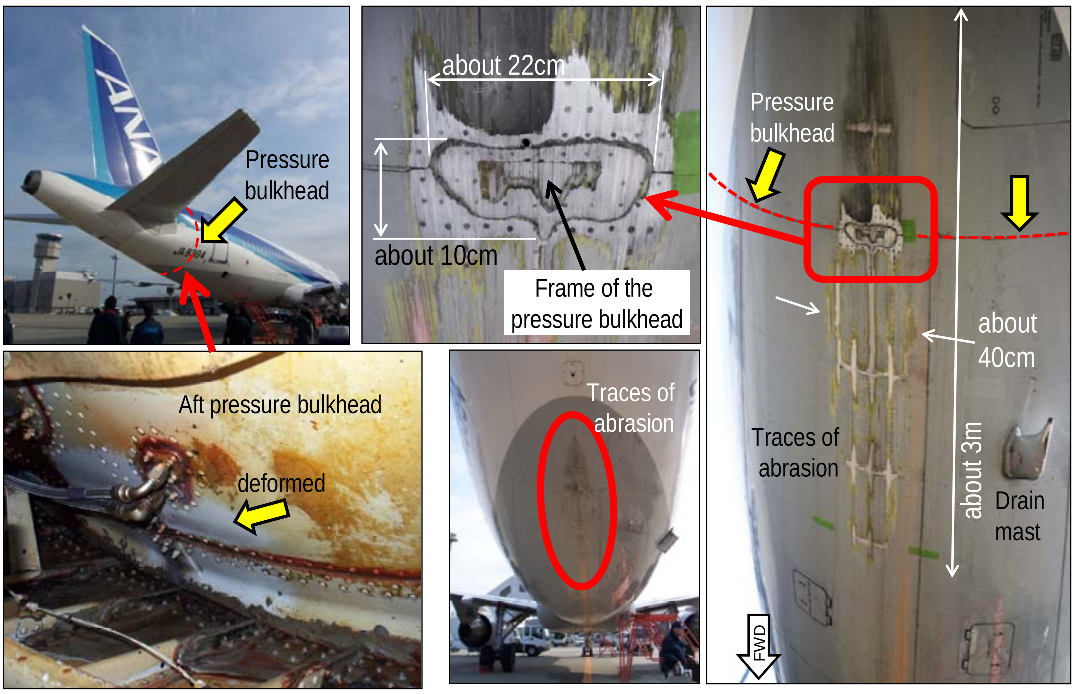


Photo B : Damage to the Fuselage

2.3 Personnel Information

(1) Captain　　Male, Age 46

Airline transport pilot certificate (Airplane)	March 28, 2003
Type rating for Airbus A320	July 7, 1995
Class 1 aviation medical certificate	
Validity	July 11, 2012
Total flight time	10,211 hr and 51 min
Flight time in the last 30 days	56 hr and 29 min
Total flight time on the type of aircraft	8,042 hr and 27 min
Flight time in the last 30 days	56 hr and 29 min

(2) First Officer　　Male, Age 31

Commercial pilot certificate (Airplane)	October 28, 2005
Type rating for Airbus A320	January 28, 2011
Instrument flight certificate	November 4, 2005
Class 1 aviation medical certificate	
Validity	February 26, 2012
Total flight time	2,642 hr and 16 min
Flight time in the last 30 days	53 hr and 04 min
Total flight time on the type of aircraft	573 hr and 57 min
Flight time in the last 30 days	53 hr and 04 min

2.4 Aircraft Information

2.4.1 Aircraft

Type	Airbus A320-200
Serial number	151
Date of manufacture	December 18, 1990
Certificate of airworthiness	No. Tou-10-566

Term of validity: Period starting October 28, 1998 during which the maintenance regulations (All Nippon Airways Co., Ltd. (ANA) or other carriers which use this Aircraft in their joint projects with ANA) apply

Category of airworthiness	Airplane　Transport T
Total flight time	43,423 hr and 57 min

Length of flight time after periodic inspections (C17 inspection conducted on July 28, 2011) 1,089 hr and 19 min

(See Figure 2 "Three angle view of Airbus A320-200")

2.4.2 Weight and Balance

When the accident occurred, the weight of the Aircraft is estimated to have been 136,700 pounds, and that the center of gravity is estimated to have been 29.8% MAC. Therefore, it is also estimated that both were within the allowable range (maximum landing weight: 142,198 lb.; CG range that corresponded to the weight at the time of the accident: 20.5-38.9% MAC).

2.4.3 Ground Clearance

If the main landing gears of the Aircraft touches the ground at a roll angle (inclination to the right or left from the horizontal plane; positive when inclined to the right) of zero degree, the rear portion of the fuselage touches the ground at a pitch angle (inclination to the front or rear from the horizontal plane; positive when the nose is raised) of 11.7 degrees if the shock absorbers of the main landing gears are compressed completely and at a pitch angle of 13.5 degrees if it is extended completely (see 2.9.5 (1)).

The Aircraft does not equipped with a system that detects the occurrence of a tailstrike and inform the cockpit crew thereof.

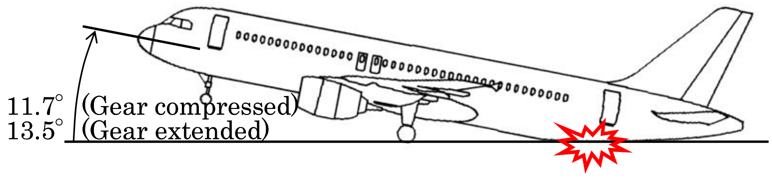


Figure D : Ground Clearance

2.5 Meteorological Information

The aviation weather observations at Sendai Airport during the time period when the Aircraft arrived there were as follows:

09:00 Wind direction: changing; wind velocity: 2 kt; prevailing visibility: 60 km
Clouds - Cloud volume: FEW (1/8); cloud shape: cumuli; height of cloud base: 2,000 ft
Temperature: 1°C; dew point: −8°C
Altimeter setting (QNH): 30.28 inHg

09:11 Wind direction: changing; wind velocity: 2 kt; prevailing visibility: 60 km
Clouds - Cloud volume: FEW (1/8); cloud shape: cumuli; height of cloud base: 2,000 ft
Temperature: 2°C; dew point: −8°C
Altimeter setting (QNH): 30.28 inHg

At Sendai Airport, anemometers are placed at three locations along Runway 09/27 (on the 09, vicinity of the center, and on the 27 threshold). At two of the three locations—on the 27 threshold, which is close to the accident site, and vicinity of the center—during the time period related to the accident, no major fluctuations in wind direction and wind velocity were observed with the instantaneous wind direction fluctuating from about 140 degrees to 170 degrees and the instantaneous wind velocity at 2 kt.

2.6 Information on DFDR and CVR

The Aircraft was equipped with a DFDR (part number 980-4700-003) manufactured by Honeywell of the United States of America and a CVR (part number: S200-0012-00) manufactured by L-3 Communications of the United States of America, and records of the accident when it occurred were left in both recorders.

The time calibration for DFDR and CVR was conducted by comparing the time signals recorded in the air traffic control communication records with the VHF radio signals recorded in DFDR and air traffic control communications recorded in CVR.

2.7 Accident Site Information

Sendai Airport is located 5.6 ft above sea level and has two runways: 09/27 of 3,000 m in length and 45 m in width and 12/30 of 1,200 m in length and 45 m in width. Runway 27 has the PAPI placed on its left side at an angle of three degrees 439 m away from the threshold.

At a location about 1,140 m from the Runway 27 threshold was a white contact mark of about nine meters in length and about 40 cm in width, and metal fragments were left in the grooves (which are dug to drain water and improve the effects of braking) on the runway. In parallel with this mark, fine contact marks were also left on the right-hand side of the direction of flight. The conditions of these marks on the runway almost corresponded with the locations of those of abrasion on the lower part of the rear fuselage and damaged drain masts.

There was no damage to the runway, lights and markings.

(See Figure 1 "Estimated Flight Route.")

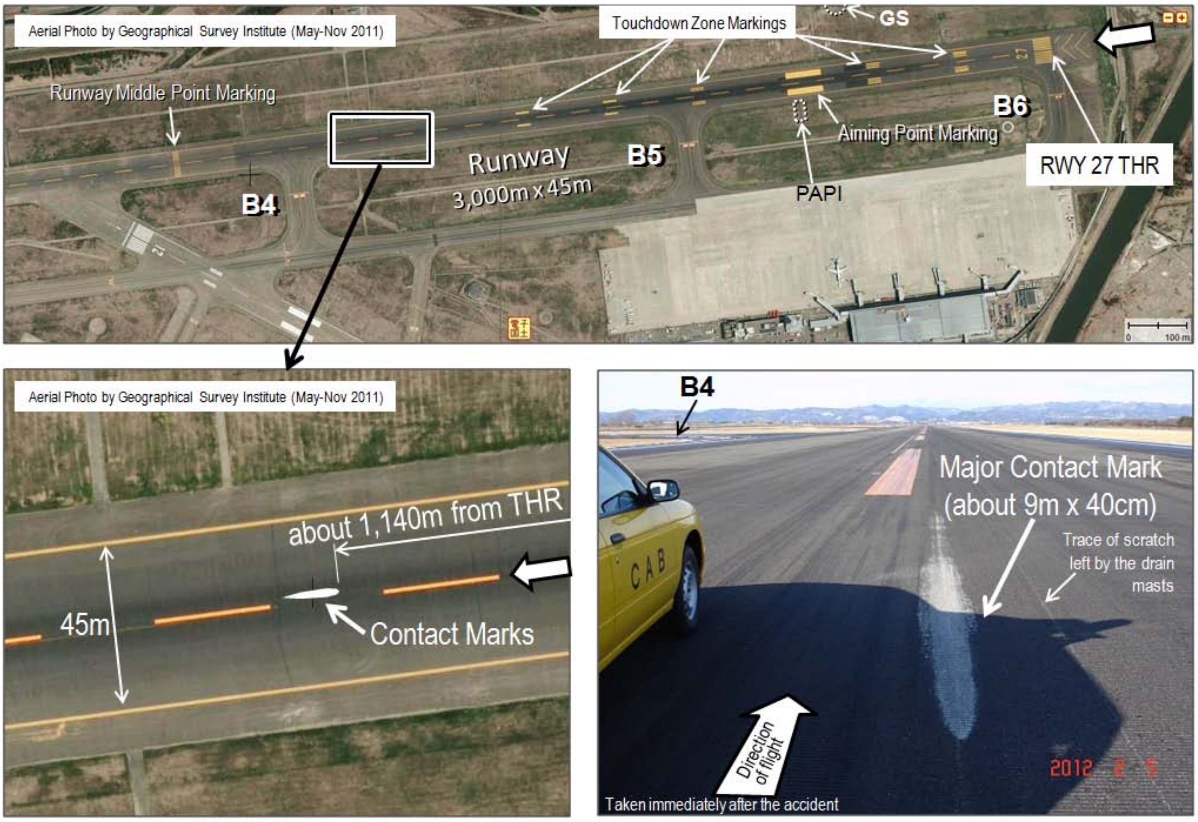
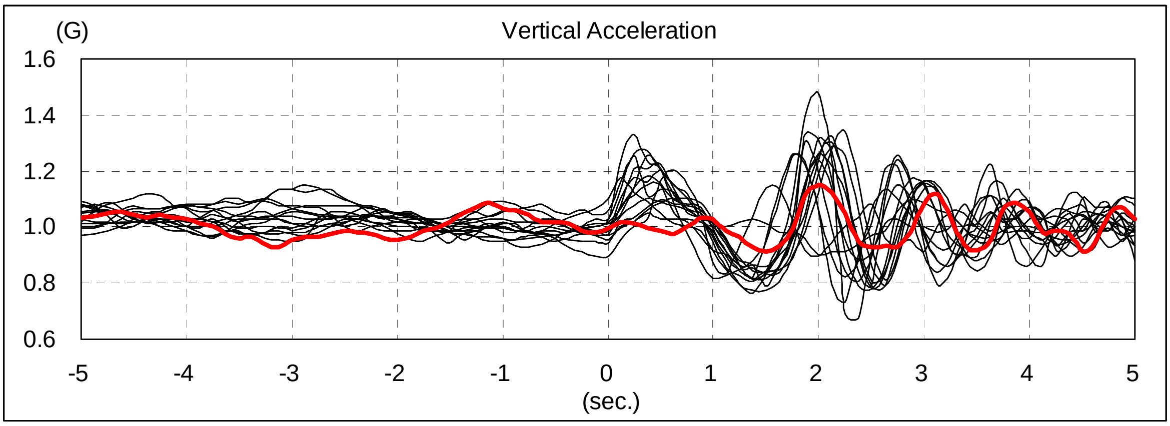


Photo C：Condition of the Runway

2.8 Data Retained in DFDR and QAR Data

Records of vertical acceleration for the past 15 touchdowns (13 prior to the accident, one at the time of the accident, and one thereafter), which were retained in the DFDR of the Aircraft, were compared.

In most of the previous landings, the vertical acceleration increased sharply to the positive side when the main landing gears touched down (average increase: +0.19 G), but when the accident occurred, the change in vertical acceleration remained within the range of 0.98 G to 1.04 G (increase: +0.06 G) when the right main landing gear touched down, followed by the left one.



・Vertical accelerations for previous 15 touchdowns retained in DFDR
・The time when any landing gears touched down is zero.
・All waveforms are smoothed.
・The thick red line shows the G's of this event.

Figure E：Vertical Acceleration at Touchdown

In addition to the DFDR records, QAR records were used to analyze the operation of the thrust reversers and some of the speeds calculated using a computer.

The DFDR records did not indicate that the locked thrust reversers for individual engines had been released, but according to the QAR records, the locked thrust reversers for both the engines of the Aircraft were released for an instant when the thrust levers were temporarily set to the FULL REVERSE position.

According to the QAR records, the V_{LS} (described later in 2.9.4 (2)) for the Aircraft during its final approach was 130.25 kt.

2.9 Additional Information

2.9.1 Motion Characteristics of Pitching

(1) Pitch control

The pitch angle of the Aircraft is controlled using the elevators and THSs. The raising or lowering of the elevators is controlled by the forward or backward operation of the sidestick (pushing and pulling).

The elevators can be moved by up to 30 degrees to raise the nose of the Aircraft and by up to 17 degrees to lower it, and THSs can be moved by up to 13.5 degrees to raise the nose and by up to four degrees to lower it.

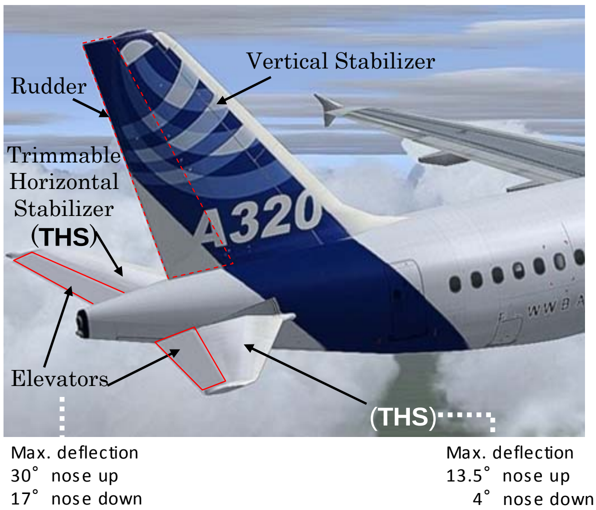


Figure F：Tail

In this report, the raising or lowering of the elevators refers to the movement of the trailing edges, and the raising or lowering of THSs refers to the movement of the leading edges.

(2) Pitching Moment

In case of an aircraft go-around after touching the runway, the cockpit crew needs to take into consideration the factors shown in Table A and Figure G below when raising or lowering its nose.

	Raising the nose	Lowering the nose
Elevators	Trailing Edge Up	Trailing Edge Down
Horizontal stabilizers	Leading Edge Down	Leading Edge Up
Wheel brakes	--	Brake pressure increased
Spoilers *	Deployed	--
Thrust reversers	Retracted	Deployed
Engine thrusts	Increased	Decreased

* : Compensations to minimize the pitching tendency are not considered.

Table A: Pitching Moment

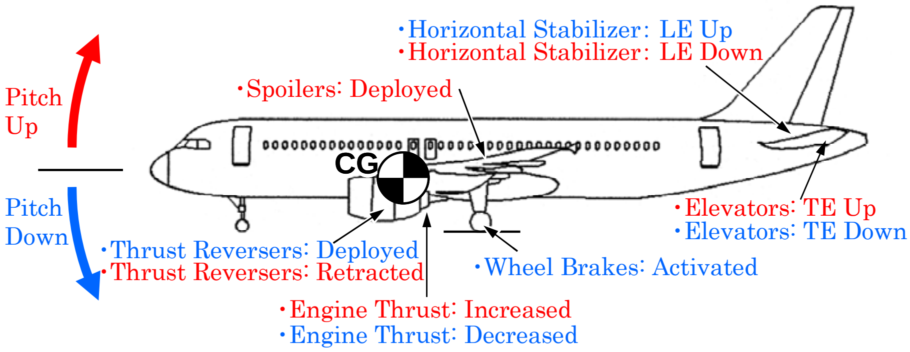


Figure G : Pitching Moment

2.9.2 Spoilers

The Aircraft has a total of ten spoilers, five on its right wing and five on its left. As soon as the main landing gears touch the ground, all these ten spoilers are deployed to reduce the dynamic lift of the wings. They are also effective in reducing the speed of the Aircraft.

If all spoilers are deployed properly, green upward arrows are displayed on the ECAM Wheel Page as shown in Figure J. (See 2.9.4 (5))

Figure H : Spoilers

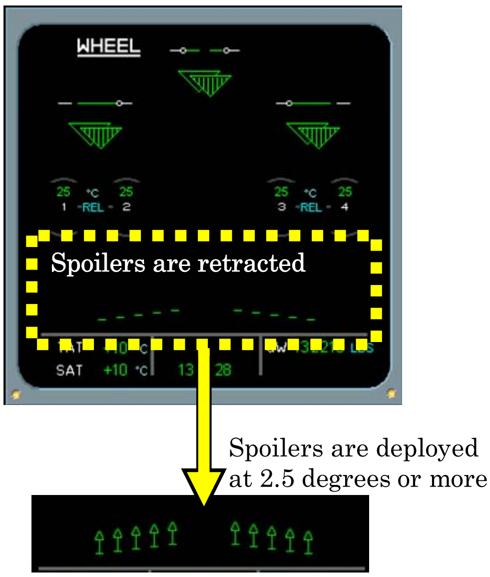


Figure J : ECAM Wheel Page

2.9.3 Thrust Levers

If the thrust levers are pushed full forward (+40 degrees), they are set to the TO/GA positions.

If the thrust levers are returned to the IDLE position (zero degree); then, unlocked, and further pulled backward, they are set to the REVERSE position, prompting the thrust reversers for the engines to function. If the thrust levers are pulled full backward (–20 degrees), they are set to the FULL REVERSE position.

Despite it is technically possible to set the thrust levers to the REVERSE position when aircraft is in the air, in that case and as per design, the reversers would not work.

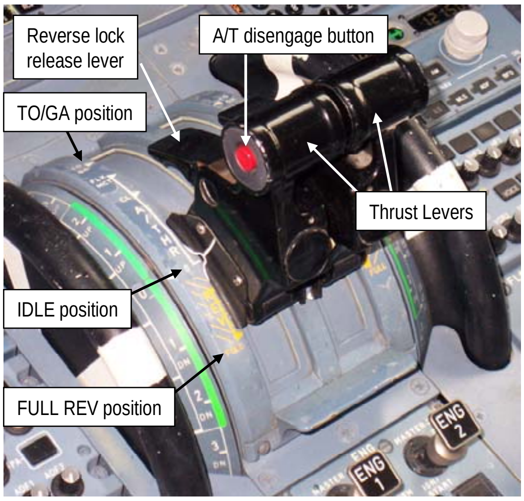


Figure K : Thrust Levers

2.9.4 Aircraft Operations Manual (AOM)

(1) Go-around and landing procedures

Chapter 3 “Normal Procedures” of AOM established by the Company for the Aircraft states as follows (excerpts):

3-1-15 GO-AROUND

If an aircraft continues to approach and land, and if there is concern about the subsequent safety of the aircraft, the cockpit crew must perform a go-around without hesitation.

If there is concern about the safety of landing, PM shall also call, “Go around,” irrespective of whether he is the captain or first officer. Even if PM calls, “Go around,” the final decision shall be made by the captain (PIC).

A go-around shall be performed according to 3-9-2 “GO AROUND PROCEDURE.”

3-9-2 GO AROUND PROCEDURE

PF	*PM*
The operations listed below shall be performed at the same time. *Call “GO AROUND, FLAP 3 (OR 2)”* *Give an instruction for one-level shallower flaps than the pre-go-around ones.* *THRUST Levers .... TO/GA (NOTE 1)* *Rotation .... PERFORM* *If auto pilot is not used, the nose of the Aircraft shall be raised smoothly to the pitch attitude designated by the SRS pitch command bar.*	*FLAPS Lever .... SET 3 (OR 2)*

Call "GEAR UP."	*Call "POSITIVE (CLIMB)."* *Landing Gear Lever .... UP*

The AFTER TAKEOFF Procedure shall be followed. (NOTE 2, NOTE 3)

(*NOTE 1*, *NOTE 2*, and *NOTE 3* are omitted)

3-9-3 LANDING ROLL PROCEDURE

PF	*PM*
Thrust Levers .... IDLE *At the same time* *BRAKES .... APPLY* *Confirm the operation of the Auto Brake.* *Apply Pressures on both Brake Pedals to Take Over Brake Control if necessary.* *Thrust Levers .... REV* *Shift to MAX REV* immediately after the main landing gear touches the ground.* *CAUTION: A go-around must not be attempted after the reverse thrust is used.*	*Spoilers .... CHECK* *Confirm on the ECAM WHEEL PAGE after touchdown that all Ground Spoilers are extended completely.* *If the spoilers are not in the UP position, Call "NO SPOILERS."* *Confirm that REV (Green) is indicated on the ECAM upper display.* *Monitor engine parameters.*

Deceleration .... CHECK

Confirm that the aircraft is reducing its speed.

(Omitted)

** : It is not necessary to shift to MAX REV if required to reduce noise or serve other purposes or if there is a sufficient distance left on the runway to bring the aircraft to a complete stop.*

(2) Approach speed

Chapter 3 "Normal Procedures" and Chapter 4 "Supplementary Procedures" of AOM for the Aircraft state as follows (excerpts):

3-1-14 TARGET APPROACH SPEED

Use of the Managed Speed is recommended. PF shall make a decision according to the situation, however, taking into consideration the characteristics of Managed and Selected Speeds.

4-2-1 Airplane General

OPERATING SPEEDS DEFINITION

V_{LS}: *Lowest Selectable Speed. This Speed is indicated at the upper end of the Amber Strip by the Airspeed Scale.* (The rest is omitted)

V_{APP}: *Final Approach Speed* (Omitted)

$$V_{APP} = V_{LS} + \text{Wind Correction} + 5kt$$

(The rest is omitted)

$V_{APP\ TARGET}$: (Omitted)

Effective as a speed guidance if the wind direction and velocity are unstable
(omitted)
$V_{APP\ TARGET}$ *= GS_{mini} + Actual Headwind (measured using ADIRS)*
GS_{mini} = V_{APP} − Tower Headwind (Head Wind Components along the runway as calculated by FMGC based on Tower Winds inputted in MCDU)

(3) Operation of speed brakes and spoilers, and pitch control

Chapter 6 "System Descriptions" of AOM for the Aircraft states as follows (excerpts):

6-9 FLIGHT CONTROLS

DESCRIPTION

SPEED BRAKES AND GROUND SPOILERS

GROUND SPOILERS CONTROL

Full Extension - Landing Phase

The Ground Spoilers are automatically extended in the following case:

—If both the right and left main landing gears touch the ground with the Ground Spoilers armed and both Thrust Levers in the IDLE position

Retraction

The Ground Spoilers are retracted in the following cases:

- (Omitted)
- *If, in the case of "Touch and Go," at least one of the Thrust Levers is advanced by 20 degrees or more*

NOTE: The Landing Gear is considered to have touched the ground if one of the events occurs:

- *If the wheel speeds for both landing gears exceed 72 kt*
- *If RA becomes less than 6 ft, and if both main landing gear struts are compressed*

NORMAL LAW

PITCH CONTROL

GROUND MODE

In Ground Mode, the operation volume for the Sidestick has direct relationships with that for the Elevator, and the Auto Trim does not function.

THS is automatically set to zero degree (within the Green Band).

After landing, if the Pitch Attitude exceeds 2.5 degrees, the resetting of THS to zero degree is immediately stopped and frozen. If the Pitch Attitude becomes less than 2.5 degrees, the automatic resetting of THS to zero degree begins immediately.

* Note for the quotation: In addition, AOM indicates that five seconds after touchdown, the ground mode shifts to active one (ground law).

FLIGHT MODE

The Flight Mode remains Active from Takeoff to the time when it shifts to Flare Mode at Landing.

The Automatic Pitch Trim is frozen in the following cases:

— (Omitted)

— If the aircraft is at 50 ft RA or less (100 ft or less if the A/P Engage is used)

FLARE MODE

At landing, the flight mode shifts to flare mode if the altitude becomes 50 ft or less. The pitch attitude at an altitude of 50 ft is memorized and used as an initial reference for pitch attitude control.

If the altitude becomes 30 ft or less, the pitch attitude is lowered from the one at an altitude of 50 ft to minus two degrees, and it takes eight seconds to lower the pitch attitude this much. Therefore, the pilot's operation to flare the body of the Aircraft is required.

(4) Autobrakes

Chapter 6 "System Descriptions" of AOM for the Aircraft states as follows (excerpts):

(3) AUTO BRK panel

Use the MAX/MED/LO push-button switch (spring loaded) to select the desired deceleration rate for arming.

—The MAX mode is usually used at takeoff. (Omitted)

—The MED or LO mode is usually used at landing.

- LO Mode (Omitted)

- If the MED mode is selected, pressure is supplied two seconds after the deployment of ground spoilers so that the deceleration rate of 3.0 m/s^2 (9.8 ft/s^2) is obtained.

—Lights

- The green DECEL light comes on when the actual deceleration is 80 % of the selected rate. For example the DECEL light might not appear when the autobrake is selected on a contaminated runway, because the deceleration rate is not reached with the autobrake properly functioning.

(5) ECAM Wheel Page

Chapter 6 "System Descriptions" Section 6-15 "Landing Gear" of AOM for the Aircraft states as follows (excerpts):

BRAKES AND ANTI-SKID

<u>CONTROLS AND INDICATORS</u>

ECAM WHEEL PAGE (indicated in the same way as in the FLT CTL page)

(3) AUTO BRK

MED, LO, or MAX is indicated below the AUTO BRK display according to the deceleration rate selected.

<u>ECAM F/CTL PAGE</u>

(1) Spoilers/Speed Brakes

 *: SPOILER DEFLECTED BY MORE THAN 2.5° (GREEN)*

 : SPOILER RETRACTED (GREEN)

 *: SPOILER FAULT DEFLECTED (AMBER)*

 *: SPOILER FAULT RETRACTED (AMBER)*

(6) Automatic callout

Chapter 6 "System Descriptions" of AOM for the Aircraft states as follows (excerpts):

RADIO ALTIMETER

AUTOMATIC CALL OUT

(Omitted) *The automatic callout uses synthetic voice to make radio height announcements through the loudspeaker if the radio altitude is 100 ft or less.*

(Omitted)

Predetermined CALL OUT

Altitude callouts are made at the thresholds listed below.

Height	*Call Out*
(Omitted)	(Omitted)
100	*ONE HUNDRED*
50	*FIFTY*
30	*THIRTY*
20	*TWENTY*
10	*TEN*
(Omitted)	(Omitted)

If the aircraft maintains the height listed above for some time, a corresponding callout is triggered periodically.

Intermediate CALL OUT

If the interval between one altitude callout and the next is too long (omitted) *four seconds or more if the altitude is 50 ft or less), the callout that corresponds to the current altitude is repeated every four seconds.* (Omitted)

Retard Announcement

A "RETARD" callout is made in the following cases:

— (Omitted)

— *If the auto thrust is not engaged at 20 ft RA* (Omitted)

(7) Checklist used at the time of a tailstrike

Chapter 2 "Non-normal Procedures" of AOM for the Aircraft states as follows (excerpts):

TAILSTRIKE

LAND ASAP

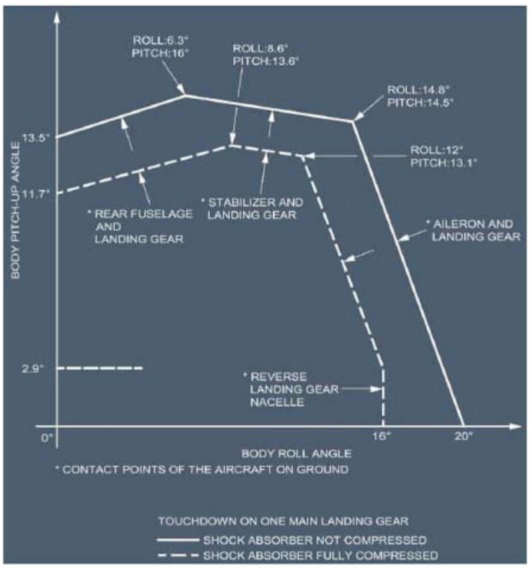
CAUTION: Pressure must not be added to the fuselage due to the possibility of structural damage.

— MAX FL .... 100 or MSA PF
— RAM AIR .... ON PM
— PACK 1 and 2 .... OFF PM

2.9.5 Flight Crew Operating Manual (FCOM)

(1) Ground clearance

The "Standard Operating Procedures – Landing" (right-hand figure), which are included in the Aircraft's FCOM issued by the designer and the manufacturer of the Aircraft, present a ground clearance diagram, which provides the following information (excerpts):



If the main landing gears touch the ground with the body's roll angle at zero degree, the rear fuselage is in contact with the runway:

- When the pitch-up angle is 11.7 degrees if the shock absorber is compressed completely, and

- When the pitch-up angle is 13.5 degrees if the shock absorber is not compressed.

These procedures also include the following description:

Ground clearance

Avoid flaring high.

Be aware of the pitch-up tendency, with ground spoiler extension.

(2) Flare

The "Standard Operating Procedures – Landing," which are included in the Aircraft's FCOM, state as follows (excerpts):

Flare

- In stabilized approach conditions, the flare height is approximately 30 ft.

Flare .... PERFORM

Attitude .... MONITOR

The PM should monitor the attitude, and call out:

- "Pitch, pitch" if the pitch angle reaches ten degrees.

- "Bank, bank" if the bank angle reaches seven degrees.

Thrust levers ...... IDLE

In manual landing conditions, the "RETARD" callout is triggered at 20 ft Radio Altitude (RA), in order to remind the pilot to retard the thrust levers.

2.9.6 Flight Operations Briefing Notes (FOBN)

(1) Preventing tailstrike at landing

The "Landing Techniques - Preventing Tailstrike at Landing," which are included in FOBN, issued by the designer and the manufacturer of the Aircraft, state as follows (excerpts):

IV Prevention Strategies and Lines of Defense

IV.1 Flying Techniques

Landing

The flight crew should avoid "holding off the aircraft" in an attempt to make an excessively smooth landing.

Immediately after main landing gear touchdown, the PF should release the back pressure on the sidestick (omitted) *and fly the nose wheel smoothly, but without delay, on to the runway.*

The PM should continue to monitor the attitude.

V Summary of key points

- (Omitted)
- *Do not hold off the aircraft to make an "extra smooth" landing*

(2) Preventing tailstrike at takeoff

The "Takeoff and Departure Operations - Preventing Tailstrike at Takeoff," included in FOBN, state as follows (excerpts):

III Operational and Human Factors Involved in Tailstrikes at Takeoff

III.2 Rotation technique

Rotation rates that are too fast increase the risk of tailstrike, whereas rotation rates that are too slow increase the takeoff distance and takeoff run.

If the established rotation rate is not satisfactory, the pilot must avoid rapid and

large corrections, which cause sharp reaction in pitch from the aircraft.
If, to increase the rotation rate, a further and late aft sidestick input is made around the time of liftoff, the possibility of a tailstrike is significantly increased. This is especially a risk on aircraft that may have a large inertia (e.g. long aircraft) since the initial rotation rate produced by a given sidestick input takes time to build up.

IV Preventive Strategies and Lines of Defense

IV.2 Crew rotation technique

- *At V_R, the flight crew should initiate the rotation with a smooth positive backward sidestick input in order to achieve a continuous rotation rate of approximately 3 degrees per sec.*

2.9.7 Training Manual

Basic landing method

The training manual for the type of Aircraft, established by the Company, states as follows (excerpts):

1. LANDING GENERAL

2. Basic landing method for A320

(Omitted) *If the average final approach speed is taken into consideration, the appropriate altitude to commence the flare is considered to be around 20 ft AGL.*
(Omitted)

(3) FLARE to TOUCHDOWN

1) Altitude to commence the flare

The appropriate altitude to commence the flare is around 20 ft.
AUTO CALLOUT at 20 ft RA is effective in reminding the cockpit crew of the appropriate altitude, but the cockpit crew must prepare to begin the flare when hearing the "30 feet" callout.

(4) LANDING ROLL

1) REVERSE THRUST

If the main landing gears touch the ground, the thrust lever shall be shifted to the MAX REVERSE position and maintained there.
The lever shall smoothly be returned to the IDLE REVERSE position at 70 kt and held there for some time.

4) SIDESTICK AND STEERING

The pitch attitude must not be increased after touchdown because increasing it may cause a tailstrike. The cockpit crew shall swiftly let the nose landing gear touch the ground smoothly.

11. GO AROUND (AOM3-9-2)

<Essential points and points to note>

- *The INITIAL TARGET PITCH for MANUAL GO AROUND is 2ENG 15° and 1ENG 10°. Later, the speed should be checked and adjusted to follow SRS COMMAND. In the case of 2ENG, attention should be paid so that the initial target pitch does not exceed 20 degrees.*

In addition, in order to determine the touchdown point, it is graphically indicated that the A320 touchdown zone is between 500 ft and 1,750 ft (about 150 m and 530 m) from the threshold.

According to the Company, at the time when the accident occurred, cockpit crew was not trained so that they should perform a go-around after, at landing, the main landing gears touched the ground, spoilers were deployed, and the autobrakes started to actuate.

2.9.8 Airplane Operations Reference (AOR)

(1) Prevention of tailstrikes

AOR for the Aircraft, established by the Company, states as follows (excerpts):

2-1-12 Avoiding Tail Contact

1. Ground Pitch and Roll Angle Limit

(Omitted)

(3) Tail Contact vs Pitch Angle

When the roll angle is zero degree, there is a possibility of tail contact if the pitch angle is 13.5 degrees and the shock absorber is not compressed, and if the pitch angle is 11.7 degrees and the shock absorber is fully compressed.

2. Operational Guidances

A. Takeoff Rotation and Lift off

Pitch up the aircraft in SRS mode at a rate of about three degrees per second from the prescribed V_R . The nose of the Aircraft should be raised smoothly up to a degree of 20 degrees. (Omitted)

B. Landing Flare and Touchdown

- Maintain an appropriate approach speed.

(Omitted)

- Avoid bleeding off excessively.

(Omitted) *If* V_{TD} *is equal to* V_{REF} *, the touchdown pitch angle is about 6.5 degrees, and if* V_{TD} *becomes lower,* θ_{TD} *becomes larger. Therefore, bleeding off excessively makes tail contact easy to occur.*

- Do not float the aircraft.

Floating the aircraft to make the touchdown as smooth as possible results in keeping the nose high, and combined with the loss of the ability to locate oneself against the ground, this makes tail contact easy to occur.

- Commence the flare at an appropriate altitude.

If the aircraft is flared at a high location, and the power is throttled, the only way to prevent a rise in sink rate is to pitch up the aircraft.

Usually, commence the flare at an altitude of about 20 ft.

Also start to reduce the power gradually at an altitude of about 20 ft.

- After touchdown, ensure that the nose landing gear touches the ground swiftly.

Pay attention to the fact that the extension of ground spoilers leads the aircraft to pitch up.

(2) Managed speed

AOR for the Aircraft states as follows (excerpts):

2-1-19 Effective use of managed speed

A320 aircraft have two types of target approach speeds: selected speed and managed speed. (Omitted)

The managed speed is (omitted) *a speed that is displayed by FMGS on the speedometer by changing the target approach speed as time passes so that during the approach, the speed of the aircraft does not go below the ground speed (called* GS_{mini}*)*

expected at touchdown.

The managed speed is effective when the wind is strong to the extent that it exceeds a certain level (Omitted)

In indicating the managed speed, as winds change, the target approach speed changes only in the cases specified below. In other cases, it does not change.

(1) If the head components of the current winds are larger than 10 kt in case the head components of ground winds are 10 kt or less (Omitted)

In other words, $V_{APP\ TARGET}$ *changes from* V_{APP} *in the managed speed only if the actual headwind components are strong to a certain extent (10 kt or more) and larger than tower headwind components.* (Omitted)

The minimum value for $V_{APP\ TARGET}$ *is* V_{APP}*.*

2.9.9 Measures taken by the designer and the manufacturer to prevent tailstrikes

According to the articles in the safety information magazines published by the designer and the manufacturer to prevent tailstrikes and related materials, the measures taken by them for that purpose were as described in (1) and (2) below.

The improvement measures described in (1) and (2) below, which were offered by the designer and the manufacturer as optional, had not been taken for the Aircraft.

(1) Improvement of the flight control program

In April 2008, the designer and the manufacturer improved the flare law for A320 and A321 Aircraft. This was intended to limit the pitch-up rate (degrees per second) varied by sidestick operation at landing by revising the software for the Elevator Aileron Computer (ELAC).

This flare law starts to work when the spoilers are deployed after touchdown, and therefore, it does not work at takeoff or go-around, and it is effective only at landing. In addition, if the pitch angle is less than 2.5 degrees, and the aircraft runs on the ground for five seconds, the flare law gives way to the ground law, causing the function of limiting the pitch-up rate to cease working.

(2) Warning indication and aural warning

By improving the display management and flight warning computers, the designer and the manufacturer offer the functions of displaying the pitch limit indicator, which indicates the maximum angle to which the nose can be raised, on PFD and issuing a aural warning “Pitch, Pitch,” if the pitch angle exceeds a certain level.

3 ANALYSIS

3.1 Qualifications of Personnel

The captain and the first officer held both valid airman competence certificates and valid aviation medical certificates.

3.2 Aircraft Airworthiness Certificates

The Aircraft had valid airworthiness certificates and had been maintained and inspected as prescribed.

3.3 Relations to Meteorological Condition

As described in 2.5, visibility at Sendai Airport during the time period related to the accident was good with almost no cloud seen at a low altitude. According to the records from the anemometers placed at the airport, no major fluctuation in wind direction and wind velocity was observed at two locations: on the Runway 27 threshold, which the Aircraft approached, and at the vicinity of center of the Runway 27.

As described in 2.1.2 (1), on the other hand, it is possible, given that the captain felt that the Aircraft was lifted up slightly near the vicinity of the Runway 27 threshold, that there were some fluctuation in wind direction and wind velocity around the area.

Based on these facts, it is highly probable that the meteorological condition at that time were not so serious that they affected the landing of the Aircraft, and that they had no direct effect on the accident.

3.4 Situation Leading up to Go-around

3.4.1 Descent and Approach to Sendai Airport

As described in 2.1.2 (1), the captain was in the left seat and in charge of flying as the PF. According to the DFDR records, the first officer did not operate the sidestick for the right seat from the Aircraft's decent and approach to Sendai Airport through after its go-around.

The Aircraft obtained a landing clearance from the Tower past 09:00 and continued to descend to the final approach course for Runway 27 through visual approach.

(1) Approach angle

As described in 2.1.1, nearly at an altitude of 500 ft on the final approach course, the captain called, "Stabilized," confirming that the approach was stable. The Aircraft generally continued a stable approach, but as shown by the estimated final approach angle in Figure B, the Aircraft temporarily experienced a low approach angle at about 400 ft RA to 200 ft RA. It is highly probable that as described in 2.1.2 (2), all four PAPI lights temporarily turned red when the Aircraft was at such an altitude.

Later, A/T was disengaged at about 200 ft RA, and the Aircraft headed for Runway 27 while returning to the standard approach angle.

(2) Descent rate

As described in 2.1.1, judging from the time interval between the "One hundred" Auto Callout and the "Fifty" Auto Callout about four seconds later, and the radio altitudes at which these callouts were triggered, it is highly probable that the descent rate for the Aircraft at these altitudes was about 740 ft/min, almost the same as that for the standard approach angle of three degrees (742 ft/min for the ground speed of 140 kt and 715 ft/min for the ground speed of 135 kt).

(3) Approach speed

As described in 2.1.1, at 09:03:02, the movement of THSs stopped, and the Aircraft passed above Runway 27 threshold at about 50 ft RA. The speed of the Aircraft from the time when A/T was disengaged at about 200 ft RA to the time when the Aircraft passed above Runway 27 threshold at about 50 ft RA ranged from 134 kt to 144 kt.

As described in 2.1.2 (1), the captain used the managed speed as a target approach speed. As described in 2.5, since the ground wind velocity at Sendai Airport was weak, at about 2 kt, it is probable that the head wind component on the approach course was less than 10 kt, and according to the description in 2.9.8 (2), it is highly probable that $V_{APP\ TARGET}$ was equal to V_{APP} with the former not revised by winds.

According to the QAR records mentioned in 2.8, V_{LS} during the final approach was 130.25 kt, and it is highly probable; therefore, that V_{APP} (that is, $V_{APP\ TARGET}$) was about 135 kt (V_{LS} + 5 kt). Based on this, it is highly probable that the Aircraft approached at a speed of 134 kt to 144 kt (median value: 139 kt), slightly higher than the target speed indicated by the managed speed.

3.4.2 Touchdown

(1) Timing for the flare and thrust idling

As described in 2.1.1, after the Aircraft passed the Runway 27 threshold, a series of Auto Callouts were triggered, saying, "Fifty," "Thirty," and "Twenty" in the stated order, followed by the "Retard" callout three times.

As indicated in Figure C, at around the time when the radio altitude became 50 ft or less, the sidestick started to be slightly pulled, and the pitch angle began to rise when the Aircraft descended to 30 ft RA. At around that time, it is highly probable that the captain commenced to flare the Aircraft.

According to FCOM, as described in 2.9.5 (2), it is appropriate to commence the flare at an altitude of about 30 ft, and according to the training manual mentioned in 2.9.7 and AOR mentioned in 2.9.8 (1), it is appropriate to do so at an altitude of around 20 ft. It is highly probable that the flare at the time of the accident was largely permissible operation though it began slightly earlier.

About four seconds after the flare commenced, the thrust levers were returned to the IDLE position immediately after the first "Retard" Auto Callout. According to AOR, as described in 2.9.8 (1), the thrust should start to reduce gradually at an altitude of about 20 ft. The thrust levers were returned to that position at 20 ft RA or less, but it is highly probable that the choice of this timing was largely permissible. At that time, the airspeed was 138 kt.

(2) Altitude just before touchdown

As described in 2.1.1, after the Auto Callout at 20 ft RA, the "Retard" Auto Callout was triggered three times. The Auto Callout for 10 ft was not issued because it overlapped the "Retard" Auto Callout. By the time the Aircraft's right main landing gear first touched the ground, more than about seven seconds had passed since the Auto Callout at an altitude of 20 ft, and more than about four seconds had passed since the last "Retard" Auto Callout. During this interval, no Auto Callout was repeated.

Therefore, judging from the description in 2.9.4 (6), it is highly probable that the Aircraft slightly deferred its touchdown while flying at an altitude of less than 10 ft above the runway.

(3) Condition of the Aircraft at touchdown

According to Figure C, the pitch angle remained stable, at about five degrees, after the flare commenced, but grew to up to 6.3 degrees just before the Aircraft touched the ground. This was due to the operation of the sidestick in preparation for touchdown, and it is highly probable that it was close to the standard pitch angle used at touchdown, which is about 6.5 degrees as described in 2.9.8 (1).

According to the DFDR records, it is highly probable that the Aircraft's right main landing gear first touched the ground nearly 700 m (near Taxiway B5) from the Runway 27 threshold, and then the left one touched the ground.

As described in 2.8, a comparison of changes in vertical acceleration for 15 touchdowns, retained in DFDR, confirmed that the impact of touchdown at the time of the accident was minor, and that as described in 2.1.1, the clear sound of the main landing gears touching the ground and running on the runway, that of vibrations from the airframe, and other sorts of noise were not confirmed in the CVR records. And judging from the statements in 2.1.2, it is highly probable that neither the captain nor the first officer noticed the main landing gears touch the ground.

According to the CVR records, immediately after the main landing gears touched the ground, the captain said, "Oh, no good." It is highly probable that this meant that the main landing gears had not touched the ground. It is probable that this supports the assumption that at that time, the captain was not aware that the main landing gears had touched the ground.

(4) Followability of the elevators, the effects of THSs and the flare law

As indicated in Figure C, since the operation of the sidestick to control the pitch axis was well linked to the movement of the elevators, it is highly probable that there was no problem with the pitch axis control system. Since the operation of THSs was suspended from the time when the Aircraft passed about 50 ft RA to the time when they were set to the TO/GA positions, meanwhile, changes in the positions of THSs did not have impact on the control of the Aircraft when the Aircraft was flared or its main landing gears touched the ground.

As described in 2.9.4 (3), if its radio altitude becomes 30 ft or less, the Aircraft is controlled by lowering its nose in flare mode for eight seconds. When the accident occurred, it is highly probable, as shown in Figure C, that the radio altitude became 30 ft past 09:03:05, and that the nose was lowered by changing the pitch angle, which was about 3.2 degrees at an altitude of 50 ft, at a rate of about 0.65 degrees per second until around 09:03:13, eight seconds later. Just when this control was completed, the right main landing gear touched the ground, followed by the left one. During this interval, the captain prevented the nose from falling by largely operating the sidestick so that the nose was raised; therefore, it is highly probable that the flare mode law did not affect the occurrence of the accident.

3.4.3 Landing Run

(1) Confirmation of the spoiler actuation by PM

As described in 2.9.4 (3), the touchdown of both main landing gears automatically prompted the deployment of all spoilers, and as shown in Figure C, all of the ten spoilers on right and left wings were deployed completely in about two seconds.

As described in 2.9.2, ECAM Wheel Page indicates the spoiler actuation. As described in 2.9.4 (1), PM is supposed to confirm this indication after touchdown and call "No spoilers" in case of incomplete spoiler deployment.

This indication is not necessarily intended to confirm the touchdown of main landing gears, but given that the spoilers do not deploy completely without grounded both main landing gears, it is probable that this indication can be used to confirm the touchdown of the Aircraft.

Since the touchdown of both main landing gears automatically prompted the deployment of spoilers, it is highly probable that the deployment of spoilers was indicated on the ECAM Wheel Page as described in 2.9.2 and 2.9.4 (5). However, as described in 3.4.2 (3), neither the first officer nor the captain noticed the touchdown of the main landing gears assuming that they were still floating. It is highly probable that the first officer, as the PM, was not ready to confirm the post-touchdown spoiler deployment and did not shift his attention to the ECAM Wheel Page as described in 2.1.2 (2).

(2) Autobrake activation and indication

Subsequently, as described in 2.1.2 (1) and 2.9.4 (4), the autobrakes, set to the MED position (deceleration rate: medium), started to activation. As the brake pressure for the main wheels rose, the longitudinal acceleration registered –0.23 G (A negative value indicates deceleration), indicating the increased deceleration rate.

Based on this fact, as described in 2.9.4 (4), it is possible that the DECEL light illuminated on the AUTO BRK panel as shown in Figure A. Although this indication is meant to show the deceleration rate and is not necessarily intended to confirm the touchdown of the main landing gears, it is probable that this indication can be used to know the touchdown of the aircraft.

As described above (1), it is probable that the PM was not ready to confirm the post-touchdown spoiler deployment and did not shift his attention to the DECEL light, as the confirmation of the light was not required in AOM.

(3) Possibility that the cockpit crew recognized the touchdown of the Aircraft

As described in 2.1.1, the CVR records indicated that from about the time when the brake pressure rose, what sounded like the noise of the main landing gears running on the runway and vibrations of the airframe gradually became large. In addition, after both main landing gears touched the ground, the vertical acceleration changed cyclically, fluctuating between 0.91 G and 1.15 G, and it is highly probable that this was because the airframe moved up and down as its load fluctuated after it touched the ground. If these records and the rise in deceleration rate mentioned in (1) of this section are taken into consideration, it is possible that the captain and the first officer failed to recognize the moment when the Aircraft touched the ground, but that they had a bodily sensation of it having already done so.

(4) Sidestick operation and misunderstanding of floating

As shown in Figure C, the nose of the Aircraft gradually went down as its main landing gears touched the ground; however, as described in 3.4.2 (3), it is highly probable that the captain and the first officer did not notice the touchdown of the main landing gears, assuming that the Aircraft was in the state of floating. Accordingly, it is also highly probable that in an effort to prevent the nose landing gear from touching the ground first as the nose went down, the captain tried to maintain the attitude of the Aircraft with the nose raised by pulling the sidestick.

Since the nose continued to go down despite his attempt, it is highly probable that the sidestick was made full aft input. That operation shifted the elevator angle to –27 degrees, close to the maximum deflection.

As described in 2.1.2 (1), it is highly probable that as the time passed during which he felt the floating of the Aircraft and its speed decreased gradually, the captain thought that it was undesirable to allow the floating to continue while there was little energy left in the airframe. Consequently, it is highly probable that the captain determined that it was safer to go around than to land and increasingly concentrated on deciding when to go around.

3.4.4 Go-around

(1) Reverse and go-around operations by the captain

As described in 2.9.4 (3) and (4), with the touchdown of both main landing gears, spoilers were deployed completely, the autobrakes started to activation, and the brake pressure rose. Later, as shown in Figure C, the thrust levers were advanced to the TO/GA positions at 09:03:19-21, immediately after it was set almost in the FULL REVERSE position.

As described in 2.1.2 (1), it is highly probable that this was because the captain, determining that the main landing gears had already touched the ground if the circumstances in his field of vision were taken into account, shifted the thrust lever to the REVERSE position for some time, but because he reconsidered, believing that the Aircraft was still in the air as he felt vibrations like buffeting immediately after that operation and decided to go around. According to the DFDR records, which indicated that both main landing gears had already touched the ground, it is also highly probable that what the captain felt was buffeting was in fact vibrations from ground run.

As shown in Figure C, when the captain advanced the thrust lever to the TO/GA position, the nose of the Aircraft had gone down to a pitch angle of about 1.8 degrees, and with the sidestick was made full aft input, the elevator angle had deflected to –27 degrees, close to the maximum elevator angle of –30 degrees, so that the nose was raised. With the TO/GA operation, the autobrakes was released, suddenly releasing the brake pressure, and at the same time, spoilers started to be retracted. In addition, THSs began to move from –2.1 degrees to a positive angle (to reduce the effects of raising the nose).

(2) Occurrence of a tailstrike

As shown in Figure C, at around 09:03:20-22, as the pitch angle started to increase, the captain returned the sidestick to lower the nose of the Aircraft, but the nose rose to up to +12.7 degrees.

At that time, the pitch angle of the Aircraft sharply increased from +1.8 degrees to +12.7 degrees in 2.25 seconds. This means that the nose was raised at an average rate of about 4.4 degrees per second (momentarily up to about 8.4 degrees per second), sharper than the rate of about three degrees per second recommended at takeoff as described in FOBN in 2.9.6 (2) and AOR in 2.9.8. (meaning that the nose was raised very sharply). Based on the statements of the cockpit crew included in 2.1.2, however, it is highly probable that neither the captain nor the first officer recognized during the go-around operation that the nose of the Aircraft went up substantially.

As shown in Figure C, at around 09:03:22, the vertical acceleration fluctuated significantly during an extremely short period of time, the pitch angle increased to 12.7 degrees, the maximum for approach, and as described in 2.4.3, the angle at which the lower part of the rear fuselage touches the runway is 11.7 degrees to 13.5 degrees. Given these, it is highly probable that at that time, a tailstrike occurred to the Aircraft.

As indicated by the statements included in 2.1.2 (1) and (2), the captain felt in the course of go-around operation that the right main landing gear had touched the ground and the first officer felt that the main landing gears had touched the ground in a hard way. It is highly probable that the reason why both the captain and first officer felt so was that they mistook the impact of a tailstrike for the touchdown of the main landing gears.

(3) Effects of reverse operation and so on

According to the QAR records mentioned in 2.8, when the captain shifted the thrust levers to the REVERSE positions, the reverser doors were unlocked (DFDR did not record the unlocking of the doors), but neither DFDR nor QAR recorded the opening of the reverser doors.

It is highly probable that this was because the thrust levers were advanced to the TO/GA positions before the reverse doors started to be opened, preventing the thrust reversers from functioning. In other words, it is highly probable that this temporary reverses operation did not generate reverse thrust, and that therefore, this operation had no direct effect on the accident.

Although this did not apply to this accident in hindsight, a go-around after the deployed thrust reversers should be avoided as stated in AOM in 2.9.4 (1), because it can lead to unsafe conditions due to unequal retraction of reverser, delayed engine revving, and other unfavorable reasons.

(4) Issuance of master warnings

As described in 2.1.1, at around 09:01:41, the flaps were fully extended for landing. Since the thrust levers were advanced to the TO/GA positions to attempt a go-around from the runway, it is highly probable that that operation satisfied the conditions for issuing a takeoff configuration warning (adding TO/GA thrust on the runway with all flaps extended), causing such a warning to be issued.

It is highly probable that the aural warning at the time of go-around mentioned in 2.1.1 and 2.1.2 (2) was a master warning issued because a takeoff configuration warning was generated.

3.4.5 Pitching Moment at the Time of Go-around

As described in 3.4.4 (1), as the sidestick was made full aft input, the thrust levers were advanced to the TO/GA positions, and this operation released the brake pressure for the main wheels and started to retract the spoilers, which had been deployed completely. THSs also started to function.

At that time, the pitching moment described in 2.9.1 (2) exhibited as follows:

(1) Elevators

As described in 3.4.3 (4), since the sidestick was left full aft input, the elevator angle was deflected substantially, to –27 degrees, close to the maximum elevator angle of –30 degrees, so that the nose of the Aircraft was raised. After the TO/GA operation, the elevators started to return to their original position gradually, but a major moment to raise the nose was generated because the shift in angle was large.

(2) THSs

As shown in Figure C, after the Aircraft passed the Runway 27 threshold at an altitude of about 50 ft, THSs stopped working for about 17 seconds while being kept at an angle of –2.11 degrees (A negative value indicates that the nose of the Aircraft is raised).

After the TO/GA operation, THSs were shifted by +0.26 degrees in the direction that reduced the effects of the nose being raised, to –1.85 degrees, but a pitch-up moment was still being generated.

(3) Brakes for the main wheels

As described in 3.4.4 (1), the TO/GA operation released the previously applied brake pressure for the main wheels, and the pitch down moment generated by brake pressure application was disappeared.

(4) Spoilers

As described in 3.4.4 (1), with the onset of TO/GA operation, the ten fully deployed spoilers began to retract. The designer/manufacturer believes that the pitch-up tendency with ground spoiler extended is minimized by the flight control law—temporary phenomenon, and the ground spoiler retraction gave less effect on pitching moment.

(5) Thrust reversers

As described in 3.4.4 (3), since the thrust reversers did not work with the reverser doors only unlocked, the pitching moment was not affected.

(6) Engine thrust

As shown in Figure C, since it took several seconds before the engine thrust increased following the TO/GA operation, the pitching moment was not affected when the nose of the Aircraft was raised sharply.

It is highly probable that all these events described above in (1) to (6) comprehensively mean the following; Up until the moment before the TO/GA initiation after the touchdown of the main gears, gradual nose-down deflection indicates almost balanced pitching moment with general tendency of nose-down. The TO/GA operation disrupted the balance of the pitching moments, consequently leading to an abrupt nose-up attitude mainly caused by a large deflection of the elevator as shown in (1).

3.5 Recognition of the Tailstrike

3.5.1 Condition of the Aircraft after the Go-around

According to the DFDR records, after it raised its flaps by one level from the FULL DOWN position and retracted the main landing gears, the Aircraft entered the left downwind leg at an altitude of about 1,000 ft. Later, after the chief purser made an announcement to the passengers, a rear flight attendant informed the chief purser that there was a possibility of a tailstrike because an unusual sound had been heard at the back of the Aircraft, and the chief purser conveyed the information to the cockpit crew. Therefore, the captain performed a go-around again and requested the Tower to inspect the runway for caution's sake. The Aircraft climbed to an altitude of 1,500 ft and held near the south downwind leg.

In general, when a tailstrike occurs, the cockpit crew does not necessarily recognize it, and climbing to a high altitude without noticing it may entail danger. Therefore, if any of the flight attendants notices an unusual sound or other irregularities at the back of the Aircraft, it is important for him or her to report it to the cockpit crew early.

3.5.2 Awareness of the Cockpit Crew

According to the CVR records and the statements included in 2.1.2, the captain and the first officer thought that they had heard a sound and experienced an impact because the main landing gears touched the runway when the Aircraft proceeded from the state of floating to a go-around. It is highly probable that until they received a report from the chief purser, they were not aware that the lower part of the rear fuselage had touched the runway.

It is highly probable that following the report from the chief purser, the captain and the first officer, aware of the possibility that the lower part of the rear fuselage touched the runway, requested the Tower to check the runway for caution's sake taking into consideration the possibility of damaged fragments and other objects being left on the runway.

When the Aircraft was waiting in the left downwind leg, the Tower informed the captain and the first officer that there were white traces of scratch on the runway, and it is highly probable that they determined that the lower part of the rear fuselage might have touched the ground.

3.5.3 Tailstrike Checklist

As described in 2.9.4 (7), AOM for the Aircraft provides a checklist that should be used when a tailstrike takes place, but according to the CVR records, this checklist was not used after the accident occurred.

As described in 2.9.4 (7), the checklist requires the cockpit crew to land the Aircraft as soon as possible and avoid pressurization. Since the Aircraft climbed only to an altitude of about 1,500 ft after the occurrence of the accident, it is highly probable that failure to use the checklist did not have any effect on the airframe.

3.6 Decision to Go Around

The procedures for go-around described in 2.9.4 (1) state that "*If an aircraft continues to approach and land, and if there is concern about the subsequent safety of the aircraft, the cockpit crew must perform a go-around without hesitation*."

As described in 3.4.3 (4), the captain presumed that the floating was continuing without the main landing gears touching the ground, but even if the main landing gears had touched the ground, there would not have been a problem with shifting from the floating to a go-around. As described in 3.4.4 (1), since they felt that the vibration of the airframe was due to buffeting, it is highly probable that the cockpit crew believed that it was safer to go around. In general, delay in decision to go around presents a greater risk to safe operation.

The procedures for landing described in 2.9.4 (1) state, on the other hand, that "A go-around must not be attempted after the reverse thrust is used." This is prohibited because performing a go-around is risky after the speed of the Aircraft is reduced substantially due to the functioning of the thrust reversers. It is highly probable that the reason the captain performed the full reverse operation though temporarily but did the TO/GA operation was that he recognized that the thrust reversers had not yet brought about substantial effects in reducing the speed of the Aircraft, and that at that time, he decided to go around following the basic principle of "*if there is concern about the subsequent safety of the aircraft, the cockpit crew must perform a go-around without hesitation*."

In fact, as mentioned earlier, it was not necessary to go around because both main landing gears had touched the ground, and the Aircraft could have landed if it had proceeded as planned. Since both the captain and the first officer failed to recognize the touchdown of the Aircraft, however, it is highly probable that the captain's decision to go around was inevitable.

3.7 Effectiveness in This Case of Measures Taken by the Designer and the Manufacturer to Prevent Tailstrikes

As described in 2.9.9, the designer and the manufacturer have taken two measures to prevent tailstrikes: the improvement of the flight control program, which is effective at landing, and the provision of the function of issuing warning display and warning sound, which is effective at both takeoff and landing.

These measures are generally effective, but are not necessarily effective for the behavior of an aircraft, which, unlike ordinary takeoff or landing operations, involves a go-around performed after post-touchdown deceleration as in this case, causing a rapid, significant change in the pitching moment, for the following reasons:

(1) As described in 2.9.9 (1), if the thrust levers are set to the TO/GA positions, the spoilers are retracted, preventing the function of limiting the pitch-up rate from working.

(2) In this case, when the thrust levers were set to the TO/GA positions, the Aircraft already shifted from the flare law to the ground law. As described in 2.9.9 (1), the function of limiting the pitch-up rate did not work.

(3) In case of a rapid nose-up, it would be difficult for the cockpit crew to take countermeasures even with the help of the pitch limit indicator and the aural warning which were described in 2.9.9 (2).

4 CONCLUSION

4.1 Findings

(1) It is highly probable that near the Runway 27 threshold, the Aircraft was flying at a standard rate of descent and at a slightly faster approach speed. (3.4.1)

(2) It is highly probable that the timing for the captain to commence the flare and shift the thrust levers to the IDLE position was largely permissible. As the Aircraft flew at an altitude of less than ten feet above the runway, its touchdown was slightly deferred, and it is highly probable that it touched the ground about 700 meters from the Runway 27 threshold at a standard pitch angle. It is highly probable that, at that time, the impact of touchdown was minor, and that the captain and the first officer did not notice the touchdown of the main landing gears.

It is also highly probable that changes in the position of THSs did not have impact on the control of the Aircraft, nor did the flare law affect the occurrence of the accident. (3.4.2)

(3) Judging from the circumstances immediately after touchdown and other factors, it is possible that the captain and the first officer had a bodily sensation that the Aircraft had already touched the ground.

Since the first officer did not reach the stage at which he confirmed the deployment of spoilers after touchdown, it is highly probable that he had not yet turned his eyes to the ECAM Wheel Page.

The captain, presuming that the Aircraft was in the state of floating, maintained the attitude of the Aircraft with the nose raised in an effort to avoid the nose landing gear touching the ground first. It is highly probable that he determined that it was safer to go around because it was not desirable to continue the floating with little energy left in the airframe and increasingly concentrated on deciding when to go around. (3.4.3)

(4) The captain, determining that the main landing gears had already touched the ground if

the circumstances in his field of vision were taken into account, performed the reverse operation, but immediately after the operation, it is highly probable that he reconsidered, believing that the Aircraft was still in the air, and decided to go around because he mistook vibrations from ground run for those from buffeting.

It is also highly probable that when the captain performed the go-around operation, balanced pitching moment was disrupted, a major deflection of the elevator angle mainly affected the attitude of the Aircraft, raising its nose sharply, and that this caused a tailstrike. (3.4.4, 3.4.5)

(5) The captain and the first officer were not aware that the lower part of the rear fuselage had touched the runway, but it is highly probable that they considered the possibility of having touched the runway from the report of a flight attendant and requested the runway inspection, and that following the report of the Tower on traces of scratch on the runway, they determined that the lower part of the rear fuselage might have touched the ground. (3.5)

(6) Since neither the captain nor the first officer recognized the sure touchdown of the Aircraft, it is highly probable that the captain decided to make a go-around because he thought that he did not have substantial deceleration after shifting the thrust levers into the reverse position. (3.6)

4.2 Probable Causes

In this accident, it is highly probable that when the Aircraft rejected the landing after touching Runway 27, its nose was raised sharply, causing the lower part of the rear fuselage to contact with the runway and be damaged.

It is highly probable that the substantial pitch-up moment caused the quick Aircraft nose-up with the following reasons: The captain decided to reject the landing under the circumstance where he could not recognize the touchdown of main landing gears due to the soft landing; Balanced pitching moment was disrupted by the captain's nose-up elevator input as his go-around was initiated from the full-aft sidestick position.

5 SAFETY ACTIONS

5.1 Safety Actions Taken

All Nippon Airways Co., Ltd. (ANA), which merged with Air Nippon Co., Ltd. on April 1, 2012, has taken the safety actions listed below to prevent the occurrence of similar events.

(1) Measures to ensure clear recognition of touchdown

In order to ensure that after touchdown, the PM informs the PF without fail that spoilers have been deployed, ANA issued an AOM Bulletin to include the "Spoilers" callout in "Landing Roll Procedure" for AOM normal procedures on June 28, 2012.

(2) Measures related to points to note when recognizing the state of floating

ANA decided to add to the "Avoiding Tail Contact" section of the current AOR the factors that caused the accident, the necessity of monitoring instruments when the PM recognizes the state of floating, and points to note, and prior to the publication of AOR, it issued INFORMATION on June 15, 2012. This INFORMATION will be included in AOR in the future.

(3) Measures related to go-around training in periodic training

ANA decided to include a go-around from a low altitude, which causes or may cause the Aircraft to touch the ground, in its training program, on July 1, 2012, it started to provide training in going around from touchdown as part of its periodic training program for all Aircraft models.

(4) Measures to prevent the recurrence of similar accidents by presenting case study

ANA took up this accident in its company magazine issued on September 20, 2012 to prevent the recurrence of similar accidents by providing all the cockpit crew with details of the accident and to ensure that they can also prevent tailstrikes caused for reasons other than the one that caused the recent one.

5.2 Safety Actions Required

5.2.1 System that Enables Recognition of Touchdown

In this accident, at landing, the cockpit crew did not notice the touchdown of the main landing gears, and then rejected the landing, presuming that the floating was continuing, but in this process, a sudden change in the pitching of the Aircraft caused its airframe to be damaged. If the cockpit crew had recognized without fail that the main landing gears had touched the ground, the accident would not have occurred.

Usually, if the main landing gears touch the ground, the cockpit crew feels some impact and recognizes the touchdown mainly through vibrations and sounds from ground run. The cockpit crew is reminded to avoid an excessively smooth landing, but it is probable that they achieve unintended extremely smooth landing though it is rare..

Some improvements can be expected through operational methods such as call out for proper spoiler deployment, but at the same time, establishment of a reliable system that enables aircraft to recognize their touchdown would bring even greater effects on preventing the recurrence of similar accidents. This system will also help cockpit crew respond to a severe bouncing which may lead to a major accident, and their go-around decision.

Therefore, it is desirable that the designer/manufacturer of aircraft should consider developing, introducing, and spreading a reliable system that enables the PF to recognize the touchdown of the main landing gears.

5.2.2 Reminders for and Training in Go-around

It is not assumed that as in this case, aircraft go around after its main landing gears touch the ground, spoilers are deployed, and the automatic brakes start to activation, and the Company did not provide cockpit crew with training or otherwise that guided them to meet such an unusual situation. There are few opportunities of going around in such a situation, but if it becomes necessary to go around in a similar situation for an unavoidable reason, it is essential to pay closest attention to how to control and operate the aircraft because the behavior of the aircraft along the pitching axis sometimes undergoes sudden, significant changes as in this accident.

Cockpit crew might not necessarily be able to cope with major changes in the behavior of the aircraft that arise instantaneously even if the tail strike prevention measures currently offered by the designer and the manufacturer are taken.

Based on these facts, it is desirable that operators of same type of aircraft should fully remind their cockpit crew in advance how to control and operate such aircraft when going around in a similar situation and train them accordingly.

Figure 1: Estimated Flight Route

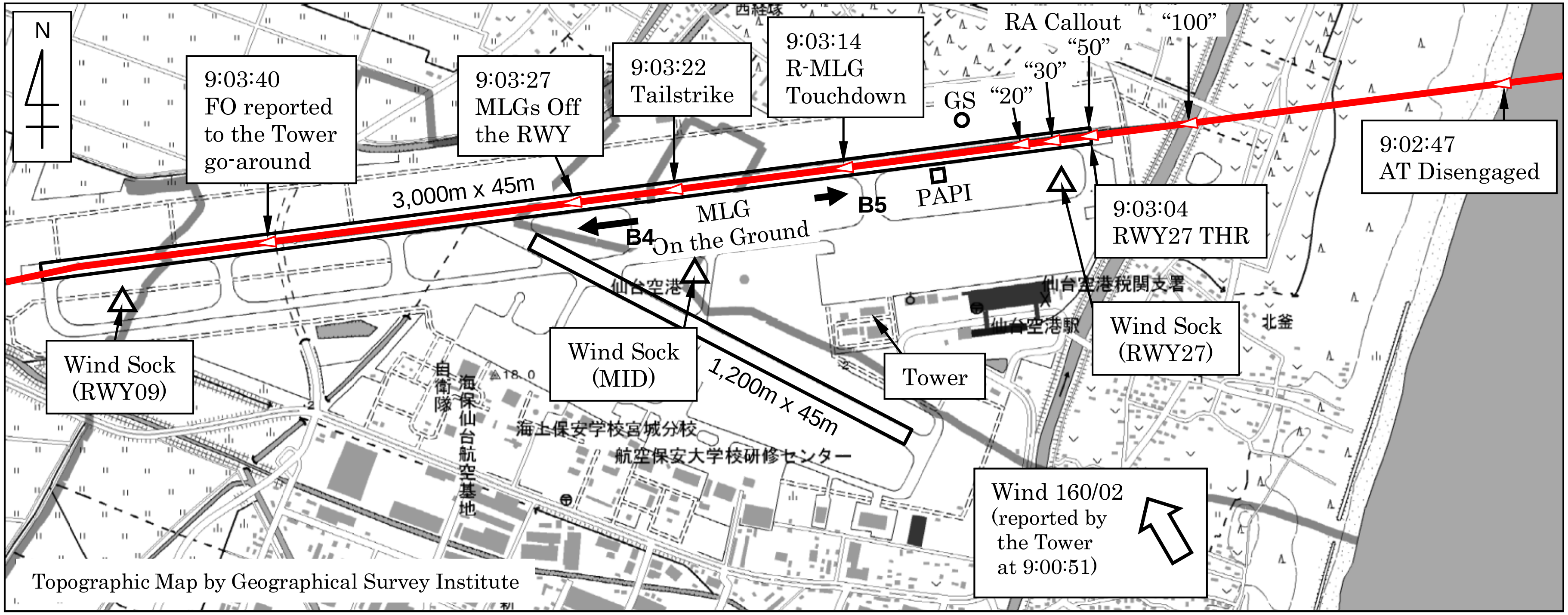


Figure 2：Three angle view of Airbus A320-200

Unit：m

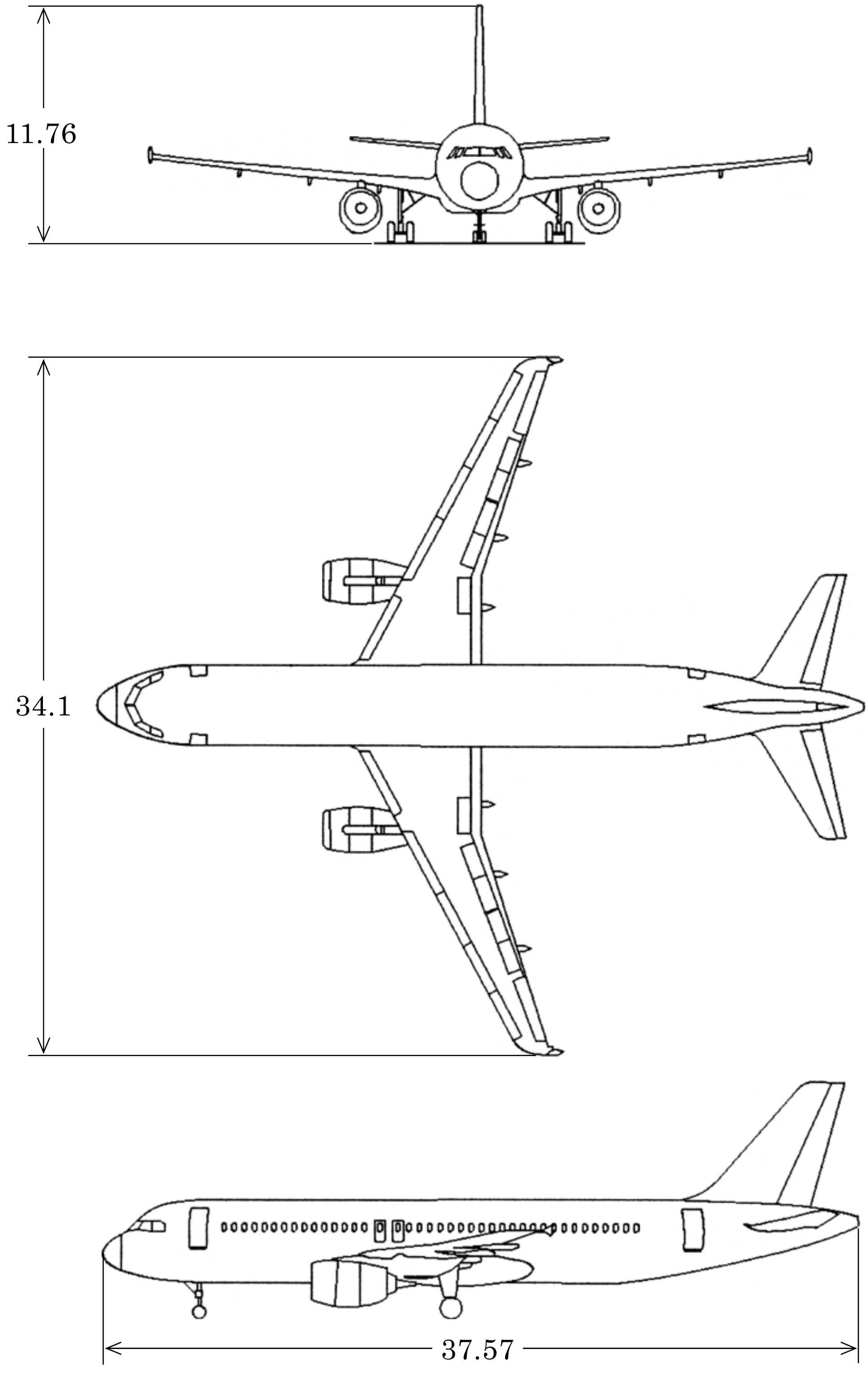


Figure 3: Condition of Touchdown based on DFDR/CVR