AI2014-4

AIRCRAFT SERIOUS INCIDENT INVESTIGATION REPORT

ALL NIPPON AIRWAYS CO., LTD.
J A 5 7 A N

September 25, 2014

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 prevent future accidents and incidents. 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 SERIOUS INCIDENT INVESTIGATION REPORT

OVERRUN
ALL NIPPON AIRWAYS CO., LTD.
BOEING 737-800, JA57AN
EAST END OF THE RUNWAY AT SHONAI AIRPORT, JAPAN
AT ABOUT 22:26 JST, DECEMBER 8, 2012

August 22, 2014
Adopted by the Japan Transport Safety Board

Chairman: Norihiro Goto
Member: Shinsuke Endoh
Member: Toshiyuki Ishikawa
Member: Sadao Tamura
Member: Yuki Shuto
Member: Keiji Tanaka

SYNOPSIS

<Summary of the Serious Incident>

On December 8 (Saturday), 2012, a Boeing 737-800, registered JA57AN, operated by All Nippon Airways Co., Ltd. took off from Tokyo International Airport as a scheduled Flight 899 of the above-mentioned company, and landed at Shonai Airport at around 22:26 Japan Standard Time. The landing ended up a runway overrun and it came to a halt in a grass area.

There were a total of 167 people on board, consisting of a PIC, five crew members, and 161 passengers. No one was injured, nor was there any damage to the aircraft.

<Probable Causes>

In the serious incident, it is highly probable that the overrun occurred as the Aircraft failed to exert the expected braking force under the informed runway conditions after the landing.

It is probable that the changed runway conditions due to snowfall and other elements near freezing temperature after the snow/ice measurement negatively affected the expected braking force.

The abbreviations used in this report are as follows:

AACU:	Antiskid/Autobrake Control Unit
AC:	Advisory Circular
AFTN:	Aeronautical Fixed Telecommunication Network
AOM:	Airplane Operations Manual
ARC:	Aviation Rule Making Committee
ATC:	Air Traffic Control
CAS:	Computed Air Speed
CMM:	Component Maintenance Manual
CMV:	Converted Meteorological Visibility
CVR:	Cockpit Voice Recorder
DFDR	Digital Flight Recorder
EPROM:	Electrical Programmable Read Only Memory
ETA:	Estimated Time of Arrival
FAA:	Federal Aviation Administration
FL:	Flight Level
FMC:	Flight Management Computer
GS:	Ground Speed
ICAO:	International Civil Aviation Organization
LSPS:	Low Speed Performance Software
MAC:	Mean Aerodynamic Chord
NOTAM:	Notice to Airmen
NTSB:	National Transportation Safety Board
NVM:	Non Volatile Memory
PAPI:	Precision Approach Path Indicator
QAR:	Quick Access Recorder
QRH:	Quick Reference Handbook
RTO:	Rejected Take-Off
RVR:	Runway Visual Range
SNOWTAM:	Snow NOTAM
TALPA:	Take-off and Landing Performance Assessment
VOR:	VHF Omni-directional radio Range

Unit Conversion List

1 nm:	1,852 m
1 atmosphere:	29.92 in Hg: 1,013 hPa
1 psi:	0.06895 bar
1 ft:	0.3048 m
1 kt:	1.852 km/h (0.5144 m/s)
1 in:	2.54 cm

CONTENTS

1 PROCESS AND PROGRESS OF THE AIRCRAFT SERIOUS INCIDENT INVESTIGATION

1.1 Summary of the Serious Incident

On December 8 (Saturday), 2012, a Boeing 737-800, registered JA57AN, operated by All Nippon Airways Co., Ltd., took off from Tokyo International Airport as a scheduled Flight 899 of the above-mentioned company, and landed at Shonai Airport at around 22:26 Japan Standard Time (JST: UTC+9 hours, all times are indicated in JST on a 24-hour clock). The landing ended up a runway overrun and it came to a halt in a grass area.

There were a total of 167 people on board, consisting of a PIC, five crew members, and 161 passengers. No one was injured, nor was there any damage to the aircraft.

1.2 Outline of the Serious Incident Investigation

The occurrence covered by this report falls under the category of "Overrun (limited to when an aircraft is disabled to perform taxiing)" as stipulated in Clause 3, Article 166-4 of the Ordinance for Enforcement of the Civil Aeronautics Act of Japan, and is classified as a serious incident.

1.2.1 Investigation Organization

On December 9, 2012, the Japan Transport Safety Board designated an investigator-in-charge and two other investigators to investigate this serious incident.

1.2.2 Representatives of the Relevant State

An accredited representative of the United States of America, as the State of design and manufacture of the serious incident aircraft participated in the investigation.

1.2.3 Implementation of the Investigation

December 9 and 10, 2012: Interviews, aircraft examination, and on-site investigation
December 13: Interviews

1.2.4 Comments from the Parties Relevant to the Cause of the Serious Incident

Comments were invited from the parties relevant to the cause of the serious incident.

1.2.5 Comments from the Relevant State

Comments on the draft report were invited from the relevant State.

2 FACTUAL INFORMATION

2.1 History of the Flight

On, December 8 (Saturday), 2012, a Boeing 737-800, registered JA57AN (hereinafter referred to as "the Aircraft"), operated by All Nippon Airways Co., Ltd. (hereinafter referred to as "the Company"), took off from Tokyo International Airport for Shonai Airport (hereinafter referred to as "the Airport") as a Company's scheduled Flight 899 at around 20:56.

The outline of the flight plan was as follows:

Flight rules: Instrument flight rules

Departure aerodrome: Tokyo International Airport

Estimated off-block time: 20:15

Cruising speed: 437 kt

Cruising altitude: FL 270*1

Route: PLUTO (waypoint) — SYE (Sekiyado VOR/DME) — Y11 (via RNAV) — JD (Nikko NDB) — Y115 (via RNAV) — USUBA (waypoint) — YSE (Shonai VOR/DME)

Destination aerodrome: The Airport

Alternate airport: Tokyo International Airport

Total estimated elapsed time: 45 minutes

Fuel load expressed in endurance: 3 hours and 47 minutes

In the cockpit of the Aircraft, the Pilot In Command (PIC) was in the left seat as the PF (Pilot Flying: pilot mainly in charge of flying) and the First Officer (FO) sat in the right seat as the PM (Pilot Monitoring: pilot mainly in charge of duties other than flying).

The history of the flight up to the time of this serious incident is summarized below, based on the air traffic control (ATC) communications records, the records of the digital flight data recorder (DFDR), and the records of the cockpit voice recorder (CVR), as well as the statements of the crew members and the air traffic services flight information officer (hereinafter referred to as "the Information Officer"):

2.1.1 History of the flight Based on the ATC communications records, and the records of the DFDR and the CVR

2.1.1.1 Approach and Landing

21:19:11: The Company's Shonai Airport Office (hereinafter referred to as the "Shonai Office") reported to the Aircraft of the following information: weak radar echoes observed over the area around Shonai are moving northeast; the said echoes covers broad area, and therefore will probably in the area until landing; fine snow is falling, but snow cover is unlikely; the snow/ice conditions are being measured, and the results will be available sometime between 21:25 and 21:30.

21:28:11: The Aircraft, descending toward the Airport, started radio communications with the information officer at the Air Assistance Station of Shonai Aerodrome (hereinafter referred to as "the Radio") approx. 18 nm south of Shonai VOR (hereinafter referred to as "the VOR") at an altitude of approximately 9,500 ft.

*1 "FL" is a flight altitude that is used high altitude. A 3-digit number following "FL" signifies an altitude in hundreds of feet. This is a barometric altitude obtained in such a way that the reference value of a barometric altimeter is set to the atmospheric pressure (1,013.2 hPa) of the International Standard Atmosphere at the mean sea level. Generally, this barometric altitude is not equal with the true altitude. In Japan, "FL" is used for flight altitudes of 14,000 ft or more above mean sea level. FL 270 means a flight altitude of 27,000 ft above mean sea level.

21:28:17: The Aircraft reported it to the Radio that approach clearance had been received, that it would start the localizer approach to Runway 27 after flying over the VOR, and that the VOR estimated time of arrival (ETA) would be at 21:33.

21:28:29: The Radio reported it to the Aircraft that the wind direction was 310° (bearings are expressed in the magnetic bearing) at 10 kt, and that the temperature was 1°C.

21:28:49: The Radio reported to the Aircraft of the results of the runway snow/ice condition assessment done at 21:26.

21:33:30: The Aircraft reported to the Radio of leaving high station.

21:33:34: The Radio reported it to the Aircraft that the wind 340° at 9 kt.

21:36:25: The Radio reported it to the Aircraft that the visibility at 21:24 was 4,000 m.

21:36:46: The Radio sent a one-way transmission message (communication demanding no response) to the effect that the visibility at 21:35 was 500 m.

21:37:35: The Radio inquired the Aircraft whether a go-around could be made for another measurement of snow/ice condition at the request of the Shonai Office.

21:37:41: The Aircraft accepted it, and requested clearance of holding at 3,500 ft over the VOR. The clearance was granted.

21:37:52: The Aircraft reported it to the Radio of the excuting missed approach.

21:41:27: The Aircraft requested the Radio for clearance to climb to 6,000 ft. The clearance was granted.

21:57:08: The Aircraft requested the Radio for clearance to climb to 12,000 ft.

21:58:32: The Radio reported to the Aircraft of clearance to hold at 12,000 ft over the VOR.

22:00:10: The Radio sent a one-way transmission message on the 22:00 special observation weather report.

22:01:52: The Aircraft reported to the Radio of the reaching to an altitude of 12,000 ft.

22:03:25: The Radio reported to the Aircraft as follows: On runway 09 end, the wind 020° at 3 kt, while on runway 27 end, 020° at 3 kt.

22:08:17: The Radio reported it to the Aircraft that the runway was reopened at 22:07.

22:08:43: The Aircraft requested the clearance for an ILS approach to Runway 09 from high station and to descend in the holding pattern.

22:09:42: The Radio reported it to the Aircraft of the approach clearance to the Airport.

22:12:03: The Radio reported it to the Aircraft of the 22:07 SNOWTAM (NOTAM*2 pertaining to the snow/ice conditions).

22:15:16: The Radio reported it to the Aircraft that the ground wind was a crosswind, blowing from 010° at 4 kt.

22:18:52: The Aircraft reported to the Radio leaving high station.

22:18:56: The Radio reported it to the Aircraft that the wind was blowing from 360° at 4 kt. Also the Radio instructed the Aircraft to report the completion of the

---

*2 A “NOTAM” (A Notice to Airmen) is a type of information which is necessary for the operation of aircraft, and is issued by aeronautical information organizations. “NOTAM” refers to information which pertains to the setting, conditions, changes, or the like regarding matters such as aviation-related facilities, operations, methods, and hazards, and which is distributed by the Aeronautical Fixed Telecommunication Network (AFTN).

base turn.

22:22:48: The Aircraft reported to the Radio of the base turn inbound (the latter half of the base turn).

22:22:50: The Radio reported it to the Aircraft that Runway 09 was clear, with the wind blowing from 320° at 13 kt.

22:24:09: The Radio sent a one-way transmission message regarding the 22:24 special observation weather report: a visibility of 3,000 m, and light shower of snow and snow pellets.

22:24:27: The Radio sent a one-way transmission message saying that the wind was blowing from 310° at 11 kt.

22:24:40: The flaps of the Aircraft were set to "30."

22:25:28: The Radio sent a one-way transmission message saying that the wind was blowing from 320° at 11 kt.

22:25:42: The autopilot was disengaged (the Aircraft became flying in the manual mode) when the Aircraft was at a barometric altitude (BA) of 674 ft, at an altitude of 408 ft above ground level (AGL), at a computed air speed (CAS) of 142 kt, and at a ground speed (GS) of 154 kt.

22:25:51: A "Minimum*3"automatic callout was uttered when the Aircraft was at 540 ft BA, at 298 ft AGL, at 145 kt CAS, and at 153 kt GS.

22:26:11: At 140 kt CAS, and at 147 kt GS, both main landing gear touched down in the vicinity of the centerline approx. 480 m from the approach end of Runway 09 (within the touchdown zone marking).

2.1.1.2 Landing Roll

(1) Immediately after the touchdown (between 22:26:11 and 22:26:16)

One second after the touched down of the main landing gears (at 22:26:12), the activation of the autobrakes were followed by: increment of the brake pressure; deployment of the speed brakes; movement of the reverse thrust levers (see 2.11.4) to the maximum position activating the thrust reversers (braking system utilizing the engine thrust); and the sharp increment of the engine power. The deceleration rate (negative longitudinal acceleration) increased rapidly to a maximum of 0.27 G. When it exceeded 0.22 G, the brake pressure started to drop causing the deceleration rate to drop to 0.22 G. During this interval, the CAS decreased from 140 kt to 116 kt, while the GS from 147 kt to 127 kt.

(2) Deceleration by the automatic braking (between 22:26:16 and 22:26:30)

The deceleration rate remained at a level of 0. 22 G. The brake pressure gradually rose, but its peak value was 1,000 psi or less. At 22:26:21, the PIC said, "I'll disarm the autobrakes." At 22:26:30, the brake pressure rose instantaneously to 1,000 psi or more. At the same time, the autobrakes were released. The remaining distance of the runway at this time was approx. 500 m. At 22:26:29, the FO called out, "60." The reverse thrust levers started to return from the maximum position. During this interval, the CAS decreased from 116 kt to 59 kt, while the GS from 127 kt to 70 kt.

---

*3 When the terrain clearance measured by a radio altimeter reaches a preset altitude value, the radio altimeter system sets off a "minimum" automatic voice to draw crew's attention.

(3) Deceleration by the manual braking (between 22:26:30 and 22:26:38)

Immediately after the deactivation of autobrakes, the deceleration rate began to fluctuate with increasing range even with the operating thrust reversers and speed brakes. The fluctuation range gradually decreased. At 22:26:35, the brake pressure dropped instantaneously followed by immediate increase. At 22:26:36, the reverse thrust levers moved to the "Idle" position (see 2.11.4). The brake pressure gradually rose. At 22:26:36, the FO said, "GS still 50." At 22:26:38, the brake pressure rose to the maximum pressure value (3,000 psi). At the same time, the reverse thrust levers moved to the "Down" position (see 2.11.4). The thrust reverser sleeves (thrust reverser component that changes the engine thrust direction) were retracted. The engine power dropped. At this moment the remaining runway distance was 230 m. During this interval, the CAS decreased from 59 kt to a value less than the indication limit of 45 kt or less, while the GS from 70 kt to 54 kt.

(4) Recognition of the unusual situation and the urgent actions taken (between 22:26:38 and 22:26:55)

The brake pressure remained at the maximum level at all times. At 22:26:38, the PIC repeatedly said , "This is not good." At 22:26:40, the FO said, "We're not going to make it." At 22:26:45, the maximum left rudder input changed the aircraft heading to the left by approx 5°. However, with the neutral pedal input the heading returned to original direction.

At 22:26:41, the PIC said, "Oh, No! We can't stop!" At 22:26:43, the reverse thrust levers moved from the "Down" position to the "Idle". At 22:26:45, the reverse thrust levers moved to the maximum position when the runway remaining distance was approx. 80 m. By then, the engine power had dropped to almost the idle speed. Although the engine power was increased slowly around 22:26:47, the deceleration rate began to decrease rapidly from stabilized 0.1 G between 22:26:51 and 22:26:53, with concurrent GS decrease to approx. 30 kt. With the left rudder input, the heading gradually deviated leftward.

(5) After overrunning through the overrun zone (between 22:26:55 and 22:27:08)

At 22:26:55, the Aircraft crossed the end of the overrun zone at 18 kt GS. By this time, the deceleration rate rapidly increased to 0.2 G following the sharp engine power increase. One second after crossing the end of the overrun zone (at 22:26:56), the deceleration rate instantaneously rose to the maximum level of 0.34 G, it immediately decreased and leveled off 0.2 G until the halt of the Aircraft. At 22:26:57, the thrust levers moved to the "Down" position. The thrust reversers were retracted. The engine started to wind down from almost the full power.

At 22:27:01, the Aircraft came to a halt with the heading at 0 46°. At 22:27:05, the PIC said, "Report, 'Overrun.' " At 22:27:08, the Aircraft reported it to the Radio that taxiing was unable due to the overrun.

(See Figure 1 "Estimated Flight Route" and Figure 2 "Records of the DFDR.")

2.1.2 Statements of Crew Members

(1) PIC

As a low pressure system was developing in northern Japan and it was in the vicinity of the Airport, the PIC performed preflight checks putting special consideration on snow, strong winds, and turbulent airflow. Streaky snow clouds intermittently flowed into the area of the Airport. The PIC deduced that visibility would be good some times and poor at the other times. He loaded more fuel than usual adding one-hour extra fuel. He checked the calculation of the landing performance under slippery conditions with piled snow, and approved the flight plan. In a meeting with the cabin crew he suggested that with snow fall and strong winds the Aircraft would experience turbulence during the approach to the Airport, and during peak period of strong winds, there would be a possibility of go-around. Although the scheduled takeoff and landing were at 20:15 and 21:15, the Aircraft departed a little after 20:40 due to the delayed arrival of the preceding flight to Tokyo International Airport.

On the way to the Airport the PIC confirmed that strong gusty northwest winds and wet runway surface without snow at the Airport. He made preparations for a non-precision localizer approach to Runway 27, as the Airplane would fly into winds on final.

The PIC received information from Shonai Office on the approaching snow clouds, and on present visibility and ceiling which were not deteriorated enough to deny the landing. The PIC started the localizer approach to Runway 27 from the VOR. He received the information from Shonai Office and the Radio during the base turn, to the effect that the visibility was 500 m and the cloud height measured by a ceilometer was 150 ft. He was considering aborting the approach as the tried approach under the worsened conditions would not allow landing. At this time, the Radio instructed the Aircraft to execute a missed approach, on the grounds that the Airport would measure the runway snow/ice conditions. So he aborted the approach.

The Aircraft climbed to 3,500 ft and started the holding over the VOR. But due to the turbulent air, the PIC climbed to 6,000 ft after receiving the clearance from the Radio. Due to turbulent air and worse icing conditions at the altitude, he requested clearance to climb to 12,000 ft for holding. The holding was done almost on-top conditions with temporally in-cloud conditions. As the bumpiness subsided to the acceptable level for cabin walking so that he turned off the fasten-seatbelt sign.

During the holding, the PIC received information on weakened surface winds and changed wind direction to the northeast. Based on the information he made preparations for an ILS approach to Runway 09. Upon hearing the reopened runway he started the descent making preparations for landing. The seatbelt sign was switched on. He received the SNOWTAM during descent, in which the item “braking action,” an index for the slipperiness of the runway, was “Good” (see 2.6.5 (2)). He confirmed the allowable tailwind component was 10 kt with respect to the landing weight, but at this moment there was no tailwind component. As there was no problem in terms of the performance, he continued the approach and set the landing flaps to 30.

During the approach, the PIC received information on changed wind direction to northwest. Together with the FO, the PIC confirmed that the landing on the slippery runway under tailwind conditions would be possible provided that the tailwind component was 10 kt or less. The Aircraft kept approaching. The target speed was established by adding 5 kt (as per the pertinent regulation) to the reference speed of 135 kt that was calculated by the flight management computer (FMC)—140 kt.

Before entering the final approach path, the PIC reported to the Radio of the position. The Radio reported it to the PIC that the runway was clear. At that time, the wind was blowing from 320° at 11 kt. The tailwind component of this wind was calculated to be 7 kt. This value was within the limit of 10 kt. Therefore, the PIC continued to approach. He visually confirmed the approach lights at an altitude of 700 ft, and decided to land. Later the autopilot was disengaged and he flew the aircraft manually. During the final approach phase, the turbulent air caused the airspeed to fluctuated to some extent until touchdown. There was no significant deviations in terms of approach speed or approach path. However, the FO made an “airspeed” deviation call only once, which is supposed to be made when the airspeed drops below [(Target speed) – 5 kt] or exceeds [(Target speed) + 10 kt]. PAPIs (Precision Approach Path Indicators) lights were viewed within the normal range, no “four red lights” or “four white lights.” After normal flaring the Aircraft touched down without floating. Automatic call-outs regarding altitudes were no different from usual. The PIC intended to execute a go-around, if he failed to touch down short of the end of the touchdown marking (22.5 m in length) that extends from a spot 450 m from the runway approach end. He thought that the touchdown position was short of the first above-mentioned end. Although he felt that the runway appeared more whitish than expected, the runway marking was visible.

Almost as soon as the touched down, the speed brakes were activated, and the thrust reversers were used. The autobrake performance is divided into stages “1,” “2,” “3,” and “MAX” in increasing order of effectiveness. It is specified that stage “MAX” should be used when the minimum stopping distance is required. He used stage “3”as he was sure of sufficient margin of performance. Under normal circumstances, a sense on deceleration is felt when the autobrake stage “3” is used. This time, however, at the stage where the autobrakes automatically started to be effective, the sense of deceleration was felt to be unsatisfactory. As he felt unsatisfactory, he stepped down on the brakes in the manual mode earlier than usual, but to no avail. He tried again further. The result was the same. He suspected that the tires themselves were slipping, released the brakes once to allow the tires to regain grips of the runway surface, and stepped on the brakes. He thought he had retarded the thrust reverser levers to the “Idling” position, however, the records of the quick access recorder (QAR) showed that they were retarded to the “Down” position. Once more, the brakes and the thrust reversers were used to the maximum extent; however, no sense of deceleration was obtained. In the meantime, the runway remaining distance diminished. With the brakes and the thrust reversers fully used, the Aircraft crossed the runway end, then the end of the overrun zone, and finally came to a halt in the grass zone on the east side. As it was somewhat likely to steer away the non-recessed overrun zone light to the left, the steering system was effective. It was somewhat likely to confirm the indications displayed when the thrust reversers and the autobrakes were activated. No indication of any problem was displayed.

Later the PIC reported to the Company, the Radio, and the cabin crew members of the overrun and checked the aircraft damage and cabin status.

(2) FO

During the holding over the Airport, the FO felt that the situation was severe because of the turbulent airflow, worse icing conditions and a risk of lightning strikes. So he proposed to climb to higher altitude for holding. The airflow was gentle during the holding at 12,000 ft. During the final approach, the airflow was fairly bumpy, and the speed fluctuated to a considerable extent. Although the airspeed exceeded Target speed + 10 kt once, no deviation from the glide path or the localizer occurred: PAPI indications were two red lights and two white lights; the attitude was stable; and the airspeed was controlled by the engine power.

He did not feel that the touchdown point was shifted further away from the approach runway end. After the touchdown, he confirmed the deployed speed brakes. He also confirmed that the PIC pulled the thrust reverser levers without delay. At that time, he felt that the aircraft would stop soon. He observed the indication of the speed tape which indicates CAS. After the "60 kt" call, the PIC started to return the thrust reverser levers. He felt temporarily weakened deceleration then. The FO considered the GS against the remaining runway distance, and judged that the deceleration was slow. Then he said "Still 50 kt." The PIC pulled the thrust reverser levers once again. However, no deceleration occurred. The FO also pressed down on the brake pedal. The PIC said he would avoid a light located beyond the runway centerline and steered the Aircraft to the left, resulting in an overrun. During the landing roll, lateral control was good aligning the Aircraft on the centerline.

(3) Chief Purser

At the time of landing, the Chief Purser was seated on a cabin crew seat in the left forward part of the Aircraft. The Aircraft jolted significantly during approach, but touchdown was smooth. A little after touchdown, she heard crunchy noise mixed with vibrations which are normally experienced while driving on a road covered with a mixture of snow and ice. She felt no usual sense of deceleration. The aircraft came to a halt. The PIC informed of the runway overrun. The cabin crew checked for injured passengers, but there were none.

2.1.3 Statement of the Information Officer

The Information Officer was working alone in the air traffic control tower. Due to the snow fall, the Aircraft was not visible when it was on long final. His visual contact with the Aircraft was made when it was on short final. He visually confirmed the landing and used keyboard to enter the arrival information into a terminal. When he shifted his attention to the Aircraft, it was rolling down the runway midpoint with faster-than-usual speed. He did not pay his attention until its halt. He received the runway overrun report and sent a simultaneous notice using the crash phone (emergency direct line to the stations concerned).

The place of the occurrence of this serious incident is the east end of Shonai Airport runway (38°48'51"N, 139°47'58"E). The time of the occurrence was 22:26.
(See Figure 1 "Estimated Flight Route")

2.2 Injuries to Persons

No one was injured.

2.3 Damage to the Aircraft

There was no damage to the Aircraft.

2.4 Personnel Information

(1) PIC: Male, Age 35

Airplane transport pilot certificate (Airplane):	May 26, 2011
Type rating for Boeing B737:	February 28, 2005
Class 1 aviation medical certificate	
Expiration date:	October 1, 2013
Total flight time:	4,494 hours 40 minutes
Flight time in the last 30 days:	38 hours 24 minutes
Total flight time on the type of aircraft:	4,272 hours 56 minutes
Flight time in the last 30 days:	38 hours 24 minutes

(2) FO: Male, Age 25

Commercial pilot certificate (Airplane):	June 25, 2010
Type rating for Boeing B737:	June 16, 2011
Instrument flight certificate:	July 1, 2010
Class 1 aviation medical certificate	
Expiration date:	July 29, 2013
Total flight time:	1,014 hours 02 minutes
Flight time in the last 30 days:	57 hours 46 minutes
Total flight time on the type of aircraft:	790 hours 43 minutes
Flight time in the last 30 days:	57 hours 46 minutes

2.5 Aircraft Information

2.5.1 Aircraft

Type:	Boeing B737-800
Serial number:	33894
Date of manufacture:	July 10, 2009
Certificate of airworthiness:	No. 2009-026
Validity date:	From September 25, 2009 to the end of the period during which the Maintenance Regulations (of All Nippon Airways Co., Ltd.) are applied
Category of airworthiness:	Airplane Transport T
Total flight time:	7,615 hours 44 minutes

Flight time since last periodical check (C02C inspection conducted on May 29, 2012):
1,264 hours 14 minutes

(See Figure 3 "Three-Angle View of Boeing B737-800.")

2.5.2 Weight and Balance

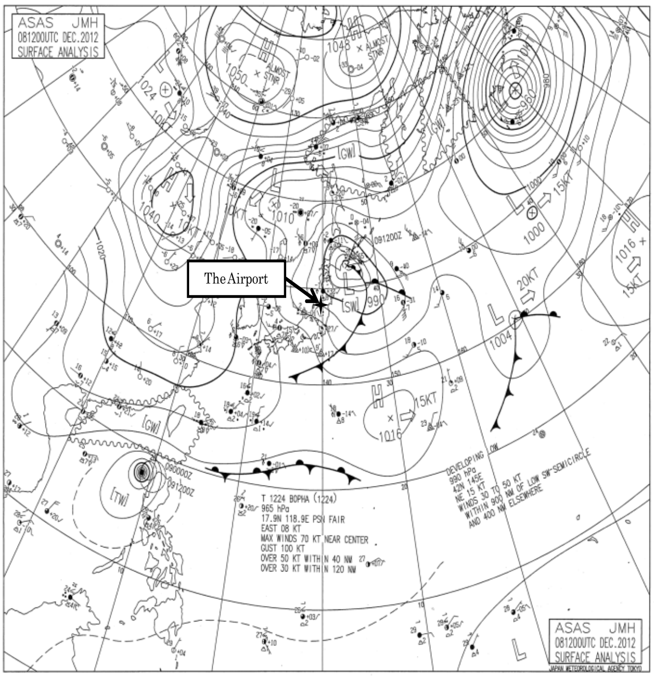
When this serious incident occurred, the weight of the Aircraft is estimated to have been 132, 900 lb and the position of the center of gravity is estimated to have been

23.1% MAC*4, both of which are estimated to have been within the allowable range (maximum landing weight of 144,000 lb, and -6 to 36% MAC corresponding to the weight at the time of this serious incident).

2.6 Meteorological Information

2.6.1 General Conditions Based on Surface Analysis Chart

According to the Asia Pacific Surface Analysis Chart at 21:00 on December 8, 2012 (the chart), a well-developed low pressure system southeast of Hokkaido was moving northeast. Japan was covered by a typical winter pressure pattern marked by a high pressure system to the west and a low pressure system to the east. Isobar spacing in the vicinity of the Tohoku Region, where the Airport is located, were very close.



2.6.2 Aeronautical Weather Observations at the Airport

The routine and special aeronautical weather observation reports around the time of this serious incident were as follows:

21:24: Wind direction 280°, variable 240°-330°, Wind velocity 13 kt;
Maximum instantaneous wind velocity 25kt;
Visibility 4 km; Light shower of snow;
Cloud: Amount 1/8, Type Stratus, Cloud base 800 ft
Amount 7/8, Type Cumulus, Cloud base 3,500 ft;
Temperature 1°C; Dew point -3°C;
Altimeter setting (QNH) 29.64 in Hg

21:35: Wind direction 340°, variable 300°-010° Wind velocity 12 kt;
Maximum instantaneous wind velocity 27kt;
Visibility 500 m;
RVR: Runway 09 Above the measurement range of 1,800 m, No change; Light shower of snow;
Cloud: Amount 7/8, Type Stratus, Cloud base 800 ft;
Temperature 1°C; Dew point, -2°C;
Altimeter setting (QNH) 29.64 in Hg

21:45: Wind direction 340°, variable 300°-360°,Wind velocity, 9 kt;

*4 "MAC" stands for Mean Aerodynamic Chord. This term denotes a wing chord that represents aerodynamic properties of the wing. In cases where wing chords are not constant, as exemplified by a swept-back wing, MAC represents the average value. For example, 23.1% MAC denotes the position 23.1% away from the leading edge of this average aerodynamic chord.

Maximum instantaneous wind velocity 19kt;
Visibility 1km;
RVR: Runway 09 Above the measurement range of 1,800 m, Rising 1,600 m minimum; Light shower of snow;
Cloud: Amount 7/8, Type Stratus, Cloud base 800 ft;
Temperature 0°C; Dew point -2°C;
Altimeter setting (QNH) 29.65 in Hg

21:54: Wind direction 340°, variable 310°-020°,Wind velocity 8 kt;
Visibility 4 km; Light shower of snow;
Cloud: Amount 1/8, Type Stratus, Cloud base 200 ft
Amount 7/8, Type Stratus, Cloud base 800 ft;
Temperature 0°C; Dew point -2°C;
Altimeter setting (QNH) 29.65 in Hg

22:00: Wind direction 360°, variable 310°-060°, Wind velocity 6 kt;
Visibility 4 km; Light shower of snow;
Cloud: Amount 1/8, Type Stratus, Cloud base 200 ft
Amount 7/8, Type Stratus, Cloud base 800 ft;
Temperature 0°C; Dew point -2°C;
Altimeter setting (QNH) 29.64 in Hg

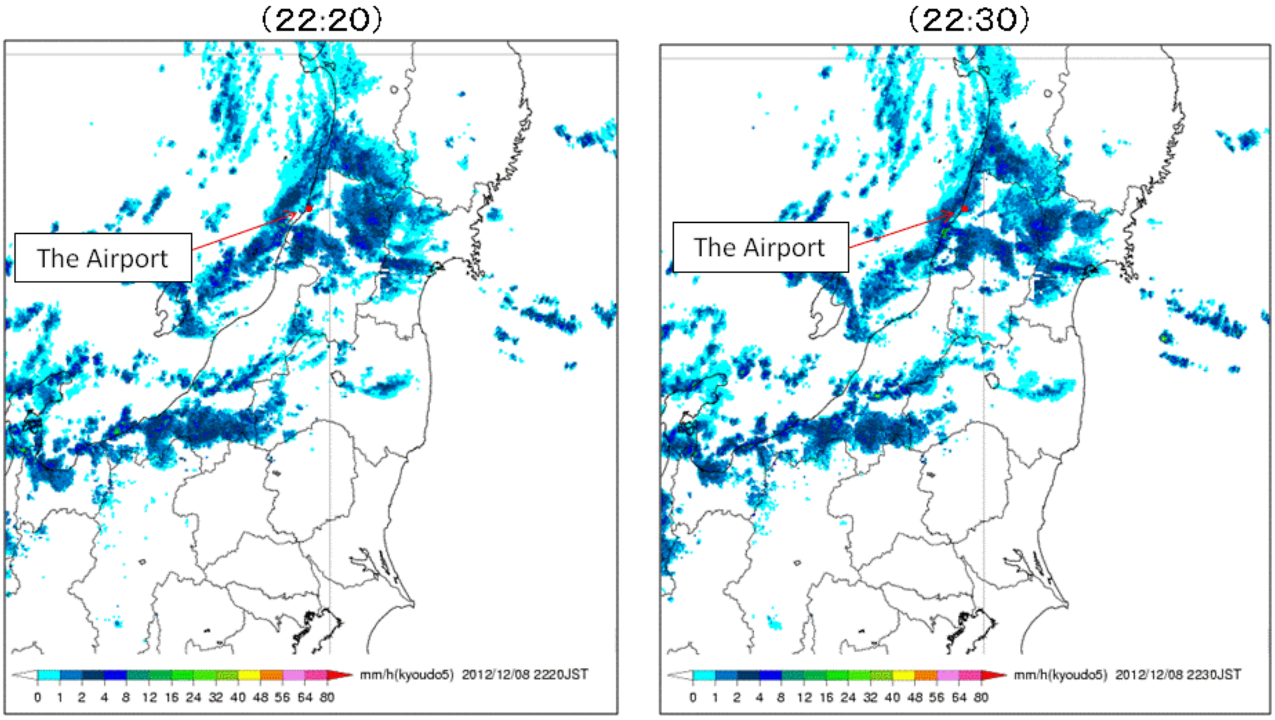
22:24: Wind direction 310°, Wind velocity 8 kt;
Maximum instantaneous wind velocity 19kt;
Visibility 3 km; Light shower of snow and ice pellets;
Cloud: Amount 1/8, Type Stratus, Cloud base 200 ft
Amount 7/8, Type Stratus, Cloud base 800 ft;
Temperature 1°C; Dew point -1°C;
Altimeter setting (QNH) 29.63 in Hg

22:32: Wind direction, 320°, variable 280°-350°, Wind velocity 13 kt;
Visibility 1,500 m;
RVR: Runway 09 Above the measurement range of 1,800 m, No change; Light shower of snow;
Cloud: Amount 1/8, Type Stratus, Cloud base 200 ft
Amount 7/8, Type Stratus, Cloud base 800 ft;
Temperature 1°C; Dew point -1°C;
Altimeter setting (QNH) 29.63 in Hg

2.6.3 Information on the Data Observed by the Radar

The following charts depict the radar returns from snow clouds, which were observed at the Airport during the time frame of the serious incident. The radar returns formed north-south streaky shape near the Airport with the overall peak altitude of approx. 6,700-13,300 ft (2-4 km), some reaching approx. 13,300-20,000 ft (4-6 km). The radar returns as a whole were moving southeast. The Airport was located at the northwest edge of the streak at 22:20, and was fully covered by the snow clouds that had strong radar returns at 22:30.

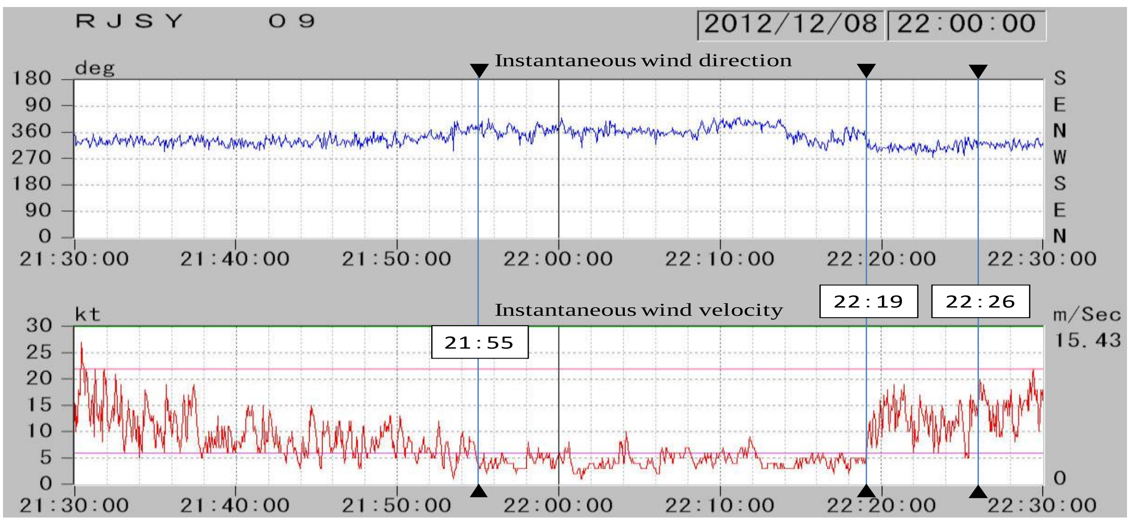
Radar observation data (Intensity)



2.6.4 Observations of Instantaneous Wind Directions and Wind Velocities at the Airport

The following charts depict the instantaneous fluctuation of wind direction and velocity near touchdown point of runway 09 during the time frame of the serious incident.

At about 21:30, general wind direction was northwest, and instantaneous wind velocities exceeded 25 kt. However, the winds gradually abated by about 21:55. Between about 21:55 and 22:19, the wind direction fluctuated between northwest and northeast; the instantaneous wind velocity exceeded 10 kt twice and exceeded 5 kt several times. In general the instantaneous wind velocity remained near 5 kt or less. Starting at 22:19, the instantaneous wind velocity suddenly exceeded 10 kt. The wind direction stabilized approximately in the northwest direction. At 22:26:09, the wind from 332° exceeded 20 kt.



2.6.5 Information on the Snow Ice Conditions at the Airport

(1) SNOWTAM Values

The SNOWTAM during the time frame of the serious incident was as follows:

22:07: Runway Area A (one third of runway length from 09 end):
Wet snow; Depth, 2 mm; Covered area, Less than 40%
Braking action Good
Runway Area B (the middle one third length of the runway):
Wet snow; Depth, 2 mm; Covered area, Less than 60%
Braking action Good
Runway Area C (one third or runway length from 27 end):
Wet snow; Depth, 2 mm; Covered area, Less than 80%
Braking action Good
Braking action in the taxiway and at Spot 2 Good

(2) Types of snow, and braking action

The snow/ice condition assessment at the Airport before the serious incident was conducted in accordance with the "Manual for Work Related to Snow Removal (FY 2012)" (hereinafter referred to as the "Snow Removal Manual"). It was compiled by Shonai Airport Office, Construction Department of the Shonai Comprehensive Branch Office of Yamagata Prefecture referring to the "Guidelines for Airport Operation" formulated by the CAB (Civil Aviation Bureau), Ministry of Land, Infrastructure, Transport and Tourism (MLIT) in compliance with the "Guidelines for Airport Safety Management Regulations." The Snow Removal Manual contains the following contents.

4 Types of Snow, and Braking Action

(1) Types of Snow

1)	DRY SNOW	Dry snow, and ordinary snow which does not contain much water
2)	WET SNOW	Snow which contains a considerable amount of water that oozes out when gripped by a gloved hand.
3)	SLUSH	Snow which contains a considerable amount of water that splashes when trampled by the heel or kicked by the toes.
4)	COMPACTED SNOW	Snow which is compacted by snow plows.
5)	ICE	Ice

(2) Braking Action

1)	GOOD	Coefficient of friction (μ): 0.40 or more
2)	MEDIUM TO GOOD	Coefficient of friction (μ): 0.36 or more Less than 0.40
3)	MEDIUM	Coefficient of friction (μ): 0.30 or more Less than 0.36
4)	MEDIUM TO POOR	Coefficient of friction (μ): 0.26 or more Less than 0.30
5)	POOR	Coefficient of friction (μ): 0.20 or more Less than 0.26
6)	VERY POOR	Coefficient of friction (μ): Less than 0.20

(3) Points to be noted on types of snow and to braking action

- *In the case of slush, measurement of friction coefficient is not necessary.*
  (The rest is omitted.)

(3) Criteria for the Initiation of Snow Removal

The Snow Removal Manual contains the following contents:

(1) Criteria for the Initiation of Snow Removal

The Snow Removal Plan requires removal actions when:

1) *the runway, taxiway, or apron has snow cover of 3 cm or more, or it is judged that snow cover will be 3 cm or more;*
2) *the braking action is "Medium to Poor" or lower (μ = Less than 0.30);*
3) *freezing is predicted; or*
4) *snow removal is otherwise deemed necessary*

However, in order to guarantee the takeoffs and landings of aircraft, snow removal is initiated under the any of the following circumstances, among others: The runway is covered by blanket of snow; snow removal is requested by airlines.

(4) Measured values of friction coefficients

The actual friction coefficients (μ) measured with the equipment manufactured by ASFT Industry and used for 22:07 SNOWTAM (mentioned in (1) above) were as follows:

Time of measurement	21:59:50
Runway Area A	0.69
Runway Area B	0.60
Runway Area C	0.56
Maximum	0.79
Minimum	0.30
Average	0.62;
Surface temperature	-0.42°C;
Ambient temperature	0.95°C
Ice	0%

2.6.6 Statement of the Person in Charge of Snow Removal

The person in charge of snow removal takes case of snow removal and assessment of snow/ice conditions at the Airport. On the day of the serious incident, when he started runway inspection at about 20:40, he received the Aircraft's ETA to be about 21:41. 21:05 runway condition was "wet and normal" (wet runway without snow or ice) and he forwarded it to Shonai Office. Shonai Office requested him to do a snow/ice condition assessment again by 21:25 as the Airport was likely to be covered by snow clouds with strong radar return. The Information Officer instructed him to vacate the runways by 21:29. 21:26 runway condition was "wet and normal" And he forwarded it to the Information Officer and Shonai Office. The latter acknowledged this information.

At about 21:30, when the person in charge of snow removal returned to the office, it started to snow so hard that he could not see the runway from the office. The snow was unlikely to melt. At about 21:40, the apron was covered with blanket of snow. He decided to remove snow. He checked with the snow removal team for the time necessary for snow removal. 20 minutes was the response. He submitted a request to the Information Officer to issue a NOTAM of runway closure until 22:10. At about 21:45, the team started their work with six snow removing vehicles. Snow is removed by placing plows (snow is pushed sideways with diagonally placed plow) very close to the runway surface allowing no gap between them, followed by sweepers (a machine with rotating brushes) to brush away snow from the surface. The team entered the runway via the taxiway. First, the snow on the north side of the runway was cleared from the west to the east. At the east-end of the runway, the turning area was cleared only runway width. Then the team cleared the southern half of the runway to the west. The person in charge stayed at runway east end. Upon receiving a radio transmission that the team arrived at the west end, he started the measurement of breaking action. The team cleared the west turning area and started clearing the north side of the runway. The person in charge measured west turning area. The measurement ended at 21:58. Upon receiving the report that the team entered the taxi way, he started east-bound measurement and ended at 21:59. He directed the team to vacate the taxi way. The team cleared the taxi way cleaning the snow there. He measured the braking action in the taxi way after skipping the east turning area. The measurement ended at 22:06. He measured #2 spot and vacated the apron area. He radioed the CAB of the completion with the measurement result at 22:07. Shonai Office acknowledged the radio transmission and informed the change of approach direction.

All the runway surface was covered with snow before the cleaning. He assessed that after the snow removal work, from the west to the east, the first third, the second third, and the last third of the runway surface was covered with snow, 40%, 60% and 80%, respectively. The depth of snow was judged to be 2 mm by visual measurement. Snow Removal Manual does not require to measure friction coefficient if the snow is slush condition. He walked around the snow-covered area to check the snow condition. His assessment was negative—not slush.

Although it was snowing even after the runway reopening, it was not as heavy as it was at about 21:30. Visibility was good and he was watching the approach direction until the Aircraft came into his view. He was not sure its touchdown point. He felt that its speed of landing roll did not drop. He was puzzled why it was stationary even after its halt. Then he heard a radio message that it had overrun the runway.

2.7 Information on DFDR and CVR

The Aircraft is equipped with a DFDR (Part number: 980-4700-042) manufactured by Honeywell International Inc. in the United States and a CVR (Part number: 2100-1020-00) manufactured by L3 Communications Holdings, Inc. in the United States. The records at the time of the occurrence of this serious incident are therefore in-tact.

In this respect, time calibration for the DFDR and the CVR was carried out in such a way that the NTT (Nippon Telegraph and Telephone Corporation) time signals recorded in the air traffic control communications records were correlated to the VHF keying signals recorded in the DFDR and the CVR.

2.8 Information on the Place of the Occurrence of This Serious Incident

2.8.1 Conditions at the Airport

The Airport is located in the vicinity of the seashore of the Shonai Plain, which is a heavy snowfall area facing the Sea of Japan. Operational hours begin at 07:00 and end at 22:00. It has a single runway, Runway 09 (088°) and Runway 27 (268°). Its length is 2,000 m extending almost east and west, with width of 45 m. It has a 0.4 % climbing inclination from the west to the east with 59 ft of the elevation at the west end and 86 ft for the east end, respectively. A 60 m long paved overrun zone stretches at either end of the runway. A grass area extends outside of either overrun zone. The runway surface is grooved across the runway length of 2,000 m with 30 m width.

The instrument approach established for Runway 09 is a precision approach—ILS Category I (the pertinent document revised on August 27, 2009 was applicable at the time of the serious incident) with the decision altitude*5 of 271 ft and the landing minima RVR/CMV*6 600 m, while that for Runway 27 is a non-precision localizer approach (the pertinent document revised on August 27, 2009 is applicable) with the minimum descent altitude of 520 ft and the CMV 1,400 m for the category to which the Aircraft belongs.

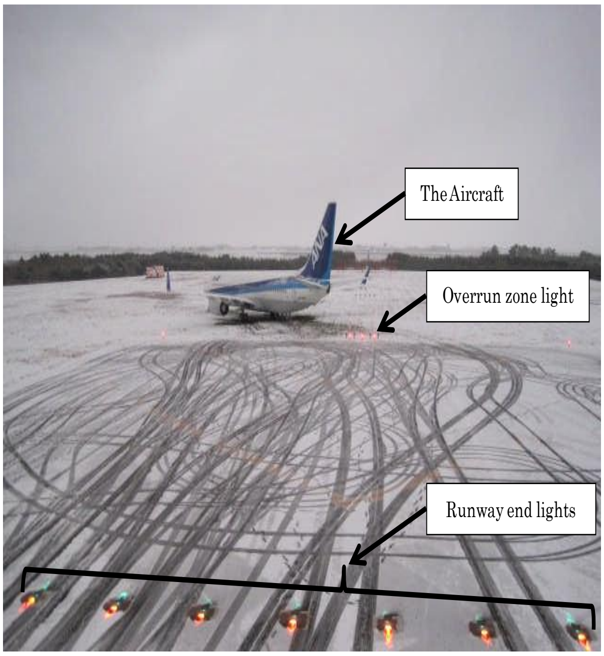
As the serious incident occurred at night with the approach lights and the runway lights in operation, the conversion rate for CMV based on ground visibility is 2.0.

*5 The "decision altitude" means the limit approach altitude in the case where a precision approach or a non-precision approach involving vertical path information is made. This altitude is expressed in terms of the altitude above mean sea level.

*6 "CMV (Converted Meteorological Visibility)" means a value obtained in such a way that the value of an observed ground visibility (prevailing visibility) is multiplied by a specific factor that depends on the way aviation lights are operated and on whether the pertinent approach is made in the daytime or the nighttime. CMV is applied in the case where RVR cannot be used under the minimum meteorological conditions (landing minima) for the approach procedure and in the case where RVR exceeds the maximum operating value.

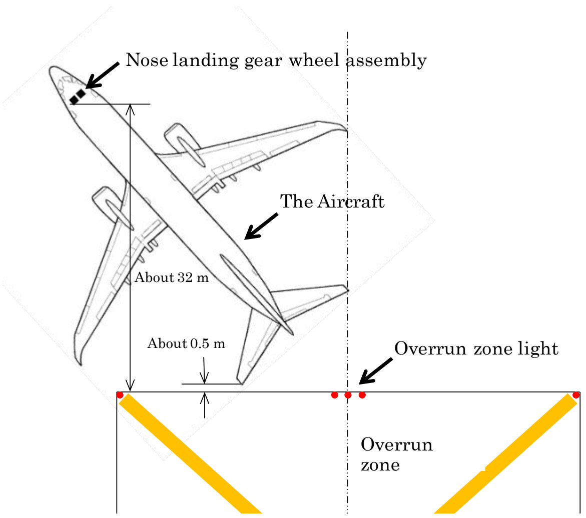
2.8.2 Conditions of the Aircraft

The Aircraft that made an overrun
(Photographed by the Company in early morning on December 9, 2012)



The Aircraft was sitting in the thinly snow-covered grass area orienting itself to 046° after crossing the runway east end and overrun zone. Its nose landing gear wheel assembly was about 32 m away from the west end of the overrun zone. The nearest aircraft part from the end of the overrun zone was the left horizontal stabilizer tip that was about 0.5 m away from the said end. The tip of the right wing and that of the right horizontal stabilizer lay approximately on the extension of the runway centerline.

Tire marks left by the Aircraft were not identified, neither on the runway nor the overrun zone. The lines of tire marks left in the overrun zone pointed to 070°, and they gradually veered leftwards in the grass area.



The nose landing gear sank into the ground to a depth equal to about 30% of the wheel diameter—the wheel rim was almost the ground level. The left main landing gear sank into the ground to a depth equal to about 10% of the wheel diameter—part of its side wall was below the surface level. The right main landing gear sank into the ground to a depth equal to about 40% of the wheel diameter—the lower half of the wheel was below surface level.

Nose landing gear of the Aircraft (Photographed by the Company in early morning on December 9, 2012)

Left main landing gear of the Aircraft (Photographed by the Company in early morning on December 9, 2012)

Right main landing gear of the Aircraft (Photographed by the Company in early morning on December 9, 2012)

2.9 Information on Fire and Firefighting

At 22:28, the first crash phone message "Possible overrun" put the Airport Fire-Fighting Team into garage stand-by. At 22:35, the team received the second crash phone message to the effect that "Possibly no injuries, no aircraft damage, and no fire." The team continued the garage stand-by. At 22:52, it received the third message to the effect that "No injuries, no aircraft damage, no fire, and that additional information or changes will be given." The team continued garage stand-by. At 04:25 on December 9, the stand-by was lifted.

2.10 Tests and Research for Fact-Finding

2.10.1 The Aircraft Inspection at Shonai Airport

The aircraft systems and equipments which are tested under on-board conditions were tested by the Company at the Airport. The results were as follows:

(1) Brake system

On December 10 and 11, 2012, the brake system inspection found no anomalies.

(2) Autobrake system

On December 11, 2012, the autobrake system inspection found no anomalies.

(3) Wheels and tires

On December 9, 2012, the inspection of the wheels and tires found no anomalies. Although the right tire of the nose landing gear had a cut of 39 mm (length limit: 40 mm) by 0.100 in. (width limit: 0.125 in.) by 3 mm (depth limit: 4 mm), it was within the tolerable limits.

(4) Thrust reversers

On December 12, 2012, the operational inspection found no anomalies.

(5) Engine accessories

On December 12, 2012, the inspection of engine accessories found no anomalies.

2.10.2 Detailed Inspection of the Brake Assemblies

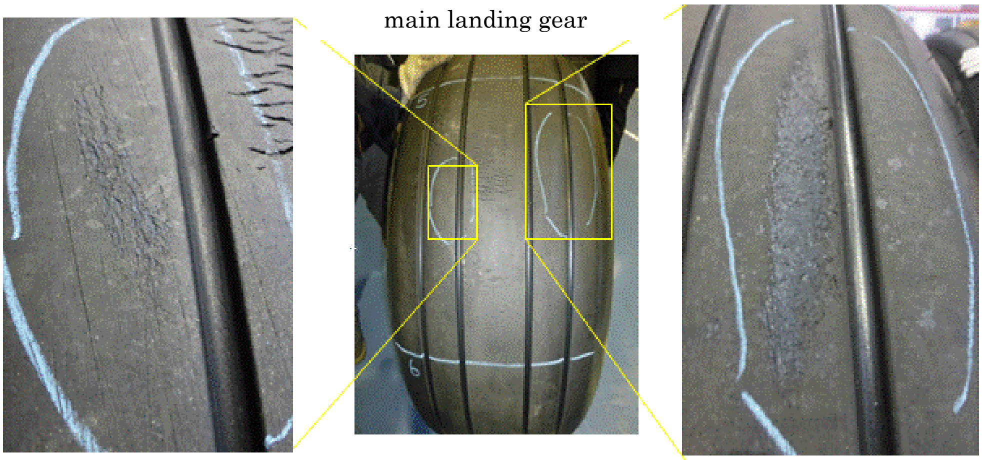
Although the four brake assemblies removed from the Aircraft were sent to the Company's contracted maintenance company for detailed inspection, the inspection found no anomalies.

2.10.3 Detailed Inspection of the Wheel Assemblies

A total of six wheel assemblies were removed from the Aircraft: the left and right wheels of the nose landing gear, and those of the left and right main landing gears (the wheels of the main landing gears are labeled #1 through #4 starting from the left wheel of the left main landing gear). Company's contracted maintenance company conducted the detailed inspection of the six wheels.

Visual inspections found that all tires from the main landing gears exhibited degraded tire tread as shown in the following photos. No other anomalies were found.

Tread rubber degeneration of main landing gear



2.10.4 Detailed Inspection of the AACU

The detailed inspection of the removed AACU at its manufacturer found no anomalies.

2.10.5 Estimation of Airplane Braking Coefficient and Landing Stopping Distance

The Aircraft QAR data was sent to the designer/manufacturer of the Aircraft for analysis of the braking coefficients and landing stopping distances. The analysis found:

(1) Airplane Braking Coefficient

The airplane braking coefficient (μ_A) is a dynamic friction coefficient which is defined as the ratio of the wheel brake force to the vertical load acting on the wheel. A wheel brake force is a value obtained by subtracting the aerodynamic drag and the thrust reverser thrust force from the total braking force of an airplane. The vertical load acting on a wheel is expressed by "(Weight) – (Lift force)".

We have following formulas in regard to the coefficient μ_A.

$$D_W = \mu_A \cdot F_W$$

$$D_T = D_W + D_A + D_R$$

$$F_W = W - L$$

With these combined μ_A is given as

$\mu_A = (D_T - D_A - D_R) / (W - L)$, where:

W denotes weight,

L denotes lift,

Fw denotes vertical load acting on the wheel,

Dw denotes wheel brake force,

Da denotes aerodynamic drag,

Dr denotes thrust force of the thrust reversers and

Dt denotes the total braking force.

This means that μ_A does not necessarily match up with the friction coefficient (μ) between tires and runway surface, which is measured with the ground vehicles at airports.

The average μ_A value calculated during a landing roll based on the QAR data, on and after the use of the manual brakes is approx. 0.08.

(2) Landing stopping distance

The Aircraft's landing distances were calculated using the Low Speed Performance Software that was developed by the designer/manufacturer and used for analysis of takeoff/landing performance. The matrix was set with three brake conditions (Autobrake 3, Autobrake MAX, and Manual Brake MAXIMUM) against three runway conditions and one friction coefficient ("Good," "Medium," and "Poor," and μ_{A}=0.08). The stopping distance was measured from the approach runway end. The following table shows the result.

These calculations used the serious incident QAR data except for brake operations.

Brake condition	Runway conditions or $\mu_A = 0.08$	Stopping distance
Autobrake 3	Good	6,085 ft (1,856 m)
	Medium	6,676 ft (2,036 m)
	Poor	7,955 ft (2,426 m)
	$\mu_A = 0.08$	7,025 ft (2,143 m)
Autobrake MAX	Good	4,935 ft (1,505 m)
	Medium	6,274 ft (1,914 m)
	Poor	7,834 ft (2,389 m)
	$\mu_A = 0.08$	6,758 ft (2,061 m)
Manual Brake MAXIMUM	Good	4,608 ft (1,405 m)
	Medium	6,113 ft (1,864 m)
	Poor	7,807 ft (2,381 m)
	$\mu_A = 0.08$	6,646 ft (2,027 m)

2.11 Additional Information

2.11.1 Company's Regulation on Restrictions on Slippery Runway Takeoff/ Landing

The Company's Aircraft Operation Manual (AOM) includes the following contents regarding to the landing on slippery runways.

1-2 Airplane Limits

(This portion is omitted.)

Operational Limits

Maximum Takeoff and Landing Tailwind:

Runway Length	*Maximum Takeoff and Landing Tailwind*
1,801 m or more	*15 kt*
1,800 m or less	*10 kt*

(This portion is omitted.)

1-4 Miscellaneous Limits

(This portion is omitted.)

Maximum crosswind during takeoff and landing

The maximum crosswind component (average) during takeoff and landing that was substantiated on a dry runway on the occasion of awarding the type certificate is 33 kt. This value shall be taken as the upper limit in terms of operations in our company. Maximum crosswind values during takeoff and landing that correspond to the runway conditions shall be as follows.

However, the temporary exceedance of these values after the initiation of takeoff or landing or after deciding on landing shall be permitted.

Runway conditions			*Maximum crosswind value (kt)*
DRY (including DAMP)			*33*
WET (provided with grooving)			*25*
WET (not provided with grooving)			*20*
FLOODED			*10*
ICE or SNOW	*Braking Action*	*GOOD*	*20*
		MEDIUM TO GOOD	*20 (15)**
		MEDIUM	*20 (15)**
		MEDIUM TO POOR	*15 (10)**
		POOR	*10*
SLUSH	*Deep Snow*	*2 mm or less*	*15*
		3 – 12 mm	*10*

* *Any value in parentheses ( ) shall apply to a runway less than 2,000 m in the case of -700/700ER* (Boeing 737-700 or 737-700ER) or to *a runway less than 2,100 m in the case of -800* (Boeing 737-800).

(This portion is omitted.)

Restrictions due to the runway conditions

1. Restrictions due to snow or water depth

If the runway conditions fall under any of the following cases, neither takeoff nor landing shall be made.

- *Water or slush, with a depth of 13 mm (0.51 inch) or more deep, or slush*
- *Wet snow with a depth of 51 mm (2.01 inches) or more*
- *Dry snow with a depth of 71 mm (2.80 inches) or more (Takeoff)*
- *Dry snow with a depth of 153 mm (6.01 inches) or more (Landing)*

2. Restrictions due to Braking Action

If braking action is "Very Poor" or below (that is, if the value measured by a runway friction coefficient measuring instrument is 0.19 or less), neither takeoff nor landing shall be made.

***Note 1*:** *Usually, the types of snow, the depths of snow, and braking action are reported in such a way that a runway is divided into three sections. If any one of the said three sections falls under any of the cases in item 1 and 2 above, takeoff and landing shall be prohibited.*

(This portion is omitted.)

4-3-3 Landing on Slippery Runways

(This portion is omitted.)

At as early a stage as possible during landing roll, the left and right thrust reversers shall be uniformly used. The thrust reversers are the most effective at high speed.

While the nose gear is being lowered onto the runway, the reverse thrust levers shall be pulled up to the "Interlock" position.

When the reverse interlock is released, the left and right reverse thrust levers shall be uniformly pulled up to the "Full Reverse" position, and shall be held as they are until 60 KIAS (60 kt in terms of the indicated airspeed) is reached. At this time, the reverse thrust shall be adjusted as necessary so that the engine limit will not be exceeded. When 60 KIAS is reached, the reverse thrust levers shall start to be slowly returned, and shall be returned to the "Idling Reverse" position by the time that the safe taxiing speed is reached.

In emergencies, the maximum reverse thrust may be used until the airplane comes to a complete stop.

(This portion is omitted.)

Prior to landing, selection shall be made to set the autobrake system to a desired deceleration rate level.

- *Case where the shortest stopping distance is required: Max*
- *Case where the shortest stopping distance is not required: 3*

(This portion is omitted.)

The table below shows a summary of the recommended procedure for landing. (Underlines were drawn by Japan Transport Safety Board.)

Phase	***Recommended Procedure***	***Remarks***
Approach	*1. Tailwind landing shall be avoided as much as possible.* *2. During the final approach, the airplane shall be brought into the glide path and onto the runway centerline, and the specified speed shall be met.* *3. Selection shall be made to set the autobrake system to "3" or "MAX."* *4. The speed brakes shall be armed.* *5. Errors should not be made regarding the relative bearing with respect to the runway due to the fact the airplane is flying at a crab angle when coming out of clouds.* *6. If a zero drift condition cannot be established prior to flaring, consideration should be given to a go-around.*	
Flare	*1. During flaring, no floating shall be caused to occur, nor shall drift be increased.* *2. In the case of a crosswind, landing shall be made with a crab angle maintained.*	*If landing is made with a crab angle maintained, the main gear crab effect is produced, with the result that the auto spoilers and the autobrakes are activated at earlier stages.*
Touchdown	*1. A firm touchdown shall be made as near the centerline as possible.* *2. Even if the speed is too high, the airplane shall be securely brought to the aiming point.* *3. If the touchdown point is likely to turn out to be at a greatly distant spot, consideration should be given to a go-around.*	*The firmer the touchdown, the better the wheel spin-up.* *On the runway, the deceleration effect is about three times as great as in the air. Therefore, the airplane shall not be caused to float in the air with the aim of bleeding off the speed.*

Transition to Braking Configuration (Expedite All Items)	*1. When the main gear touches down, it shall be immediately confirmed that the speed brakes have moved up.*	*If speed brakes do not automatically move up, they shall be immediately moved up manually.*
	2. The nose gear shall be immediately brought into contact with the ground.	
	3. While the nose gear is being lowered, the reversers shall be pulled up to the "Interlock" position.	
	4. If the autobrakes are not to be used, intermediate or intense steady pedal pressure shall be applied as soon as the nose gear touches down.	<u>*The brake pedal shall not be cycled.*</u>
	5. When wheels spin up, the autobrake system starts braking operation with the left and right brakes uniformly activated. By applying normal braking, the autobrake system can be disarmed at any time, with the result that a changeover can be made to manual braking.	
	6. When the reverse interlock is released, the left maximum reverse thrust and the right maximum reverse thrust shall be uniformly applied.	*Reverse thrust is more effective at high speed.*
Rollout	*1. The wing shall be held level.* *2. At high speed (about 60 KIAS or more), the direction shall be maintained by means of the rudder.* *3. At low speed, direction control shall be performed by means of nose wheel steering and rudder operation.*	*The braking performance and the ability to hold a straight line shall be improved.*

Skid or Loss of Directional Control	*1. The brakes shall be released immediately.* *2. A return shall be made to the "Reverse Idling" position, and the wing shall be held level.* *3. The airplane shall be returned to the centerline by using, as necessary, the nose wheel steering, the rudder, and the differential brakes.* *4. After the airplane is returned to a position parallel to the runway in the vicinity of the centerline, the reverse thrust and the brakes shall be used so that the maximum deceleration effect can be obtained.*	*A full reverse cycle shall be avoided.* *The optimum nose wheel steering angle on a very slippery runway is 1 – 2°. Abrupt large steering shall be avoided.*
Turnoff	*1. Prior to turnoff, the speed shall have been reduced to a safe level.*	*The touchdown zone, the taxiway connection portion, and marking surfaces are particularly slippery. Therefore, caution shall be exercised.*

(The rest is omitted.)

The Company explained the meanings of the underlined expressions as follows:

- "*The brake pedals shall not be cycled*" means "The brake pedals shall not be adjusted."
- "*A full reverse cycle shall be avoided*" means "The practice in which the reverse thrust levers are returned to the 'Down' position shall be avoided in preparation for another use the said levers."
- "*Skid or Loss of Directional Control*" is a summary of "Reverse Thrust and Cross-wind" contained in 4-3-3-(3) of the AOM. The term "*Skid*" here means a "sole state where the airplane has side skidded only."

2.11.2 Takeoff and Landing Training on Slippery Runway

(1) Periodic training (which is specified in the Supplement to the Qualifications Manual)

1) Summary

Landing on slippery runways is trained using a flight simulator within the framework of "Cold Weather Operation" contained in "Adverse Weather" that is one of the periodic training subjects.

2) Trainees

PICs and FO

3) Frequency of training

Once per year

4) Description of training (Summary)

The taxiway/runway friction coefficient is set to "$\mu = 0.15$." The following operations are carried out.

- RTO (Rejected Takeoff): One round
- Landing with one engine operative due to failure of one engine subsequent to V_1: One round
- Landing with both engines operative: One round

(2) Winter operation experience (which is specified in the Supplement to the Qualifications Manual)

1) Summary

Training is conducted in the form of simulator training.

2) Trainees

Newly appointed PICs who do not have winter operation experience in the capacity of PICs

3) Description of training (Summary)

The taxiway/runway friction coefficient is set to "μ = 0.20." The following operations are carried out.

- RTO (at low speed) with one engine malfunctioning
- RTO (at high speed [in the vicinity of V_1]) with one engine malfunctioning
- One engine malfunctioning subsequent to V_1
- Crosswind takeoff

(3) Training provided to the PIC and the FO of the Aircraft on slippery runway takeoff and landing

1) PIC

Periodic training: November 6, 2012

Winter operation experience: July 21, 2011

2) FO

Periodic training: November 29, 2012

2.11.3 General Description of Antiskid/Autobrake Systems

(1) Antiskid system

When the brakes are in use, the antiskid system controls the brake system to prevent the wheels from skidding.

1) Skid control

A normal antiskid device controls the deceleration of each wheel when a wheel speed*7 exceeds 8 kt.

2) Locked wheel protection

When the wheel speed exceeds 25 kt, the wheel speeds of both inboard wheels and both outboard wheels are compared. If a certain difference exists, the brake pressure for slower wheels is released.

3) Touchdown protection

The system prohibits the operation of the second and fourth brakes when the aircraft is in the air or for 0.5 second or less after the touchdown.

4) Hydroplaning protection

When GS becomes bigger than the wheel speed by 50 kt or more, the system reduces the brake pressure for the first and third wheels.

*7 "Wheel speed" means an aircraft speed obtained by converting the rotational speed of a wheel. A wheel speed is equal to GS if there is no slip between the ground and the wheel, but is lower than GS if there is a slip.

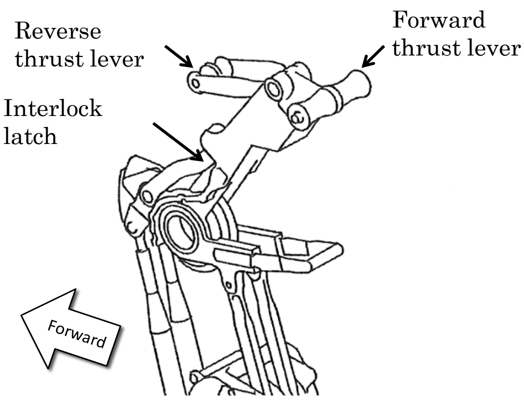
(2) Autobrake system

The autobrake system controls the deceleration rate during a takeoff and landing. During a takeoff, the selector is set to "RTO" (Rejected Takeoff). In case of aborted takeoff, it controls the brake pressure. During a landing, it controls the brake pressure from the touchdown to the complete stop to maintain selected deceleration rate set by the Autobrake Selector Switch to one of the levels "1," "2," "3," and "MAX".

A brake pressure of 3,000 psi applies to RTO regardless of speed.

Relevant deceleration rates during a landing are as follows: Level "1" corresponds to 0.12 G; level "2" to 0.16 G; level "3" to 0.22 G. In the case of "MAX" level, 0.44 G applies to 80 kt and above, and 0.37 G to less than 80 kt. The maximum brake pressure values corresponding to the above levels are: level "1" 1,285 psi; level "2" 1,500 psi, level "3" 2,000 psi; and "MAX" level 3,000 psi.

2.11.4 General Description of Thrust Levers



The thrust levers are used for engine manual control. Each engine has a dedicated thrust lever which comprises of forward thrust lever (for power up) and reverse thrust lever (for thrust reverser deployment). The reverse thrust lever is integrated into the forward thrust lever. An interlock latch prevents simultaneous operation of the forward thrust lever and reverse thrust lever.

In order to activate the thrust reversers, retard the forward thrust levers to the "Idle" position and raise the reverse thrust levers from the "Down" to the "Idle" position. This operation initiates the deployment of the thrust reverser sleeves. The interlock latches disengage when the thrust reverser sleeves for both engines are deployed more than 60%, enabling non-step power control of the thrust reverser by pulling the reverse thrust levers to the near side. The deployed thrust reverser sleeves are retracted into the original position by returning the corresponding reverse thrust levers to the "Down" position.

2.11.5 Trends in the Improvement of Runway Snow/Ice Condition Assessment

(1) The United States

The National Transportation Safety Board (NTSB), which conducted an investigation of the B737-700 overrun accident at Chicago Midway International Airport on December 8, 2005, issued a total of eight safety recommendations to the Federal Aviation Administration (FAA) on October 4 and 16, 2007. In response to these recommendations, on December 9, 2008, the FAA not only amended AC150/5200-30C (Airport Winter Safety and Operation) but also organized the Aviation Rulemaking Committee (TALPA/ARC) to address the evaluation of landing and takeoff performance. The Committee members included supervisory authorities, airline companies, aircraft manufacturers, airport administrators, etc. The

Committee studied the necessity of amendment to the Federal rules related to the evaluation of landing and takeoff performance on contaminated runways.

The Airport/Part 139 Working Group of the TALPA/ARC played a key role for studying the assessment of contaminated runway, and submitted recommendations to the FAA on April 9, 2009. These recommendations are summarized as follows: Paved Runway Condition Evaluation Tables (Matrix) should be used to provide a basis for assessment of the runway conditions for airport administrators, and to help pilots interpret the reported runway conditions referring to the standardized formats based on the aircraft performance data under different types and depths of runway contaminants.

The striking difference in evaluation technique between that included in the TALPA/ARC recommendations and the conventional one lead to operational trials to test the matrix in two winters of 2009 and 2010 at 10 airports in states including Alaska. At present, the amendment work for AC150/5200-30C is under way based on the results of the operating trials.

(2) International Civil Aviation Organization (ICAO)

The snow/ice condition assessment report format adopted by the ICAO was formulated in the 1960s. The ICAO has not only started to carry out work aimed at the adoption of the Global Reporting Format, but has been aiming to harmonize it with the above-mentioned TALPA/ARC.

(3) Japan

In FY 2011, the CAB, MLIT studied the FAA's research outcome within the framework of the "Research on the Upgraded Winter Airport Operations." Starting in FY 2012, snow/ice condition assessment method, to which FAA's research outcomes are applied mutatis mutandis on a simulation basis, was conducted as "Procedures for the Trial of Winter Airport Operations." This trial results will be compared with the current snow/-ice condition assessment method to identify problems and tasks for introduction of new methods into Japan.

3 ANALYSIS

3.1 Qualifications of Crew Members

The PIC and the FO held both valid airman competence certificates and valid aviation medical certificates.

3.2 Aircraft Airworthiness Certificate

The Aircraft had a valid airworthiness certificate and had been maintained as prescribed.

3.3 Relationship with Weather

3.3.1 Runway Used by the Aircraft

It is highly probable that as described in 2.6, the weather around the Airport at the time of the occurrence of this incident was as follows: Echoes, which in conjunction with a typical winter pressure pattern, developed into a large streaky shape extending north and south, successively covered the Airport from west to east bringing in rough unstable weather. It is highly probable that as described in 2.1.2, the PIC made preflight confirmations and predicted severe weather conditions including snowfall, strong winds, and turbulent airflow, and that he took off from the departure aerodrome after working out the measures to take.

It is highly probable that as described in 2.1.2, based on the meteorological information about the weather conditions before arrival at the Airport that was received at 21:19:11 from the Shonai Office, the PIC confirmed that strong northwest winds accompanied by strong gusts were blowing at the Airport, and that the runway was wet without snow; he thought that although snow clouds were approaching the Airport, neither visibility nor cloud heights had deteriorated to such an extent as to prevent landing; he decided that the first approach be made to Runway 27. It is highly probable that while holding high above in the air, the PIC received information that the ground winds had weakened, and that the wind direction had changed to northeast; therefore, he opted to make an ILS approach to Runway 09; during the approach, he received information that the wind conditions changed with respect to the runway conditions, but he confirmed that there was no problem in terms of the performance; he decided to land. As described in 2.8.1, the operating hours at the Airport were up to 22:00, while as described in 2.1.2, the timetable-based estimated time of arrival of the Aircraft was 21:15. The arrival of the Aircraft was significantly delayed. However, since the reason for the PIC's decision-making is as mentioned above, it is probable that the delayed arrival did not affect the PIC's judgment regarding the selection of the runway.

As described in 2.8.1, in terms of the landing minima for a localizer approach to Runway 27 at the Airport, a CMV of 1,400 m is applied to category C, to which the Aircraft belongs. As described in 2.6.2, at 21:35, which corresponds to the time at which the Aircraft made the first approach under the prevailing visibility of 500 m. As described in 2.8.1, this prevailing visibility is converted to a CMV of 1,000 m. It is highly probable that localizer approach to Runway 27 was done with the CMV value not meeting the landing minima. Although the subsequent visibility recovered once, the visibility degraded again after its landing with a prevailing visibility of 1,500 m at 22:32.

The visibility did not go below the landing minima for a localizer approach to Runway 27. As described in 2.8.1, the landing minimum for an ILS Category I precision approach to Runway 09 is an RVR/CMV of 600 m. It is highly probable that the visibility would have not gone below the landing minima between the first approach of the Aircraft and its landing.

3.3.2 Wind Conditions at the Time of the Landing of the Aircraft

As described in 2.1.1, the Radio frequently reported it to the Aircraft of the weather conditions. Prior to the landing, a one-way transmission message regarding the visibility and snow conditions was sent at 22:24:09 (2 minutes before the touchdown), and a one-way transmission message regarding winds was sent at 22:25:28 (41 seconds before the touchdown). Therefore, it is highly probable that the Aircraft had information on the up-to-date weather conditions.

The wind information sent by the Radio at 22:25:28 was that the wind was blowing from 320° at 11 kt. This corresponds to a tailwind component of 7 kt and left crosswind component of 9 kt. As described in 2.11.1, "Good" braking action allows the tailwind component up to 15 kt, and the crosswind component up to 20 kt. Therefore, the wind data communicated at the time of landing judgment was within the limits.

As described in 2.6.4, wind velocities fluctuated greatly. At 22:26:09, the moment immediately before the main landing gears' touchdown, wind was instantaneously blowing from 332° at 20 kt. This probably corresponds to the tailwind component of 9 kt and left crosswind component of 18 kt.

3.3.3 Runway Condition

As described in 2.6.6, friction coefficients on the runway were measured immediately after the snow removal. As described in 2.6.5, the braking action in the SNOWTAM announced at 22:07 was "Good" across the runway. As a result of the confirmation made by the person in charge of snow removal, the snow was not judged to be slush. As described in 2.6.5 (2), the snow/ice condition assessment was conducted in accordance with the Ice Removal Manual. It is probable that matters such as the snow removal method, slush judgment, and the condition assessment methods were appropriate. As described in 2.6.5 (1) and 2.6.6, the runway snow conditions were such that after the snow removal work, from the west to the east, the first third, the second third, and the last third of the runway surface was covered with snow, 40%, 60% and 80%, respectively. It is probable that the closer the Aircraft came to the final stage of landing roll, the wider area the snow remained on the runway. The measurement of friction coefficients was completed at 22:06. This means that after completion of this measurement, about 20 minutes elapsed by the time the Aircraft landed. As described in 2.6.2 and 2.6.6, light shower snow and snow pellets continued to fall during this period. Therefore, it is probable that the runway conditions changed between the time of measurement and landing. However, as described in 2.6.6, the snowfall after the snow removal work was not a heavy one. Therefore, it is highly probable that this snowfall did not exceed the Criteria for the Initiation of Snow Removal described in 2.6.5 (3).

As described in 2.6.2, the ambient temperature was 1°C, which was close to the freezing point but was neither equal to, nor below, the freezing point. Therefore, it is probable that a portion of snow or snow pellets melted into water, and another portion remained in a solid state without melting. In this regard, 2.1.2 contains the following statement: "He felt that the runway appeared more whitish than expected. The runway marking was visible." It is probable that this statement shows that the runway was thinly covered with snow or snow pellets that remained on the runway without melting. On the basis of the above, it is probable that the runway conditions at the time of the landing were in a slushy state due to the changes that occurred during the time that elapsed from when the snow/ice condition assessment was conducted.

3.4 Conditions of the Devices Related to Braking

It is highly probable that as described in 2.10.1 to 2.10.4, there were no anomalies in the devices related to braking.

As described in 2.10.3, tread rubber degradation marks were noticed in local portions of tire surfaces of all main landing gear wheel assemblies. It is somewhat likely that these marks were caused by a hydroplaning *8 phenomenon that occurred at an extremely low speed.

3.5 Landing Roll

(1) Touchdown and Immediately Thereafter

It is highly probable that as described in 2.1.1.1, the Aircraft made an ILS approach to Runway 09 of Shonai Airport with "Flap 30" configuration, and touched down at 22:26:11 in the vicinity of the centerline approximately 480 m from of the approach end with 140 kt CAS and 147 kt GS.

As described in 2.1.1.2 (1), the touchdown was followed by the following sequence: The autobrakes were activated; the brake pressure rose; the speed brakes were deployed; the thrust reversers were activated with simultaneous sharp engine power up. The deceleration rate increased rapidly. When 0.22 G was exceeded, the brake pressure started to drop. The deceleration rate rose to a maximum of 0.27 G, and then returned to 0.22 G. Therefore, it is highly probable that the autobrakes were set to "3," and were activated as designed as described in 2.11.3 (2). It is highly probable that during this interval, with the CAS 116 kt or more, the aerodynamically generated braking force by the speed brakes and thrust reversers exerted a great deal of action.

(2) Deceleration by Autobrakes

As described in 2.1.1.2 (2), the deceleration rate remained at a level of 0.22 G, and the brake pressure was 1,000 psi or less. Therefore, if a comparison is made with the maximum brake pressure of 2,000 psi for "Autobrake 3" described in 2.11.3 (2), it is highly probable that the Aircraft decelerated normally at a deceleration rate controlled by a brake pressure with a sufficient margin. It is highly probable that the reason of gradual brake pressure rise is explained as follows: According to the fact that the CAS dropped from 116 kt to 59 kt, the braking force generated by the speed brakes and thrust reversers dropped; autobrakes compensated the loss of braking force. As described in 2.1.1.2 (2), the PIC said, "I'll disarm the autobrakes" at 22:26:21. Because of this fact, it is highly

*8 "Hydroplaning phenomenon" is the phenomenon which occurs to the tires of a vehicle when a layer of water builds between the wheels of the vehicle and the road surface, leading to a loss of traction that prevents the vehicle from responding to control inputs.

probable that the PIC's brake pedals input explains the abrupt brake pressure rise. Also, it is highly probable that the autobrakes were disengaged due to this operation.

(3) Manual Brakes Deceleration

As described in 2.1.1.2 (2) and 2.1.1.2 (3), when the remaining distance of the runway was about 500 m, the PIC pressed down on the brake pedals, resulting in the autobrake disengagement. Immediately thereafter, the deceleration rate began to fluctuate with increasing range even with the operating thrust reversers and speed brakes. The fluctuation range gradually decreased. The disengagement of the autobrakes possibly affected the reduction of the braking force, because the manual braking, unlike the automatic braking, has difficulties of accurate control of the brake pressure depending on deceleration rates, and the brake pedals were not pressed down to the maximum extent at first. Besides, it is highly probable that the CAS less than 60 kt degraded the braking force generated by the speed brake. There is another possibility of additional negative effect on the thrust reverser caused by the tailwind.

It is probable that the brake pressure's instantaneous drop and immediate rise at 22:26:35 is explained by the PIC's brake input after releasing the brakes once to allow the tires to regain the runway traction under the suspicion of slipping tires.

At 22:26:29, the FO uttered "60" and the reverse thrust levers were released from the maximum position and set to the "Idle" position at 22:26:35 after taking six seconds. The PIC probably took time to move the reverse thrust levers as he did not feel the sense of significant deceleration and was probing the reverse thrust.

At 22:26:36, the FO said, "GS still 50." At 22:26:38, the brake pressure rose to the maximum pressure value (3,000 psi) with the runway remaining distance 230 m. At the same time, the following sequence occurred: The reverse thrust levers moved to the "Down" position while the thrust reverser sleeves were retracted; the engine power output dropped to the "Forward Idle" level, resulting in further reduction in the deceleration rate. It is highly probable that the sleeve retraction and power reduction affected the initial rise of the reverse thrust by delaying, which followed immediately after this.

(4) Recognition of the unusual situation and the urgent actions taken

As described in 2.1.1.2 (4), the brake pressure remained at the maximum level at all times. It is probable that this is because, as described in 2.1.2 and 2.1.3, the PIC and the FO pressed down on the brake pedals at the same time. At 22:26:43, as described in 2.1.1.2 (4), the reverse thrust levers moved from the "Down" position to the "Idle" position. It is somewhat likely that the PIC decided to use the thrust reversers for the second time. Although the reverse thrust levers moved to the maximum position when the runway remaining distance was approx. 80 m, it is highly probable that the engine power did not rise immediately as it was almost idle. Somewhere between 22:26:51 and 22:26:53, the GS became approx. 30 kt and the deceleration rate rapidly decreased from the steady level of 0.1 G. This mirrors somewhat likely hydroplaning phenomenon at very low velocity (see 3.4) on contaminated non-grooved overrun zone as the spinning wheels were locked.

Subsequently, between 22:26:53 and 22:26:55, not only did the engine speed rise, but also the deceleration rate increased.

As described in 2.1.1.2 (4), with the left rudder pedal input, the heading gradually deviated leftward. It is highly probable that this maneuver demonstrates, as mentioned in the statement in 2.1.2, an evasive action to clear the non-recessed overrun zone lights, meaning controllable steering capability.

(5) Beyond the overrun zone

The instantaneous rise of the deceleration rate to 0.34 G (the maximum level) followed by immediate decrease thereof, stabilizing at a level of 0.2 G until the halt of the Aircraft, was probably caused by the braking forces of the thrust reversers combined with the wheel brakes, as well as the increased resistance due to the sunk wheels in the soft grass area as described in 2.8.2.

3.6 Airplane Braking Coefficient and Landing Stopping Distance

As described in 2.10.5 (1), the average μ_A value calculated during a landing roll based on the QAR data, on and after the use of the MAXIMUM manual brakes is approx. 0.08.

As described in 2.10.5 (2), the Aircraft's landing distances were calculated using the Low Speed Performance Software that was developed by the designer/manufacturer and used for analysis of takeoff/landing performance. The matrix was set with three brake conditions (Autobrake 3, Autobrake MAX, and Manual Brake MAXIMUM) against three runway conditions and one friction coefficient ("Good," "Medium," and "Poor," and μ_A 0.08). The calculated landing stopping distances for "μ = 0.08" stood somewhere between "Medium" and "Poor" regardless of brake conditions.

As described in 3.3.3 and 3.5 (3), the snow in the 230 m-long section to the runway east end, where the maximum brake pressure was applied, was slushy with the runway conditions equivalent to "Medium to Poor." These facts probably caused the tire friction to become reduced.

As shown in the table given in 2.10.5 (2), according to the stopping distance calculated using the serious incident QAR data, it is highly probable that the Aircraft could have been able to stop within the runway length even in the case of "Autobrake 3" if the runway conditions had been "Good." This is because the calculated stopping distance is 1,856 m. However, if the μ_A had been 0.08 throughout the runway as in the case of the 230 m long section to the runway east end, and if all systems other than the brake systems had been operated in the same way as in this serious incident, the "Autobrake 3" stopping distance would have been 2,143 m in excess of 143 m; the "Autobrake MAX" stopping distance would have been 2,061 m in excess of 61 m; and the "Manual Brake MAXIMUM" stopping distance would have been 2,027 m in excess of 27 m. It is somewhat likely that in any of the above brake operation cases, the Aircraft could not have been able to stop within the runway length. Therefore, longer use of the thrust reversers than usual could have possibly shortened the landing stopping distance.

3.7 Antiskid System

The AACU detailed inspection found no anomalies as described in 2.10.4. Therefore, it is highly probable that all functions incorporated in this Aircraft's antiskid system described in 2.11.3 (1) functioned normally.

As described in 3.6, the slushy runway conditions highly probably degraded the frictional force between the tires and the runway surface. On the other hand, as described in 3.4 and 3.5 (4), degeneration mark were left on the tire surfaces of the main landing gears possibly caused by a hydroplaning phenomenon at extremely low speed.

As described in 2.11.3 (1), in case of a hydroplaning phenomenon with speed gap of 50 kt or more between the GS and wheel speed, the hydroplane protection is activated. Even if the gap is smaller, the skid control is activated. However, if the wheel speed is less than 8 kt, the skid control is not activated. The tread rubber degeneration marks mentioned in 3.4 were possibly generated in the GS range of approx. 30 kt as described in 3.5 (4). These marks were possibly generated as a result of complete wheel lock which was caused by unavailable skid control under the speed range of less than 8 kt wheel speed. This suggests that an approx. 22 kt speed gap existed between the GS and wheel speed at that time.

3.8 Approach Configuration and Post-Landing Procedure

The landing flap setting, autobrake setting and its operation, and the speed brake operation were within the scope of the "Recommended Procedure" described in 2.11.1 under the circumstance of informed "Good " braking action. However, attention should be given to the interpretation of the term "Skid" in "Skid or Loss of Directional Control" that corresponds the phase where the brake release and thrust reverser Idle are recommended in the "Recommended Procedures". It means airplane's side skidding only, and does not mean the "slip of a tire."

The Recommended Procedures probably does not include the following operations: The manual brake pedals were not pressed down to the maximum stroke but the pedal forces were released in the middle on the 2,000 m runway under snowing conditions although no sufficient braking effect was felt; and the reverse thrust levers were returned to the "Idle" position. Their impact on the overrunning is unknown. Furthermore, the operation of returning the thrust levers to the "Down" position intending to the "Idle" affected the delay in the initial rise of the reverse thrust that was to be used immediately after this operation, and it is probable that there was a lack of caution.

It is probable that as described in 3.6, the runway conditions at the time of the landing of the Aircraft were such that the braking action was lower than informed braking action "Good." Conceivable operations for shorter landing role than that at the time of the serious incident are: reduced approach velocity with the flap position set to "40"; setting the autobrakes to "MAX" and using the autobrakes for sufficiently a long time; and using the thrust reversers for longer time. On slippery runways in particular, there are cases where wheel brakes cannot demonstrate the expected performance. In order for an immediate use the thrust reversers on such an occasion, it is probably necessary to hold the reverse thrust levers in the "Idle" position not returning them to the "Down" position.

It is difficult to conduct a real-time snow/ice condition assessment for a landing. Therefore, in circumstances where drastic weather changes are expected, it is probably desirable to assume a more severe situation than the informed braking action establishing a safer approach configuration with post-landing stopping actions.

3.9 Response of the Airport Fire-Fighting Team

As described in 2.9, the Airport Fire-Fighting Team was in garage stand-by even after crash phone message No. 1 "possible overrun" was received from the air control tower. It is probable that the team should have been dispatched to the incident site in preparation for possible fire,.

3.10 Crew Training

As described in 2.11.2, the Company trained the PIC and First officer in slippery runway conditions once a year as part of periodic training. Also, when pilots are promoted to PICs, training is conducted as winter operation experience. The Aircraft flight crew received training as prescribed. Therefore, they were able to fly in accordance with the pertinent procedure. However, in addition to the proper understanding of the AOM, it may be desirable to give them clear understanding of establishing safer approach configurations and the implementation of safer post-landing role under quickly changing weather situations through education and training, and sufficient knowledge for proper situation analysis.

3.11 Trend of Snow/Ice Condition Assessment

As described in 2.11.5, the United States and an international organization are reexamining new methods of snow/ice condition assessment. In Japan, problems and tasks are being identified by the CAB, MLIT for introduction of a new system. The JTSB hopes that a system is introduced as soon as possible, which provides fresh information on the latest runway conditions to pilots, and enables their proper decision and operations.

4 CONCLUSIONS

4.1 Summary of Analysis

(1) Weather

It is highly probable that the weather around the Airport was as follows: Echoes, which in conjunction with a typical winter pressure pattern, developed into a large streaky shape extending north and south, successively covered the Airport from west to east bringing in rough unstable weather. It is highly probable that on the basis of the wind condition information received while standing by high above in the air, the PIC opted to make an ILS approach to Runway 09; during the approach, he received information that the wind conditions changed with respect to the runway conditions, but he confirmed that there was no problem in terms of the performance; he decided to land. (3.3.1)[9]

The wind data communicated at the time of landing judgment was within the limits. (3.3.2)

It is probable that the runway conditions at the time of the landing of the Aircraft were in a slushy state due to the changes that occurred during the time that elapsed from when the snow/ice condition assessment was conducted. (3.3.3)

(2) Conditions of the Devices Related to Braking

It is somewhat likely that the tread rubber degeneration marks that were noticed in local portions of the tire surfaces of all main landing gear wheel assemblies were caused by a hydroplaning phenomenon that occurred at an extremely low speed. (3.4)

(3) Landing Roll

It is highly probable that the Aircraft made an an ILS approach to Runway 09 of

*9 Numbers described at the end of the text in this section show each prime number of "3 Analysis" related to the description.

Shonai Airport with "Flap 30" configuration, and touched down at 22:26:11 in the vicinity of the centerline approximately 480 m from the approach end with 140 kt CAS and 147 kt GS. It is highly probable that the autobrakes were activated; the brake pressure rose; the speed brakes were deployed; the thrust reversers were activated with simultaneous sharp engine power up immediately after touchdown.

It is highly probable that the autobrakes were disengaged due to the fact that the PIC pressed down on the brake pedals when the remaining distance of the runway was 500 m.

The disengagement of the autobrakes possibly affected the reduction of the braking force, because the manual braking, unlike the automatic braking, has difficulties of accurate control of the brake pressure depending on deceleration rates, and the brake pedals were not pressed down to the maximum extent at first. It is somewhat likely that the tailwind affected the braking force of the thrust reversers. At 22:26:38, the brake pressure rose to the maximum pressure value with the runway remaining distance 230 m. At the same time, the following sequence occurred: The reverse thrust levers moved to the "Down" position while the thrust reverser sleeves were retracted; the engine power output dropped to the "Forward Idle" level, resulting in further reduction in the deceleration rate. It is highly probable that the sleeve retraction and power reduction affected the initial rise of the reverse thrust by delaying, which followed immediately after this.

At 22:26:43, the reverse thrust levers moved from the "Down" position to the "Idling" position. It is somewhat likely that the PIC decided to use the thrust reversers for the second time. The reverse thrust levers moved to the maximum position when the remaining distance of the runway was about 80 m. However, it is highly probable that since the engine power did not rise immediately as it was almost idle. Somewhere between 22:26:51 and 22:26:53, this mirrors somewhat likely hydroplaning phenomenon at very low velocity on contaminated non-grooved overrun zone as the spinning wheels were locked. It is highly probable that the Aircraft had controllable steering capability.(3.5)

(4) Airplane Braking Coefficient and Landing Stopping Distances

The average μ_A value calculated during a landing roll based on the QAR data, on and after the use of the MAXIMUM manual brakes is approx. 0.08. The runway conditions were such that the braking action was between "Medium" and "Poor." The snow in the 230 m-long section to the runway east end, where the maximum brake pressure was applied, was slushy with the runway conditions equivalent to "Medium to Poor." These facts probably caused the tire friction to become reduced. It is highly probable that the Aircraft could have been able to stop within the runway length even in the case of "Autobrake 3" if the runway conditions had been "Good." However, if the μ_A had been 0.08 throughout the runway as in the case of the 230 m long section to the runway east end, and if all systems other than the brake systems had been operated in the same way as in this serious accident, then it is somewhat likely that in any of the following brake operation cases, the Aircraft could not have been able to stop within the runway length: "Autobrake 3," "Autobrake MAX," or Manual Brake MAXIMUM." Therefore, longer use of the thrust reversers than usual could have possibly shortened the landing stopping distance. (3.6)

(5) Antiskid System

It is highly probable that all functions incorporated in the antiskid system functioned normally. It is somewhat likely that the tread rubber degeneration marks were generated as a result of complete wheel lock which was caused by unavailable skid control under the speed range of less than 8 kt wheel speed in the GS range of approx. 30 kt. (3.7)

(6) Approach Configuration and Post-landingProcedure

The Recommended Procedures probably does not include the following operations: The manual brake pedals were not pressed down to the maximum stroke but the pedal forces were released in the middle on the 2,000 m runway under snowing conditions although no sufficient braking effect was felt; and the reverse thrust levers were returned to the "Idle" position. Their impact on the overrunning is unknown. Furthermore, the operation of returning the thrust levers to the "Down" position intending to the "Idle" affected the delay in the initial rise of the reverse thrust that was to be used immediately after this operation, and it is probable that there was a lack of caution. On slippery runways in particular, it is probably necessary to hold the reverse thrust levers in the "Idle" position not returning them to the "Down" position. In circumstances where drastic weather changes are expected, it is probably desirable to assume a more severe situation than the informed braking action establishing a safer approach configuration with post-landing stopping actions. (3.8)

(7) Action of the Airport Fire-Fighting Team

It is probable that the Airport Fire-Fighting Team should have been dispatched to the incident site as soon as crash phone message No. 1 was received. (3.9)

(8) Crew Training

In addition to the proper understanding of the AOM, it may be desirable to give them clear understanding of establishing safer approach configurations and the implementation of safer post-landing role under quickly changing weather situations through education and training, and sufficient knowledge for proper situation analysis. (3.10)

(9) Trends of Snow/Ice Condition Assessment

New methods of snow/ice condition assessment are reexamining. The JTSB hopes that a system is introduced as soon as possible, which provides fresh information on the latest runway conditions to pilots, and enables their proper decision and operations. (3.11)

4.2 Probable Causes

In the serious incident, it is highly probable that the overrun occurred as the Aircraft failed to exert the expected braking force under the informed runway conditions after the landing.

It is probable that the changed runway conditions due to snowfall and other elements near freezing temperature after the snow/ice measurement negatively affected the expected braking force.

5 SAFETY ACTIONS

Safety Actions Taken by the Company Subsequent to the Serious Incident

(1) In view of the occurrence of this serious incident, an in-house document explaining the following matters was issued for all flight crew members, and steps were taken to make known to all those concerned about the criteria for the snow/ice landing performance, the autobrake landing performance, and the main points to note during landing on runways

covered with snow/ice (December 2012).

The main points to note in this document are as follows:

1) If there is no margin in the landing performance, then selection should be made of an autobrake setting value for which the stopping performance of autobrakes is taken into account.

2) If the brake effect cannot be confirmed in the case of autobrakes, then manual brakes should be used.
(PMs should notify PFs that autobrakes are disengaged.)

3) After touchdown, "Full Reverse" should be used immediately.

4) If a change is to be made from "Full Reverse" to "Idling Reverse," an abrupt decrease in the deceleration rate due to sudden operation should be avoided.

5) "Idle Reverse" should be used until the speed drops to the "Taxiing Speed."

6) In emergencies where, for example, the desired deceleration rate cannot be obtained by "Manual Full Brakes" and "Idle Reverse," "Full Reverse" should be used until the aircraft comes to a complete stop.

(2) An in-house document aimed at the promotion of the understanding of the method of dealing with the side skidding of aircraft during a landing roll on snow ice-covered runways, which is contained in the AOM that form part of the Operation Manual, was issued and made known to all those concerned (January 2013).

In this respect, this document contains the following statement.
The item "Skid or Loss of Directional Control" is a synopsis of "Reverse Thrust and Cross-wind" contained in 4-3-3-(3). The term "Skid" here means only a "state where the airplane has side skidded only."

(3) An in-house document explaining the following matters was issued with respect to the type of aircraft, and steps were taken to make known to all those concerned the criteria for the snow/ice landing performance; the autobrake landing performance; and the main points to note during landing on snow/ice runways (February 2013).

In this respect, a summary of the main points to note which are contained in this document and which apply to cases where autobrakes is used on a snow-ice-covered runway are as follows:

1) If there is no margin in the landing performance, then the landing distance should be calculated depending on the runway conditions, the approach speed, the tailwind. "Autobrake MAX" should be selected as necessary.
(The rest is omitted.)

2) After touchdown, "Full Reverse" should be used immediately.

3) After touchdown, if the desired deceleration rate cannot be obtained by means of the selected autobrake setting, then the manual brakes should be used.

4) If the thrust reverser settings are to be returned to "Idle Reverse" from "Full Reverse," then abrupt reduction in the deceleration rate due to sudden operation should be avoided.

(4) An in-house safety education magazine featured the case example regarding this serious incident, and points to note in the case of snow/ice-covered runways, in order to prevent the recurrence of overrun events on snow/ice-covered runways (November 2013).

The following are some of the precaution statements in the said safety education magazine, which pertain to a tailwind landing.

Generally speaking, there is a tendency that the stronger the tailwind, the more *difficult the flaring becomes, resulting in varied touchdown point locations.*

Particularly, on a snow ice-covered runway whose length is 2,000 m or less, there is no performance margin by nature. Therefore, if a tailwind landing is to be made, it is important to maintain an appropriate margin depending on the wind direction, the wind velocity variable, and gusts, to maintain the target approach speed, and to control the aircraft in such a way as to be sure to touch down at the aiming point.

If a stabilized approach is deviated from, or if the touchdown point turns out to be distant from the desired spot, execute a go-around without hesitation.

Furthermore, specific points to note in the case where landing is to be made on a snow/ice-covered runway are as follows:

After confirming the landing performance, the landing distance should be ascertained using the Landing Distance with Automatic Wheel Brake Table or the like, then the landing flap angle and the autobrake setting should be selected. At this time, the optimum flap angle and autobrake setting should be selected depending on the actual runway length, on the basis of the principle that on a snow/ice-covered runway, the deepest flap angle and the strongest autobrake setting should be used.

In this respect, in the case of a snow/ice-covered runway with a length of 2,000 m or less, "Autobrake MAX" is recommended for B737, B767, and B787, except for the case where it is evident that the snow/ice portion is only partial (such as where the "Coverage" in SNOWTAM is less than 20%).

(5) A summary of this serious incident, and points to note regarding snow/ice-covered runways, was made known to all personnel engaged in ground operations (dispatchers and operation controllers) by means of a business notice to get their attention (November 2013).

A summary of the points to note is as follows:

1) Changes in the snow/ice-covered runway conditions (particularly there is reports of cases where the ambient temperature is in the range of 0°C and wet snow, slush, etc. covers more than 60%)
   a. Information should be sufficiently shared with the airport administrator with regard to the possibility of the deteriorating runway conditions, and the measures to be taken. Take actions so that the pertinent conditions will not become worse than they already are.
   b. The runway conditions should be grasped at a timing as close to the landing time as possible, and be forwarded to the flight crew.

2) Matters such as notification of tailwinds on snow ice-covered runways

   In cases where a headwind changes to a tailwind, or where the tailwind velocity increases further, it is important to immediately notify the landing aircraft accordingly.

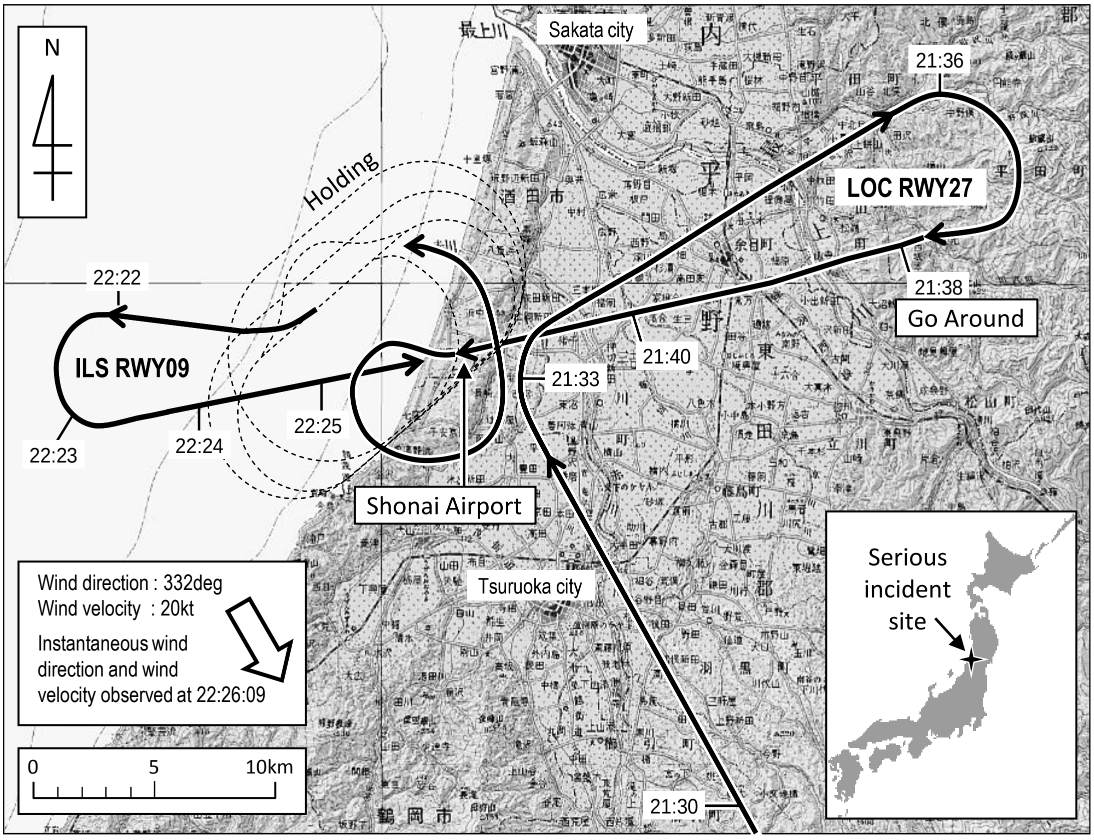
(6) The table, titled "Landing Distance with Automatic Wheel Brake," which shows autobrake stopping distances and contained in the AOM, was changed into a practical format so that it can be easily referred to during flight. This table was reflected in the Performance Handbook (a document in which performance data with high use frequencies are presented so that flight crew members can easily refer to it on board) (November 2013).

(7) As measures to be taken at Shonai Airport in the winter of FY 2013, coordination was made with the relevant organizations with regard to a framework for conducting snow/ice measurement again before landing, if necessary. Steps were taken, by means of a business

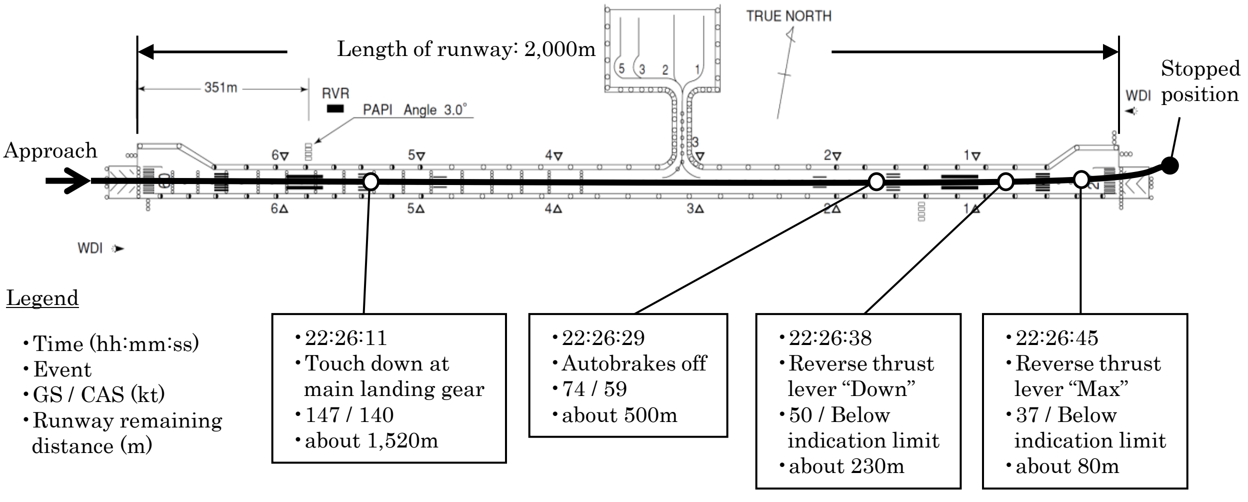
notice, to make the resulting operating procedures known to all in-house personnel concerned (December 2013).

In specific terms, snow/ice condition assessments at Shonai Airport are conducted so that the assessment results can be forwarded to the arriving aircraft by 20 minutes before the ETA (Estimated Time of Arrival). Subsequently, if the runway conditions are predicted to deteriorate due to the weather conditions, and if the ground measurement coordination is made ready for action, then the inspection is conducted again, and the results are forwarded to the aircraft from the Radio no later than 10 minutes prior to the ETA.

Figure 1: Estimated Flight Route



This figure uses information from a 1:200,000 map provided by the Geospatial Information Authority's cartographic information service.



This figure uses a figure of AIP (Aeronautical Information Publication).

Figure 2: Records of the DFDR

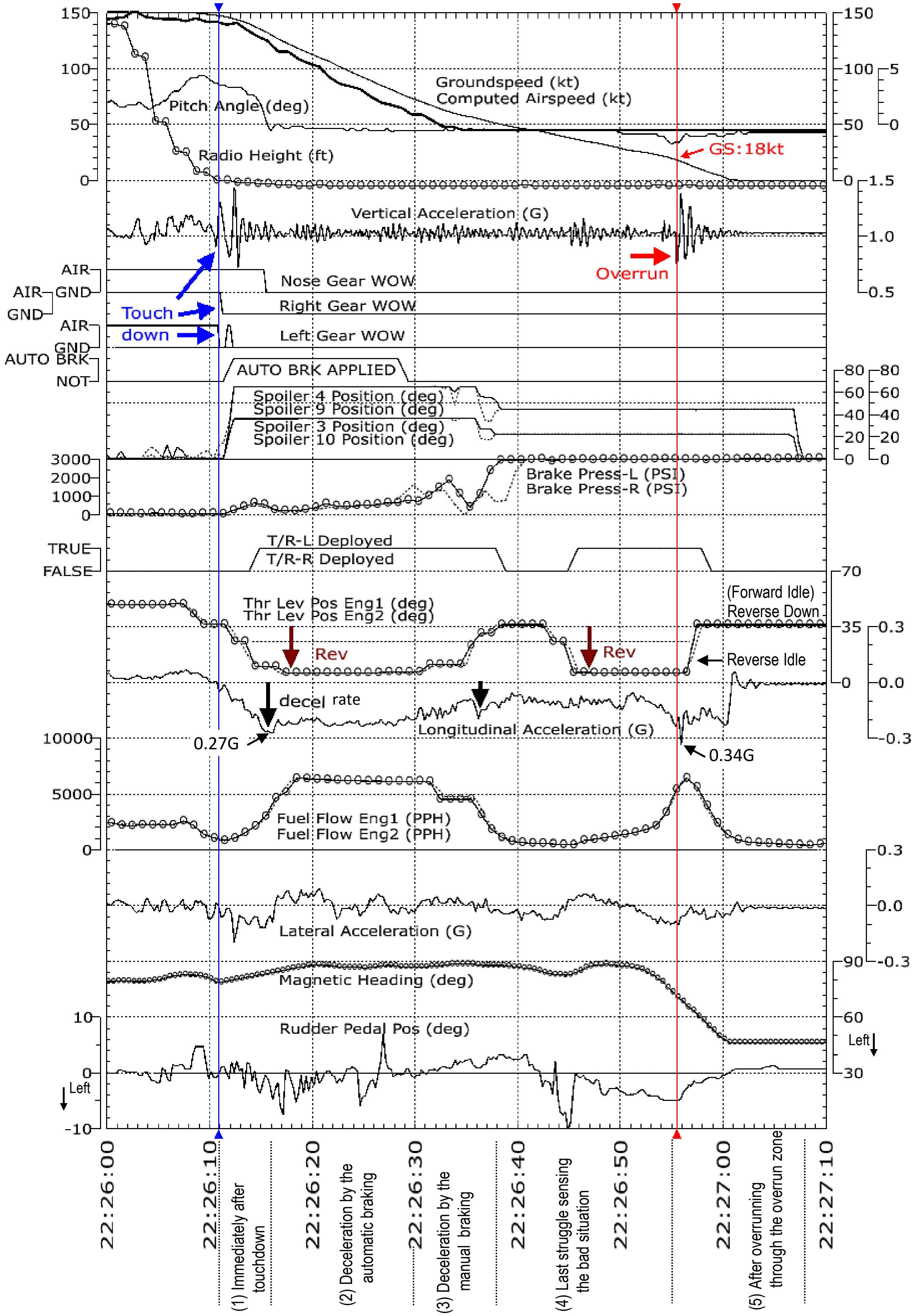


Figure 3: Three-view Drawing of a Boeing B737-800