2003-5

AIRCRAFT ACCIDENT INVESTIGATION REPORT

ALL NIPPON AIRWAYS FLIGHT 391
AIRBUS A321－131, JA104A
HAKODATE AIRPORT, HOKKAIDO, JAPAN
JANUARY 21, 2002

September 26, 2003

Aircraft and Railway Accidents Investigation Commission
Ministry of Land, Infrastructure and Transport

The investigation for this report was conducted by Aircraft and Railway Accidents Investigation Commission, ARAIC, about the aircraft accident of All Nippon Airways Airbus 321-131 in accordance with Aircraft and Railway Accidents Investigation Commission Establishment Law and Annex 13 to the Convention of International Civil Aviation for the purpose of determining cause of the aircraft accident and contributing to the prevention of accidents and not for the purpose of blaming responsibility of the accident.

This English version report has been published and translated by ARAIC to make its reading easier for English speaking people those who are not familiar with Japanese. Although efforts are made to translate as accurate as possible, only the Japanese version is authentic. If there is difference in meaning of the texts between the Japanese version and the English version, texts in the Japanese version are correct.

Junzo Sato,
Chairman,
Aircraft and Railway Accidents Investigation Commission

Abbreviated words

Abbreviated words used in this report are as follows:

AOM	:	Airplane Operations Manual
AOR	:	Airplane Operations Reference
APPR	:	Approach
ATIS	:	Automatic Terminal Information Service
A／THR	:	Auto Thrust Function
BEA	:	BUREAU D'ENQUETES ET D'ANALYSES POUR LA SECURITE DE L'AVIATION CIVILE (The French Bureau of Investigation and Analysis for Safety in Civil Aviation)
CA	:	Cabin Attendant
CAS	:	Computed Airspeed
CA／SS	:	Captain's Sidestick
CO／SS	:	Co-pilot's Sidestick
CVR	:	Cockpit Voice Recorder
CRM	:	Crew Resource Management
DFDR	:	Digital Flight Data Recorder
EGPWS	:	Enhanced Ground Proximity Warning System
FAC	:	Flight Augmentation Computer
FAF	:	Final Approach Fix
FCOM	:	Flight Crew Operating Manual
FD	:	Flight Director
FL	:	Flight Level
FMGC	:	Flight Management Guidance Computer
ILS	:	Instrument Landing System
MAC	:	Mean Aerodynamic Chord
MCDU	:	Multipurpose Control and Display Unit
OM	:	Operations Manual
PF	:	Pilot Flying
PFD	:	Primary Flight Display
PNF	:	Pilot Not Flying
P／FR	:	Pressure Falling Rapidly
RET	:	Retract
QAR	:	Quick Access Recorder

ＳＰＤ／ＭＡＣＨ ： Speed/Mach
ＳＲＳ ： Speed Reference System
ＴＬＡ ： Thrust Lever Angle
ＴＯ／ＧＡ ： Take-Off-Go-Around
ＵＴＣ ： Coordinated Universal Time
ＶＨＦ ： Very High Frequency
ＶＯＲ ： VHF Omni-Directional Radio Range
ＶＯＲ／ＤＭＥ ： VOR and DME Combination
V_{APP} ： Approach Speed
$V_{\alpha MAX}$ ： Speed for the Maximum Angle of Attack
V_{LS} ： Lowest Selectable Speed
V_{REF} ： Landing Reference Speed
V_S ： Stalling Speed

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ALL NIPPON AIRWAYS FLIGHT 391
AIRBUS A321−131, JA104A
HAKODATE AIRPORT, HOKKAIDO, JAPAN
AT ABOUT 13:03 JST, JANUARY 21, 2002

September 10, 2003

Decision by the Aircraft and Railway Accidents Investigation Commission (Air Sub-committee Meeting)

Chairman	Junzo Sato
Member	Ryouhei Katsuno
Member	Susumu Kato
Member	Sumio Matsuura
Member	Yukiko Kakimoto
Member	Kozaburo Yamane

1 PROCESS AND PROGRESS OF THE ACCIDENT INVESTIGATION

1.1 Summary of the Accident

On Monday January 21, 2002, an Airbus A321-131 of All Nippon Airways, registration JA104A, departed Nagoya Airport as scheduled passenger flight 391 to Hakodate Airport. At around 13:03, while the aircraft executed a recovery manoeuvres as wind shear warning issued during approach to Hakodate Airport, the aft fuselage contacted the ground and as a result the aircraft sustained substantial damage.

Of the 93 persons aboard flight 391 - 87 passengers and six crewmembers - three cabin attendants sustained minor injuries.

1.2 Outline of the Accident Investigation

1.2.1 The Organization of the Investigation

On January 21, 2002, the Aircraft and Railway Accident Investigation Commission (ARAIC) assigned an investigator-in-charge and two other investigators.

On October 5, 2002, a new investigator-in-charge was assigned as a result of personnel transfers, and an additional investigator was also assigned.

1.2.2 Accredited representative and adviser by Foreign Authorities

Accredited representatives from the French republic, the state of design and manufacture of the aircraft, participated in the investigation of this serious incident.

1.2.3 The Implementation of the Investigation

The investigation proceeded as follows.

January 22–23, 2002	On-site and aircraft investigation
January 22–April 23, 2002	Interviews the crew and eyewitnesses
January 22–February 22, 2002	Analysis of Digital Flight Data Recorder (DFDR) and Cockpit Voice Recorder (CVR) recordings
February 1, 2002	Assignment of Accredited Representatives from the state of manufacture
April 9, 18 and November 21, 2002	Flight tests using a flight simulator

1.2.4 Hearings from Persons relevant to the Cause of the Accident

Hearings were held.

1.2.5 Report and Disclosure to Public

Regarding the process of the accident investigation, ARAIC had submitted the interim report to the Minister of Land, Infrastructure and transport and made disclosure to public on January 31, 2003.

2 FACTUAL INFORMATION

2.1 History of Flight

2.1.1 Outline of the Flight based on the DFDR and CVR, etc.

On January 21, 2002, an Airbus A321-131 of All Nippon Airways, registration JA104A, was operating as scheduled flight 391 from Nagoya to Hakodate.

The flight plan of the aircraft which was submitted to the Nagoya Airport Office of Japan Civil Aviation Bureau (CAB) was as follows:

FLIGHT RULES: IFR, DEPARTURE AERODROME: Nagoya Airport, EOBT: 11:45, CRUISING SPEED: 436kt, CRUISING ALTITUDE: FLIGHT LEVEL 370, ROUTE OF FLIGHT: KROBE–Y13–MRE–V31–HWE, DESTINATION AERODROME: Hakodate Airport, TOTAL EET: 1 hours 01 minutes, ENDURANCE: 4 hrs 19 minutes, PERSONS ON BOARD: 93.

The flight crew were briefed for the flight by the dispatcher before departure from Nagoya Airport. The contents of the briefing relating to the weather at Hakodate Airport and its vicinity were as follows: Approach Procedure: ILS RWY 12, Ground Visibility: 5–10km, Winds: strong, but no hindrance to landing.

The aircraft took off from Nagoya Airport at 11:53, and then, the aircraft thence proceeded to Hakodate Airport via Akita VOR/DME and Aomori VOR/DME. After beginning descent from cruise altitude, the aircraft was radar vectored onto the final approach course by the Hakodate Approach Control, and commenced an ILS Runway 12 approach at Hakodate Airport.

During the approach, the Captain assumed the duties of Pilot Not Flying (PNF) from the left cockpit seat, while the right-seated First Officer assumed Pilot Flying (PF) duties.

The aircraft encountered light turbulence during the approach. Hakodate Airport Tower reported the wind for runway 12 as 130°/28kt, a strong and slightly right crosswind.

Although the approach course and flight path angle of aircraft were both normal during the approach, the aircraft's wind shear warning system issued an aural wind shear warning at around 140 m from the runway threshold, at an altitude of 53 ft above ground level (AGL) while the aircraft was flying over the approach lights for runway 12.

Although the crew initiated a go-around to recover from the wind shear, the aircraft's aft fuselage contacted the runway at around 13:03, and as a result substantial damage was sustained. The aircraft continued to go around for recovery from the wind shear after contacted aft fuselage with the runway. The crew made another ILS approach to runway 12, and landed at Hakodate Airport at around 13:21 uneventfully.

An external check after arrival found that damage had been sustained to the lower surface of the aft fuselage.

Of the 93 persons aboard flight 391 - 87 passengers and six crewmembers - three of the four cabin attendants sustained minor injuries such as bruising of the lower back etc.

2.1.2 Statements of Persons Concerned regarding the History of Flight

2.1.2.1 Statements of the Flight Crew

(1) Statements of The Captain

"Although I knew there were rain and strong winds at our destination of Hakodate, the winds were almost headwinds and I did not consider wind shear, cross wind limits nor the like.

"We flied in cloud during the descent towards Hakodate airport. There were no big changes in the upper and lower winds or wind direction during the time we were radar vectored onto the final approach course of ILS runway 12 approach by the approach control, no different to the information received from the Tower. The airborne weather radar only indicated areas of rain, no red areas that should be avoided.

"During the approach, as it was rain, I sighted the runway as we were descending through around 2,000 ft (MSL). I recognized that the wind was from 140° at strength of 30 – 40 kt, and that there were wind variances but that the average was 25 – 30 kt with occasional gusts exceeding 40 kt. Because we were flying in cloud, the engine and wing anti-ice were switched 'ON'. There were no "virga", and there were no particularly unusual changes in the cloud conditions.

"I was acting as a PNF from the left seat. The First Officer, acting as a PF, disconnected auto-thrust at 1,000 ft MSL and disengaged the autopilot at around 500 ft MSL. The wind speed was fluctuating, and I called-out 'Airspeed' as our speed dropped 5 kt below the target value. Since he was making appropriate corrections and we were not deviating from the localizer or glide path, I allowed the First Officer to continue the PF duty. At around 100 ft AGL, I called-out 'Airspeed, airspeed' as our speed abruptly dropped more than 10 kt below the target value, and the First Officer increased power.

"After that, just as the power had started to be reduced, the aural wind shear warning issued. Although we began wind shear recovery, increased power to maximum thrust, we contacted the ground during the recovery. When we contacted the ground, I thought we had made a landing hardly, but I did not realize we had scraped the tail. The target approach airspeed was 143 kt, 11–12 kt greater than the V_{LS}. Since the wind-shear warning is inhibited below 50 ft AGL, I think perhaps it sounded at a higher altitude of between 100–50 ft AGL. There was a large sink at around 100 ft AGL, but no rolling left or right. The wind information from the Tower was 130° at twenty-something knots.

"Although this type of aircraft has a tendency to land with nose down pitch attitude if the approach speed is too high, we selected +11kt against the on-board computer indication of +8kt. Since the aircraft was being handled appropriately I did not take over control as Captain. After wind shear recovery, we set flap 3 and followed the go-around procedure, and I informed the Tower 'We are going-around, due to wind shear'.

"The Tower replied 'Follow missed approach', and we engaged the autopilot and changed PNF and PF roles."

While we asked the condition at the time of hard landing from CAs, they said there was no report for the injuries. After that, we landed at Hakodate Airport uneventfully.

(2) Statements of The First Officer

"We had received information on turbulence during flight due to a low pressure system. The weather information I had heard for our destination of Hakodate Airport was that the wind was strong but was a head wind, ILS approach was available, visibility was 10 km and even if it reduced it would be to around 8 km and so present no problem, the runway was wet, there was no information on icing or snowing, etc., and there were no problems for landing.

"During the approach to Hakodate Airport, although there were no indications of substantial echoes even in the vicinity of the airport on the aircraft's weather radar, there were amber rain areas. According to the Hakodate Airport ATIS (Automatic Terminal Information Service), the wind speed was 30 kt gusting to 42 kt and the visibility 8 km, but there was no information regarding wind shear, etc. After we were radar vectored onto the final approach course, then made ILS runway 12 approach. Although we were flying in cloud till 10,000 ft, there was no buffeting. Everything went smoothly, as we intercepted the glide path, we received landing clearance.

"There was strong head wind, so we set full flap at 2,500 ft in order to stabilize early. We completed the landing checklist.

"I set the target approach speed as V_{LS} plus 10 kt when strong wind conditions. At the time of this accident, though I intended to add 12 kt in consideration of gusts, I established it to 143 kt with plus 11 kt actually.

"We encountered some rough air. I disconnected auto-thrust at 1,000 ft MSL, and disengaged the autopilot at 500 ft MSL. There was no need to make large pitch or power changes and no especial deviation from the glide path, so no problems.

"Because our speed was fluctuating within a range of about 3 kt, I set the power so that the airspeed wouldn't go into the minus side. I set power a little on the high side, stabilizing the N1 values at around 52–53%. I was not aware of any large gusts.

"After that, the airspeed twice dropped well below the target. At those times, I kept the power as it was and didn't adjust it. On the first occasion the airspeed approached to the V_{LS}. Although I increased the engine power in response, the Captain called 'Airspeed'. When the airspeed had recovered to V_{LS}+20 kt, set the power back to its previous level. Then there was another large drop in airspeed just as I had started to retard the thrust levers, and immediately afterwards the aircraft sank. Then the 'Wind shear, Wind shear, Wind shear' aural warning sounded. I think the barometric altitude at that time was around 150 ft MSL. Our airspeed dropped more than 5 kt below V_{LS}, so I immediately set TO/GA and pulled to increase pitch as the ground was coming up. After I had set TO/GA, I felt a 'thud' of impact. I thought we had touched down a little hard. The wind was around 130°/25kt.

"Thereafter, I handed over control to the Captain and landed at Hakodate Airport uneventfully.

2.1.2.2 Statement of Cabin Attendants who sustained minor injuries

(1) Statements of The CA seated at the forward cabin L1 crew seat

"Although we had heard from the Captain that there was rough air, we had been able to perform the cabin service. The buffeting during the approach was no different from normal. One to two minutes before landing it was totally white outside. I had a feeling of dropping straight down as we were. I felt an impact. I announced that we were aborting the landing.

"I didn't feel as though I'd been injured at the time, but after I returned to Tokyo at 19:00 on the day, my coccyx had started to hurt a little. It started to hurt even more at around 4 a.m. the next morning so I went to the hospital at seven, but did not have to be admitted." The CA crew seats are almost like a board.

(2) Statements of The CA seated at the aft cabin R3 crew seat

"At the time we left Nagoya Airport we were briefed that although Hokkaido-bound flights except those for Hakodate had been diverted, the weather conditions at Hakodate Airport were good.

"The seat belt signs were illuminated during the flight, and buffeting had begun during the descent. Just before landing there was a strong shake, and just as I was thinking we would go around, I felt some 'G' force. We had pitched up, the engines had started to spool up, and just as I thought we had started to climb I heard the sound of a 'bang'. I thought the second landing went smoothly. In the same day, I returned to Tokyo, I felt a sense of incongruity of my waist, next day my waist and neck became painful.

(3) Statements of The CA seated at the aft cabin R4 crew seat

"I fastened my seat belt and shoulder-harness during the approach. I felt some sideways buffet, but no up/down motions. Just before we touched down, I felt we hit something below where I was sitting. It felt as though I were being hit by the seat, since the cabin attendant's seats are hard. I felt my head-ache. After we had recovered from the go-around, there was an announcement from a CA in the forward cabin. And then, there was also an announcement from the Captain.

"There was buffeting the second time approach as well, but it was a normal landing."

2.1.2.3 Statements of eyewitnesses

(1) Statements of Hakodate Tower ATC Controller

"After a commuter aircraft landed on runway 12 at 12:38, there were no other arrivals until the accident took place. At that time the aircraft was at 4–5nm on finals, and while I could see it from an altitude of 1,400–1,500ft, it was blurred due to slanting rain. It was a normal approach up until it passed over the approach lights.

"Just when I thought it was on the verge of landing, the nose came up abruptly and I felt it had landed on its tail, but it transited to go-around at that attitude. I think the wind value measured over a two minute interval at that time was a direction of 130–140° and a speed of 28–30kt with maximum of about 38kt.

"Two other aircraft landed in the time till the accident aircraft landed again. I thought that each of these three landings, including the second landing of the accident aircraft and the two other aircraft, were almost normal albeit a little unsteady."

(2) Statements of Employee of the Aviation Safety Institute of Hakodate airport

"I left the front of the Fire Station at 1 p.m., and drove along the perimeter road toward runway 12. I didn't think it was rained heavily, but I felt the wind swirling and hitting strongly from the side. While I was driving just alongside the touch down zone of runway 12, I saw flight 391 descending above the approach lights. At that time the wings rolled as if being hit by a gust of wind, and the aircraft sank. I thought it was coming down pretty close, and at that instant a splash of water was thrown off the runway, in the midst of which I could see yellow smoke. When I could see the aircraft again after the splash had fallen, I saw that it had started to climb. I thought from the climb angle of the fuselage at the time that the tail had scraped."

2.2 Deaths, Missing Persons and Injuries

The CA who had been seated on seat R4 in the rear of the cabin complained of abnormalities of the head stricken from just after the accident. And a further two CAs were diagnosed as having minor injuries as the result of examinations by a doctor on the day after the accident. A total of three CAs of those aboard the aircraft were found to have sustained minor injuries.

There were no injuries on passengers.

2.3 Damage to Aircraft

2.3.1 Extent of Damage

Substantial

2.3.2 Damage to Aircraft by Part

(1) Skin

Skin panels on the lower part of the aft fuselage were abraded to an extent of around 4.6m in length and a maximum width of around 80cm.

(2) Frames and Stringers

There was deformation of the ten frames (#63-#72) associated with the skin panels on which abrasions were found, and seven of these (#63, #65-#70) were found to have cracks. Four stringers that cross the cracked frames (stringer #: S41R-S39L) were also deformed.

(3) Aft Pressure Bulkhead

Cracks were found in two locations on the lower part of the aft pressure bulkhead.

(4) Floor Beams

A crack was found on the aft part of a floor beam of the aft cargo compartment.

2.4 Damage to Other than the Aircraft

Markings with a width of approximately 80cm were found on the runway at Hakodate Airport, thought to have been left by the contact of the lower surface of the aft fuselage of the accident aircraft. These started at a point 14.0m along runway 12 from approach end threshold, continued along the runway for a length of 15.9m from the approach threshold. However, there was no damage to the runway.

2.5 Personnel Information

(1) Captain: Male, aged 37

Airline Transport Pilot License		Issued January 9, 1998
Type Ratings	Airplane multiengine (land)	Issued August 6, 1985
	Airbus A320	Issued April 17, 1991
Class 1 Airman Medical Certificate	Term of Validity	until March 17, 2002
Total flight time		7,195 hours 42 minutes
Flight time during the previous 30 days		47 hours 49 minutes
Total flight time on Airbus A320		3,342 hours 14 minutes
Flight time during the previous 30 days		47 hours 49 minutes
Issuance of Captain Certificate on Airbus A320		February 20, 1998

(2) First Officer: Male, aged 38

Airline Transport Pilot License		Issued October19, 2000
Type Rating	Airplane multiengine(land)	Issued April 24, 1991
	Airbus A320	Issued January 7, 1993
Class 1 Airman Medical Certificate	Term of Validity	Until March 10, 2002
Total flight time		4,403 hours 35 minutes
Flight time during the previous 30 days		54 hours 15 minutes
Total flight time on Airbus A320		1,874 hours 28 minutes
Flight time during the previous 30 days		54 hours 15 minutes
Issuance of first officer Certificate on Airbus A320		April 10, 1993

(3) Other Qualifications

The Captain obtained a qualification for allowing a First Officer to carry out a landing from the right seat on October 1, 2000. The reported weather conditions at the time of the accident were within the limits to allow the First Officer to carry out the landing.

(4) Training for recovery from low altitude wind shear

The Captain and First Officer had received flight simulator training for recovery from wind shear encounters at low altitude and CRM training.

2.6 Aircraft Information

2.6.1 The Aircraft

Type	Airbus A320-131

Serial Number		1008
Date of Manufacture		April 13, 1999
Certificate of Airworthiness		99-086
Term of validity	Until valid data of ANA Maintenance Program Manual from April 30, 1999	
Total flight time		6,140 hours 49 minutes
Flight time since scheduled maintenance	"4C" Check on May 22, 2001	1,502 hours 09 minutes

2.6.2 The Engines

Type: International Aero Engines AG (IAE) model V2530-A5

	Serial No.	Date of manufacture	Total time in service
No.1	V10533	February 2, 1999	6,140 hours 49 minutes
No.2	V10959	March 18, 2001	1,502 hours 9 minutes

2.6.3 Weights and Center of Gravity

The weight of the aircraft at the time of the accident is estimated to have been approximately 147,360lb, with the centre of gravity at 25.1% MAC, both these values being within the allowable limits (maximum landing weight 162,000lb, with an allowable centre of gravity range corresponding to the weight at the time of landing of 12.0–41.0% MAC).

2.6.4 Fuel and Lubricating Oil

The fuel on board was JET A-1. The lubricating oil was ESSO ETO 2197.

2.7 Meteorological Information

2.7.1 Synoptic Weather

According to the surface weather chart at 09:00 on January 21, there was a depression with a central atmospheric pressure of 1,006hPa over the Sea of Japan S.W. of Hakodate, and a high-pressure system of 1,032hPa N.E. of Hakodate, both proceeding N.E. at a speed of 15–25 knots. At 15:00, the depression had deepened to 1,000hPa and the high-pressure system had increased to 1,036hPa. At the time of the accident the distance between the isobars were narrowing and the atmospheric pressure gradient was very high. According to this situation, at a time of accident, atmospheric pressure situation was estimated to blow strong winds, winter style distribution of atmospheric pressure changed, as the low pressure system approaching, supreme N-E wind was weaken.

A warning of strong airport surface winds was issued at 11:40 on the same day, and airport weather information related to heavy rain was issued at 11:45. At the time of the accident the wind velocity measurement device situated near runway 12 measured the wind as 130–140° at an average speed of 28kt, with a maximum speed of 40kt and a minimum speed of around 20kt.

Further, according to automatic recordings of real-time wind direction and speed at the Hakodate Airport branch of the Meteorological Agency's Hakodate Oceanic Meteorological Office, there was no difference in wind direction or speed between the 12 and 30 ends of the runway. (See Figs. 3 ~ 7).

2.7.2 Aeronautical Meteorological Observations at Hakodate Airport

The routine and special aeronautical meteorological observations by the Hakodate Airport branch of the Meteorological Agency's Hakodate Oceanic Meteorological Office during the time period relating to the accident were as follows:

Time of Observation	11:00 JST	11:20 JST	11:36 JST	12:00 JST	12:38 JST	13:00 JST
Wind Direction	140 degrees	140 degrees	130 degrees	140 degrees	130 degrees	130 degrees
Wind Speed	28 kt	28 kt (Gust 39kt)	28 kt	28 kt	29 kt (Gust 42kt)	28 kt
Visibility	More than10km, light rain	6 km, rain	8 km Light rain	More than10km, light rain	4.5 km, rain	6 km rain
Cloud amount	1/8	1/8	1/8	1/8	1/8	1/8
Cloud type	stratus	stratus	stratus	stratus	stratus	stratus
Height of cloud base	600 ft	600 ft	600 ft	500 ft	500 ft	500 ft
Cloud amount	5/8	5/8	5/8	5/8	5/8	5/8
Cloud type	stratus	stratus	stratus	stratus	stratus	stratus
Height of cloud base	900 ft	900 ft	900 ft	900 ft	900 ft	900 ft
Cloud amount	7/8	7/8	7/8	7/8	7/8	7/8
Cloud type	stratus	stratus	stratus	stratus	stratus	stratus

Height of cloud base	2,000 ft	1,800 ft	2,000 ft	2,000 ft	2,000 ft	2,000 ft
Temperature	7°C	6°C	7°C	7°C	7°C	7°C
Dew point	4°C	4°C	4°C	4°C	5°C	5°C
QNH	30.00 inHg	29.99 inHg P/FR	29.97 inHg	29.94inHg P/FR	29.92 inHg	29.91 inHg

2.7.3 Airport Gale Warnings, etc.

(1) Airport Forecast

The Airport Warning issued by the Hakodate Airport branch of the Meteorological Agency's Hakodate Oceanic Meteorological Office at 09:00 was as follows:

TAF RJCH	210000Z 210009 11025G35KT 6000 -RA FEW005 BKN012 BKN025
	TEMPO 0003 11030G50KT 3000 RA.BR FEW003 BKN008 BKN018
	TEMPO 0309 11030G50KT 2000 +RA BR VV005

(2) Airport Gale Warning

The Airport Gale Warning relating to strong wind issued by the Hakodate Airport branch of the Meteorological Agency's Hakodate Oceanic Meteorological Office at 11:40 were as follows:

From now until 21 January 15:00 UTC, the south east wind will have a maximum speed of between 35 and 40kt with gusts of up to 50 to 60kt. Thereafter, the wind will weaken gradually.

2.8 Information related to Aeronautical Navigation Aids

2.8.1 Information related to Aeronautical Radio Navigational Aids

As a result of the inspections following the accident, no abnormalities were found in aeronautical radio navigation aids including Hakodate VOR (VHF Omni-Directional Radio Range) and the Hakodate Airport runway 12 Category I ILS.

2.8.2 Information related to Aeronautical Lighting

Hakodate Airport is equipped with lightings for Category I precision approaches, and all lights are normal. And at the time of accident, according to the aeronautical meteorological special report at 13:38 on January 21, 2002, these aeronautical lights were illuminated at maximum brightness.

2.9 The Accident Site

Hakodate Airport is located around 7km East of Hakodate City. To the south of the airport is the Tsugaru Channel to the south side of the airport, and to the north and east are residential areas backed by mountains. The approach route leading up to the point of the accident is to the west side of the airport, and proceeds from Hakodate City to the runway passing over the Yunokawa Onsen hot spring. Along this approach route, the elevation is around 4m in the vicinity of Hakodate City, and rises gently from the Matsukura River around 1,000m west of the west side of the runway to an elevation of 111.9ft (34.1m) at the airport. The elevation of the touchdown point of runway 12 is 103ft.

The runway runs almost parallel to the coastline, and is 3,000m long and 45m wide and grooved along its full length. The distance from the south edge of the runway to the coast is around 700m at the approach end threshold of the runway 12 and around 850m at the departure end threshold. Further, the distance to the coastline is around 1,000m at a point approximately 600m from the runway 12 departure threshold along the runway extended centreline in the direction of departure. From a further 500m from this point along the extended centreline, the coastline makes 50° turn in the direction of runway 12 and is engulfed by the surrounding land area in the manner of an inlet.

The whole airport region is like an elevated plateau above the surrounding area. While its slope ascends gradually from the coast for around 100 – 150 m, beyond that the slope angle becomes 30 –45° and rises to around the same elevation as the airport.

The site of the accident was over the runway 12 end markings. Silver metallic traces around 15.9 m long and with a maximum width of around 80 cm remained after the accident, starting from a point around 14.0 m inside the runway end.

No Notices to Airmen (NOTAMs) had been issued regarding hazards to the safe operation of aircraft taking-off and landing at the airport. (Refer Fig. 1.)

2.10 Information on the DFDR and CVR

(1) DFDR

The aircraft was equipped with a Honeywell model 980-4700-003 solid-state Digital Flight Data Recorder (DFDR). Except for N1 data, the other data had been recorded normally.

(2) CVR

The aircraft was equipped with a Honeywell model 980-6022-001 solid-state Cockpit Voice Recorder (CVR) which can record for 120 minutes. This recorded normally.

The CVR records only voices and sounds in the cockpit, and time is not recorded. The time correlation with Japan Standard Time (JST) was determined by matching the NTT time signal and ATC radio communications recorded on ATC recorders with the corresponding portions of ATC radio communications recorded on the CVR.

In addition to the above, data from the aircraft's QAR were used to provide supplementary data not recorded on the DFDR for the analysis.

2.11 Medical Information

The CAs who had sustained minor injuries were diagnosed as each needing 2–7 days of medical treatment due to sprain of the cervical vertebrae and waist area or coccyx.

2.12 Tests and Researches to find Facts

2.12.1 Residual Markings on the runway

Traces of silver metallic abrasions thought to be from the lower surface of the accident aircraft's fuselage were left over the runway end markings for a length of around 15.9m, starting from around 14.0m in from the runway threshold, and with a maximum width of 80cm. These traces extended in the direction of the runway, and their centre was located around 90cm to the right of the runway 12 centreline. Further, the width of the abrasion traces on the runway and the scratches on the lower surface of the aircraft's aft fuselage were almost identical.

Furthermore, no traces that could be though of as resulting from contact of the main wheels with the runway were found in the vicinity of the abrasion traces, but DFDR recorded that the main wheels were touched the runway.

2.12.2 Analysis of CVR recordings

The contents of main conversation concerning to wind and decision of final approach speed in the cockpit recorded on the aircraft's CVR were as Appendix.

2.12.3 Analysis on DFDR data

Based on DFDR and so on the said aircraft, the circumstances from when the said aircraft started to approach until the aft lower body contacted to the runway were as follows:

During final approach for the said aircraft, in the period reaching to the altitude of 177ft above ground level (AGL) from the altitude of 1,000ft AGL although computed airspeed (CAS) was varying for 132~154kt, average of 145kt and the wind speed was varying for 32～47kt, because the wind was blowing stable direction from south-east, auto-thrust was disengaged at the altitude of 900ft AGL and auto-pilot was disengaged at the altitude of 500ft AGL , then the approach was continued on glide path with manual control. The airspeed selected in SPD/MACH window was 143kt on the aircraft. The average descent rate before one minute as the aircraft reaches to the altitude of around 177ft AGL was minus around 600ft/min. The major recordings related to the flight configurations below the altitude of 177ft AGL was as the following chart:

Time (hr:min :sec)	Altitude AGL(ft)	AS (kt)	Descent Rate (ft/min)	Pitch Angle (°)	TLA (°)	Engine F/F (PPH)	Wind Direc-tion(°)	Wind Speed (kt)	Ground Speed (kt)
13:02:47	177	134	-770	3.2	8.4	2,800	119	33	102
:49	158	132	-450	2.8	16.9	2,800	124	34	102
:50	155	145	-700	3.2	14.1	3,700	125	42	103
:51	149	150	-510	3.5	8.4	5,000	126	42	104
:52	141	153	-510	3.2	2.8	4,700	124	44	104
:53	136	149	-450	2.1	2.8	3,900	126	41	104
:54	126	141	-450	1.8	2.8	3,100	127	39	103
:55	114	137	-380	2.1	2.8	2,500	124	37	102
:56	99	141	-770	2.5	5.6	1,800	128	34	102
:57	68	122	-770	3.2	8.4	1,600	121	22	101
:58	53	120	-1,150	3.5	14.1	2,000	130	14	101
:59	22	117	-1,220	4.2	33.8	2,700	122	14	103
13:03:00	4	128	1,220	7.4	42.2	5,000	129	22	105
:01	-4	124	-1,540	11.2	42.2	7,200	118	16	108
:02	0	138	-1,540	10.9	42.2	9,400	108	31	111
:03	14	141	-190	13.7	42.2	10,500	107	23	115
:04	40	142	1,220	15.2	42.2	11,500	118	30	116

Besides mentioned above, the related recordings were as follows:

At around 13:02:58, the wind-shear warning was issued.

At around 13:02:59, the side sticks for the Captain and for the first officer were back warded.

At around 12:03:01, it was recorded for the vertical acceleration of around 1.9G. At the time the side stick for the Captain side was starting to push to neutral.

At around 13:03:02, it was recorded for the main gear wheels were on the ground. At the time the side stick for the Captain side was starting to pull backward from neutral position to pitch up. At the same time the side stick for the first officer has been turned to full forward to pitch down.

However, at around 13:03:04, the side stick for the first officer has been pulled pitch up.

Note1: The altitude AGL, was used for value of the barometric altimeter at higher than 50ft, and was used for the value of the radio altimeter below 50ft.

Note2: Regarding the value of the rate of descent, the effect for the time delay is involved.

Note3: The TLA angle at maximum is 42.2 degrees, and it is 0 degree at idle position.

Note4: The engine fuel flow at maximum is around 11,500PPH, and it is around 1,000PPH at minimum.

(Refer Fig. 8-1 and 8-2)

2.12.4 Airbus A321 Aircraft

2.12.4.1 Flight Control System and Characteristic for Attitude Controls

(1) Side Stick

Regarding the flight control system on Airbus A321, it is equipped with the flight control devices called for side stick on the left side for the left hand seat pilot and on the right side for the right hand seat pilot. The flight crews are provided to be able to control in pitch and roll manually, and yaw indirect through the turn coordination. The both left and right side sticks are the device to transmit the independent signals each other to the computer, but are not mechanically linked and do not both move together. They are spring loaded to the neutral position, therefore the aircraft attitude was controlled by that the flight crews moved them to forward/aft and left/right. If both move their sidesticks simultaneously in the same or opposed direction, the signal values are added of both pilots algebraically. The total is limited to the signal that would result from the maximum deflection of a single sidestick. Further, the takeover switch is installed on each side sticks. A pilot can deactivate the other sidestick and take full control by pressing and keeping pressed the takeover button on the sidestick.

(2) High Angle of Attack Protection

High angle of attack protection is a function that the angle of attack of the aircraft increased beyond the certain value during a flight, even if the pilot pulled the side stick up to the maximum, the aircraft is provided with the function to restrict automatically not causing to control beyond the αmax (Specific Angle of Attack). As this function, an aircraft may cause not to enter into a stall. This function has the highest priority out of all the protections and includes α floor protection function.

However, at the time as this function it operates between the time from the lift off at takeoff to the altitude of 100ft AGL before landing.

(3) Flare Mode

The flare mode is designed to have an effect on a ground effect artificially to have similarity at flare with non fly-by-wire aircraft.

When descending to 50ft AGL for a landing, the system engages the flare mode and pitch down gradually while in flare till landing automatically. Pilots are requested to flare pitch up with greater moment than the pitch down moment caused by flare mode. Pitch up moment by pilots that are smaller than pitch down moment by flare mode possible to pitch down attitude at flare to landing.

2.12.4.2 Characteristic for Aircraft and tail strike limits

Because A321 model airplane is derivative type of A320 model airplane, except the longer body length, the shape and operating system is basically same as the one of A320 airplane.

As compared with the total length of A320 model airplane is 37.57m, A321 airplane is total length of 44.51m. Because of the different from the body length, on A321 airplane as compared with A320 airplane, the allowance angle for flare control which might not contact the aft body lower with the runway at landing is established less. According to the Airplane Operations Reference (AOR) issued by ANA, although this angle on A320 model airplane are established to 13.5 degrees nose up aircraft attitude when the main landing gear wheels on the ground and landing gear oleo was fully extended, and to 11.7 degrees nose up aircraft attitude when the main landing gear wheels on the ground and landing gear oleo was fully compressed, the angle on A321 model airplane are established to 11.2 degrees ,nose up aircraft attitude when the main landing gear wheels on the ground and landing gear oleo was fully extended and to 9.7 degrees nose up aircraft attitude when the main landing gear wheels on the ground and landing gear oleo was fully compressed, the angle is established to less for the amount of the length extended the body as compared with A320.

(Refer Figure 2)

2.12.5 Outline of Wind-Shear Warning System and EGPWS equipped on the aircraft

The aircraft equipped with Reactive Type wind-shear warning system and Predictive Type, as the equipment which alarms aural sound if it is forecasted to encounter to wind-shear at take-off/landing, or if it is encountered. Further, if aircraft got close to the ground etc. abruptly, it is also equipped with the warning system for EGPWS which alarms aural sound to such proximity.

The detection for wind-shear by Reactive Type out of the wind-shear warning system is computed on the aircraft energy, variances of wind around the own aircraft due to the difference between a ground speed and CAS, if it was detected that the wind speed change over 23kt occurred within 30 seconds and so on, the synthetic aural sound is alarmed as warning sound of "WIND SHEAR, WIND SHEAR, WIND SHEAR". The operating range for the system is covered from the altitude of 1,300ft AGL to 50ft AGL at the time of an approach.

Contrary to this, the detection for wind-shear by Predictive Type was utilized with Doppler Effect, which the radar wave reflected from the moving objects makes the frequency change. Especially, if it detected such as the wind speed changes over 25kt occurred within 14 seconds in the range within forward 5nm from own aircraft, within laterally 0.5nm and also angle of 25 degrees for left/right to the aircraft axis, the aural warning is issued. In Predictive Type, because the objects observed by this radar are cloud and rain droplets, if the phenomenon of precipitation for the droplets was not occurred, the wind-shear may not detected. The predictive type computed on the CAS and vertical wind speed, etc.

Further, in Predictive Type, the warning is issued by display and aural sound in the altitude from 1,200ft AGL to 50ft AGL. At the time, the synthetic sounds are issued as the warning sounds of "GO AROUND WIND-SHEAR AHEAD".

If aircraft got close to the ground abruptly, EGPWS compared the altitude at radio altimeter with rate of descent. If these values exceed the specified limit range and enter in the dangerous zone, it is the equipment which issued the warning sound to the pilot by synthetic sound of "Sink Rate" etc. in correspondence with each circumstance. The operating range of this equipment is established to the altitude from 2,450ft AGL to 10ft AGL.

The priority sequences related to the issuance for aural sound of warning in the each equipment are established in the sequence of the Reactive Type of Wind Shear, the Predictive Type one, then EGPWS. For example, during issuing the warning sound for Reactive Type, another aural sound for the warning system is established to be inhibited.

2.12.6 Establishment of a Final Approach Speed

2.12.6.1 Establishing Method of Final Approach Speed

According to the Airplane Operations Manual (AOM) issued by ANA, as described in the section 2.12.7, in establishing final approach speed on A321 airplane there are the method established by "SELECTED SPEED" mode and the method established by "MANAGED SPEED" mode. In the approach at the accident on the aircraft, the aircraft made an approach with "SELECTED SPEED" mode. The establishment of a final approach speed with manual control by “SELECTED SPEED” mode is specified as follows:

(1) At first, the approach speed (V_{APP}) is computed as the following formula

$$V_{APP} = VLS + MIN\ (15, MAX\ (5, 1/3 \text{ of head wind component}))$$

(Note: MIN (A, B) means the smaller one of either A or B. MAX means the larger one.)

The minimum control speed (V_{LS}) is specified for the value kept the speed margin for 1.23 times of a stall speed (V_S). V_{APP} is computed to add 1/3 of head wind component with V_{LS}. This addition is to keep the speed at or greater than V_{LS} at flare because of the effects of ground topography on the surface boundary layer. However, the value to be added is specified within the limit of less than 5kt or under 15kt if being larger. Here, the head wind component is computed by the average of the wind speed. More, the practical computation for V_{APP} during a flight, is displayed on FMGC automatically if data is entered.

(2) Then, the final approach speed, could be at or greater than V_{LS} at flare even if the wind is dropped rapidly, is established as adding gust component to V_{APP} by the following formula:

$$\text{Final approach speed} = V_{APP} + (\text{Maximum wind speed} - \text{Average wind speed})$$

(3) Further, a PF shall specify the final approach speed finally with the formula describing above (2) as a basic in response to the circumstances. Also, according to AOM issued by ANA, the maximum value for final approach speed is specified as up to landing reference speed (V_{REF}) plus 20kt. V_{REF} in this formula is the speed of 1.23 times of V_S, and it is the value equivalent to V_{LS} in the case.

2.12.6.2 Final Approach Speed specified in AOM in the Accident

(1) Concrete Example for Final Approach Speed (According to ATIS issued at 12:38)

The gross weight on the aircraft at the accident is estimated to 147,360lb, As computing this, the stall speed (V_S) is computed to 107kt. V_{LS} with full flap is computed to 132kt of 1.23 times of V_S. V_{REF} is also computed to 132kt in the case.

According to ATIS at 12:38, it was reported wind direction of 140°, and wind speed of 29kt with maximum 42kt. In this case, as a result of that 1/3 of head wind component is computed to 9kt, V_{APP} is computed by the following formula:

$$\begin{aligned} V_{APP} &= V_{LS} + MIN\ (15, MAX\ (5, 1/3 \text{ of head wind component})) \\ &= 132 + MIN\ (15, (MAX\ (5, 9)) \\ &= 141\text{kt} \end{aligned}$$

During a flight, the computation up to here is displayed automatically if entering the information of the wind to FMGC. The flight crews might establish the final approach speed as further computing a gust component.

Gust component 42kt – 29kt = 13kt

Final approach speed 141kt + 13kt = 154kt :

While computing as above, as V_{REF} plus 20kt is the maximum value, the final approach speed is computed to 152kt.

(2) Value of a Final Approach Speed Computed by the Information of Wind in the Accident

The OM issued by ANA establishes that a final approach speed could be calculated without a gust less than 10 kt. However, on the basis of the procedures as described above (1), as computing a final approach speed by the information of wind received, including gusts less than 10 kt, on the aircraft, it is as follows:

(i) According to ATIS issued at 12:00, because it reported the wind direction of 140°, and wind speed of 28kt, V_{APP} is computed to 141kt, because no gust blew, the final approach speed is computed to 141kt as the same.

(ii) According to ATIS issued at 12:38, as described above (2), V_{APP} is computed to 141kt, the final approach speed is computed to 152kt.

(iii) According to the information from the Hakodate Tower at around 12:56:14, because it reported the wind direction of 130°, and wind speed of 28kt, and no gust blew, V_{APP} and the final approach speed are computed also to 141kt.

(iv) According to the information from the Hakodate Tower at around 12:59:46, because it reported the wind direction of 130°, and wind speed of 28kt with maximum wind speed of 34kt, V_{APP} is computed to 141kt. Then, because the gust was blowing at 6kt, the final approach speed is computed to 147kt.

(v) According to ATIS issued at 13:00, because it reported the wind direction of 140°, and wind speed of 28kt, and no information for gust, V_{APP} and the final approach speed are computed also to 141kt.

(vi) According to the communication from the company radio at around 13:01:07, because it reported the wind speed of 32kt with maximum wind speed of 40kt, V_{APP} is computed to 141kt. Then, because the gust was blowing at 8kt, the final approach speed is computed to 150kt.

However, on the basis of the procedures as described in the OM issued by ANA, the final approach speed in (iv) above may be 141kt and (v) above may be 142kt.

2.12.6.3 Final Approach Speed Established by the Flight Crews in the Accident

Regarding the establishment for the wind condition and the final approach speed in the accident, according to the statement just after the accident, the first officer is stating as 'In ATIS issued before starting to approach, it reported the wind speed of 30kt with maximum momentary wind speed of 42kt'. However, although the statement from the first officer is consistent with the practical condition at the accident related to the whole tendency of a wind, the weather information which the value of wind speed coincides accurately with statement contents had not been provided in a fact. Then, regarding the establishment of a final approach speed, he is stating that he established the final approach speed to 143kt as intending to add 12kt in considering with the gust to V_{LS}.

On the other, the Captain as PNF is stating as 'Although the approach speed of V_{APP} indicated on FMGC was computed to 140kt (V_{LS} + 8kt), as considering with fluctuating component of the wind speed and as a result of being thought the condition as making a touch down from the aircraft nose to the ground, the final approach speed was established to 143kt'.

As having summarized the opinions from the other flight crews in ANA, they reported as 'If it must be considered with a gust in A321 airplane, the aircraft nose goes down as making airspeed high excessively, then it happens to obstruct to safe landing. However, the final approach speed should have been established in sufficient for the strong wind with a gust. In order to cope with both matters, the airspeed with the limit of V_{LS} + ΔV, maximum value of 12 ~ 13kt, is established normally'. Further, according to the data issued by ANA, it is described as the aircraft nose would go down to minus at over the speed of V_{REF} + 17kt on the almost same gross weight at the accident.

2.12.7 "SELECTED SPEED" mode and "MANAGED SPEED" mode

In AOM issued by ANA on A321 Airplane, two kinds of modes of "SELECTED SPEED" and "MANAGED SPEED" were established related to the establishment of a final approach speed. However, if making an approach by manual control for thrust lever, it is specified to establish the final approach speed with "SELECTED SPEED" mode, and then "SELECTED SPEED" mode had been also used at the time of the accident.

(1) "SELECTED SPEED" Mode

"SELECTED SPEED" mode established by ANA means that it is the control method for thrust lever generally used as usual and the thrust lever is controlled to maintain CAS constantly. In this "SELECTED SPEED" mode, the thrust lever is controlled for following the standard with the appropriate thrust (Target thrust) which the approach speed might be maintained regularly. If the head wind component increased during a flight, while

CAS might be increase momentarily by the aircraft inertial force, CAS is stabilized to the original speed after momentary irregular phenomenon recovered if not controlling to reduce thrust. However, as a result that it is necessary to decrease rate of descent in order to track on glide path because the ground speed reduces, it is required to slightly increase the thrust a little more than the target speed. Further, as the time of the accident, if having made the thrust reduce to maintain CAS at sudden increase of the wind speed, in order to recover to the original CAS and to track again on glide path after momentary irregular phenomenon recovered it is required to largely increase the thrust more than the target speed to compensate for decreased rate of the ground speed. Moreover, because CAS reduces as the head wind suddenly decreased, it is resulted that the pilot increases the thrust, and then he controls to continue an approach as putting back the target thrust with reducing the thrust after the airspeed got back to the pre-selected value of CAS.

As rearranging the characteristic for "SELECTED SPEED" mode, it is as follows:

(i) In "SELECTED SPEED" mode, the pilot establishes the final approach speed as making airspeed constant with considering to V_{APP}, average wind speed, gust component, etc.

(ii) In the case the wind speed changes, as a result that CAS of the airspeed changes if it is, it is the approach method to control as keeping the final approach speed constant by increasing or decreasing thrust.

(iii) In the case the wind speed changes in precision approach, it is required to change the rate of descent in order to continue to track on glide path because the ground speed changes.

(iv) It is able to control the thrust by manual or by auto-thrust.

(2) "MANAGED SPEED" Mode

In "MANAGED SPEED" mode, the thrust is controlled to keep the ground speed constant. In this mode, when the wind speed changes largely, it is resulted that target CAS is changed automatically. This mode is established to relieve the effect from the wind-shear. While CAS increases if the head wind component largely increased, the engine thrust increases contrary to "SELECTED SPEED" mode to keep the ground speed constant. Further, Even if CAS suddenly decreases by sudden decrease of the head wind and by sudden increase of the following wind, it is specified to establish the final approach speed up to the minimum speed of V_{APP}. Because of this, it is resulted that the engine thrust is kept in the high condition and is maintained the kinetic energy of the aircraft against the sudden decrease being peculiar at encountering the wind-shear, as it happens after sudden increase of the head wind.

Still more, although this mode is supposing to the auto-thrust, even if the thrust is controlled by manual, it is possible to make an approach with “MANAGED SPEED” mode by that the pilot controls the thrust lever as following the airspeed indicated on PFD.

As rearranging the characteristic for “MANAGED SPEED” mode, it is as follows:

(i) In “MANAGED SPEED” mode, FMGC on the aircraft computes the final approach speed as the target approach speed to keep the ground speed constant.

(ii) In the case the wind speed changes, as the result that FMGC indicates the target approach speed for maintaining the ground speed and that momentary speed of the wind speed is affected as required, the speed of CAS changes.

(iii) Because the ground speed is constant, it is not necessary to change the rate of descent for continuing to track on glide path.

(iv) Basically, the thrust is controlled by auto-thrust.

2.12.8 Relevant regulations Issued by ANA and Airbus Industries

2.12.8.1 Regulations related to the Establishment of a Final Approach Speed

Because the regulations used in the aircraft operators are established with reference to the regulations which the designer/manufacturer for the aircraft issued, as comparing with the regulations, etc. issued in Airbus as the designer/manufacturer and ANA as operator, it is described as follows:

(1) Flight Manual issued by Airbus and Airplane Flight Manual issued by ANA

The Flight Manual is issued as correspondence with the airplane flight manual in Airbus. There is no description related to “MANAGED SPEED” mode in the Flight Manual issued in Airbus. Further, the airplane flight manual issued by ANA is the same contents as the Flight Manual issued by Airbus in English except the part related to additional equipments. Because of this, there is no description related to the usage in approach/landing for “MANAGED SPEED” mode in the airplane flight manual issued by ANA for the same model of the airplane.

(2) Flight Crew Operating Manual (FCOM) issued by Airbus

The followings are described in FCOM issued by Airbus.

ILS Approach

General; (Contents for short) The approach procedures described here assume that the flight crew uses managed speed guidance which is recommended.

Non Precision Approach

Approach Speed Technique; (Contents for short) The aircraft intercepts the final descent path in the landing configuration and at V_{APP}. For this purpose, the flight crew should insert V_{APP} as a speed constraint at the Final Approach Fix (FAF). In all cases, the crew should use Managed Speed.

(3) AOM issued by ANA

In the section 4-2-1(3) for the establishment of approach speed (V_{APP}) in AOM, it is specified as follows:

V_{APP}: Final Approach Speed. It is computed by FMGC and it is displayed on the page of APPR.

$V_{APP} = V_{LS}$ + Max (Wind Correction, 5kt)

Note: the increment of 5kt is only required in Auto-land. However, this increment is always added by FMGC.

Wind correction is 1/3 times of the head wind being informed by ATC.

V_{APP} is able to be revised through MCDU.

In the section 6-11 for Flight Management and Guidance System in AOM, it is specified related to V_{APP} as follows:

V_{APP} Computation

$V_{APP} = V_{LS}$ + 1/3 of TWR Head Wind Component

But, V_{APP} is computed as the minimum of (V_{LS} + 5kt).

The speed for the wind correction is specified as the minimum of 5kt and as the maximum of 15kt.

While AOM issued by ANA is compiled as reference to FCOM issued by Airbus, the contents related to "MANAGED SPEED" mode as described above (2) was not affected accurately and the contents of the description are as follows:

Target Approach Speed is based on the following speed.

(i) If using Auto-Thrust: Managed Speed or Selected Speed

(ii) If not using Auto-Thrust: Selected Speed

Selected Speed is specified to the speed which PF establishes in correspondence with the condition as a basic of V_{APP} + (Max – Steady). (But, the maximum speed is specified to V_{REF} + 20kt.)

(4) AOR issued by ANA.

In ANA, the information related to the operation is described precisely in AOM, and regarding "MANAGED SPEED" mode and "SELECTED SPEED" mode, there is the descriptions as follows:

In the case of using Selected Speed/Managed Speed for A/THR, The thinking way for the wind correction on Target Approach Speed is as follows:

A/THR should be used at approach in gusty condition, and it is useful to utilize Managed Speed. However, it should be paid attention to be possible to lower V_{LS} due to small wind-shear, effect of geographical features and turbulence according as the circumstances.

However, in ANA, this AOR is not placed as the regulation which consists of the aircraft operation manual and also it is not material to supplement AOM, etc.

2.12.8.2 Regulations related to Avoidance from Wind-Shear, Recovery Control, Etc. in AOM.

(1) Regulation related to the Prevention from Encountering to Wind-Shear.

In the section 4-3-6 of Wind-Shear in AOM, there are the following descriptions for the weather phenomenon of how does it know the presence of wind-shear preliminarily, the receiving way for information and the method, etc. in order to not encounter wind-shear:

General

Wind-shear means the sudden changes for wind speed and wind direction in a short section along the flight path. The most effective method for coping with wind-shear is to avoid from it. If wind-shear is forecasted, it is required to take the precautionary measures as preparing to unexpected encounter. Further, if encountered, the recovery should be executed at once.

Avoidance

(Contents for short)

To foresee the presence of Wind-Shear, the following factors provide useful information.

Occurrence of Thunderstorm

Virga (Fall Streak: Rain dispersing in the descent.)

PIPEP (Pilot Reports)

LLWAS (Low Level Wind-Shear Alerting System)

Wind-Shear Prediction Function Message (Aircraft equipped with Wind-Shear Prediction Function)

(2) Cope way at Encountering to Wind-Shear.

In the subsection 4-3-6 (2) of Wind-Shear in AOM, regarding the case to be possible to encounter to wind-shear and cope way, etc. at having encountered, the cautionary matters as followings are described.

Approach and Landing

(Contents for short)

Note: If airspeed increases suddenly, as it is possible to decrease later, it should not change the thrust largely or it should not change the trim.

If necessary, it should disengage Auto-Thrust.

(3) Regulation related to the Recovery Control from Wind-Shear.

In the section 2-6-3 of Wind-Shear in AOM, there are the following descriptions.

If it encountered to wind-shear, or if wind-shear warning issued

: Immediately, it should control the following recovery from wind-shear.

PF	PNF
Thrust levers・・・・・・・・・TO/GA Auto-pilot (if engaged) ・・・ KEEP Speed-brake lever ・・・・・ RET Follow SRS Order ***	Confirm the Maximum Thrust was set. Confirm all necessary tasks completed, if not completed, call the tasks lacked.
Monitor Vertical Speed and Altitude	
Until danger for a wind-shear disappears, it should not either change the position of flaps nor gears, also the airspeed should not be recovered.	If an anxiety with ground contact, negative flight path or significant airspeed deviation were recognized, it should call the fact.

Note: If it is unable to use Flight Director (FD), pitch up to Initial Pitch Attitude of 17.5°.

Whether using FD or not, it may be pulled the side stick back to fully aft if necessary for minimizing the decrease of an altitude, if maintaining Vαmax, there is a case to be unable to keep the enough stall margin at having encountered to tail wind-shear.

2.12.8.3 Description in FCOM related to the Approach Method in Forecasting to Wind-Shear

In FCOM issued by Airbus, there are the following descriptions as the approach method in significant weather. However, there is no description with responding to this in AOM issued by ANA.

Operations in Wind-Shear or Down-Burst Conditions

Precautions for Suspected Wind-Shear

(Contents for short)

During Approach

(Contents for short)

- Select Flap 3.

- Use Managed Speed in the approach phase.

2.12.9 Test Flight using Flight Simulator, etc.

Tests were conducted using a full-flight simulator as the same model as the aircraft to study the correspondence of the aircraft and possibility for avoidance at the accident occurred, and also the measures for the prevention of recurrence as the same accident.

The simulator used for the flight tests was the first class flight simulator system and it was equipped with sophisticated visual and motion systems, and had given the capability as a Phase 3 flight simulator and had the highest level of simulation fidelity

2.12.9.1 Response for Engine Thrust to Thrust Lever Control

Purpose: Study for the engine response function in level flight at the altitude of around 200ft on the approach speed at the accident.

Test Procedure:

(1) To measure the time (second) necessary for N1 to stabilize in the revolution speed equivalent to maximum takeoff thrust as making the thrust lever advance quickly from idle position (around 25%) to the maximum takeoff position (around 91.7%).

(2) To measure the time necessary for N1 to stabilize in the revolution speed equivalent to the maximum takeoff thrust as making the thrust lever advance quickly from the position keeping N1 with 50% of thrust condition to maximum takeoff position.

Result

(1) As making the thrust lever advance quickly from idle position to the maximum takeoff position, it is found that the time required until N1 stabilizes in the maximum takeoff thrust was measured in around 6 seconds.

(2) As making the thrust lever advance quickly from around 50% N1 to the maximum takeoff thrust, it is found that the time required until N1 stabilizes in the maximum takeoff thrust was measured in around 3.2 seconds.

2.12.9.2 Required Thrust in a flight with less margin against a stall speed

Purpose: Study for the thrust required to maintain the same flight condition as CAS at less margin against stall speed in level flight within a calm atmospheric condition.

Test Procedure: To measure the thrust required to maintain the condition of level flight in the altitude of around 300ft and at the speed of 118kt that was at fewer margins against a stall speed.

Result It is found that for getting the engine thrust in a level flight at a speed of around 118kt, it is required with N1 of 69.4% and fuel flow of around 5,000PPH. Moreover, it is found that for getting the engine thrust in CAS of around 122kt it is required with N1 of 52.4% and fuel flow of 2,840PPH.

2.12.9.3 Simulated Test at the Accident and Approach in each mode with a final approach speed

Purpose: Reproduce the wind velocity in the circumstances simulated as same as possible in the accident and make the engine thrust reduce in the same condition as on the said aircraft at "SELECTED SPEED" mode, just after that, study for the possibility in response with the wind-shear warning.

Test Procedure: Regarding the wind changes in final approach, the parameters should be set as the head wind is selected to 30kt in the range from the high altitude to the altitude of 170ft AGL thereafter, gradually increase the wind speed as following to descend, and the head wind is selected to 40kt at the altitude of around 130ft AGL and finally reduce the head wind to 14kt at the altitude of around 50ft AGL.

Make the thrust reduce as same level as in the accident in "SELECTED SPEED" mode.

Study for the possibility in response if it flied in the wind as the same circumstances as in the accident in "MANAGED SPEED" mode.

Result

(1) Case of "SELECTED SPEED" Mode.

It is found that it might be recovered from wind-shear occurred in low altitude regarding the recovery control by Auto-Pilot and Auto-Thrust.

However, regarding the approach by manual, although it executed the recovery control, it is too late for the recovery from wind-shear and it came to contact to almost same as the place around the end of the runway as in the accident.

Based on these results, while it is making approach with the thrust control by manual in "SELECTED SPEED" mode, if the wind-shear warning issued unexpectedly as in the accident, it was estimated that it was difficult to respond with the thrust lever control in correspondence with the establishment of final approach speed as the flight crews on the aircraft in the accident and the change for CAS.

Further, it was thought to be rather advantageous in the case it used Auto-Pilot and

Auto-Thrust than by manual control related to the recovery control from wind-shear.

(2) Case of “MANAGED SPEED” Mode.

It is found to have been possible for the recovery from wind-shear. Further, it is found it might make stable approach even under strong wind.

2.12.9.4 Study for the Aircraft Pitch Attitude Change Following to the Airspeed Change and the Recovery Control from Wind-Shear in Final Approach

Purpose: To study the control is possible to recover from wind-shear at low altitude with “SELECTED SPEED” mode and to study for the pitch attitude change as increased final approach speed.

Test Procedure: Reproduce the wind velocity in the circumstances simulated as same as possible in the accident, and to measure the recoverable control method and speed without contacting to the runway as it makes the final approach speed gradually increase from less speed than the one in the accident with “SELECTED SPEED” mode. Moreover, in the case as how does it establish the final approach speed, to measure whether the aircraft attitude pitches down to minus.

Result: It is found that the minimum final approach speed being able to recover from the circumstances was measured in around 144kt in the case it encountered wind-shear at almost the same low altitude as in the accident in “SELECTED SPEED” mode. On the other side, if it selected the final approach speed to 142kt or less, it could not recover from wind-shear even if it increases the thrust at the same time of wind-shear warning issued. In these cases, it was not executed for the control to reduce the thrust corresponded to the CAS increase just before wind-shear warning issued.

Further, as the same as in the accident, if it controlled to reduce the thrust by manual in order to keep CAS increased in speed by the wind speed increase caused by wind-shear, even if it establishes the final approach speed to 152kt as the maximum speed, because the reduction of the wind speed by wind-shear suddenly happened while it is executing the control to reduce the thrust, it was measured to the speed less than 144kt. Therefore, if it executes the recovery control following to the wind-shear warning, it was impossible to recover from the circumstances lately.

Even if it had been executed for the approach at strong head wind of around 50kt as set the final approach speed to around 150kt, it was not measured continuously to minus while the aircraft pitch attitude pitches down to around zero degree.

2.12.10 Specification of the Seat for Passenger and for CA

In the airworthiness regulations applied at obtaining the type certification fro the aircraft, even if the aircraft landed with small scale of failures in emergency landing conditions, it is specified for the effect that the seats used by the passengers and by crews shall design to preclude from the serious injury if it received the ultimate final inertial force of 4.5G toward downward. For this, the seat for the passengers and for crews on the aircraft is satisfactory with this regulation. However, there is no regulation to preclude the injury relevant to the crews seated and the passengers except the emergency landing condition.

It was recorded for the maximum vertical acceleration of 1.9G.

The size of the seat for CA on the aircraft was measured the width of around 48cm, the depth of around 41cm and the thickness for the cushion part of around 2.8cm and the material was polyurethane, and the specific gravity was 0.099.

On the other hand, while the cushion for the passengers' seats on the aircraft was the same materials and the same specific gravity, the thickness was from 9.0 to 10.7cm. The reclining angle of a CA seat was almost vertical with no armrest. (Refer Photo 6 and 7)

3 ANALYSIS

3.1 Analysis

3.1.1 Airmen Certificates and Medical Certificates

The Captain and First Officer were certified with valid aircrew proficiency licenses and had valid medical certificates.

3.1.2 Airworthiness Certification

The aircraft was certified with a valid certification of airworthiness, and scheduled maintenance and inspections had been carried out.

3.1.3 Aviation Facilities

Aviation Facilities and Lights were operated normally.

3.1.4 Pilot Actions from the Final Approach to the Recovery after the Accident

Based on the DFDR data, CVR recordings, the statements of the flight crew, ATC communications and others concerned, the pilot actions during the period from final approach to the recovery maneuvers after the accident occurred are estimated to have been as follows:

(1) Speed Establishment, Autopilot

The selected final approach speed under "SELECTED SPEED" mode was 143kt.

In this accident, the average value of CAS from a height of 1,000ft Above Ground Level (AGL) to 177ft AGL was almost equal to the 145.0kt value selected for final approach, and it is therefore considered that the first officer, acting as a PF, was flying the approach with the aircraft in the prescribed approach configuration and at the selected final approach speed.

Further, the PF disengaged the autopilot and autothrust by 500ft AGL, after which he flew the approach manually.

(2) From 177ft AGL until just prior to the Wind Shear Warning

At around 13:02:47, before the accident had occurred, while the aircraft was descending through around 177ft AGL, the first officer recognized a sudden drop in CAS from around 145kt to around 134kt, and the Captain, who was acting as a PNF, recognized a drop in speed of greater than 5kt and called "Airspeed". It is considered that in response to these events, the first officer increased engine thrust to increase airspeed.

At around 13:02:50, while the aircraft was descending through around 155ft AGL, the first officer recognized that CAS had reached approximately 145kt, which exceeded the selected target speed of 143kt in “SELECTED SPEED” mode, and judging that the airspeed was tending to increase, began to close the thrust levers to reduce thrust in order to maintain 143kt.

At around 13:02:51, while the aircraft was descending through around 149ft AGL, the first officer recognized that CAS had reached 150kt and further retarded the thrust levers to reduce airspeed. However at this time, because of engine response delay, fuel flow had dropped to a value of approximately 5,000 lbs/hr corresponding to the thrust lever positions that had been set two seconds earlier, and thereafter continued decreasing gradually.

At around 13:02:52, while the aircraft was descending through around 141ft AGL, CAS reached around 153kt even though the thrust levers had been retarded to reduce thrust. It is thought that in order to reach the target airspeed of 143kt, the first officer continued with the thrust levers retarded since airspeed was increasing even though he had reduced thrust.

At around 13:02:53, while the aircraft was descending through around 136ft AGL, CAS reached 149kt, dropping towards to the selected final approach speed of 143kt.

At around 13:02:54, while the aircraft was descending through around 126ft AGL, CAS had dropped to 141kt, below the selected final approach speed of 143kt.

At around 13:02:55, while the aircraft was descending through around 114ft AGL, the first officer, recognizing that CAS had reached 137kt and was remaining less than the 143kt selected target value, started to advance the thrust levers to slightly increase airspeed. However, fuel flow continued to decrease due to engine response delay.

At around 13:02:56, as the aircraft was descending through around 99ft AGL, CAS increased slightly to 141kt. Taking into account the time lag of the vertical speed indicator, it is estimated that the aircraft descent rate began suddenly to increase at this time.

At around 13:02:57, while the aircraft was descending through around 68ft AGL, CAS suddenly dropped to around 122kt, and the Captain called “Airspeed” to alert the first officer. Although the first officer further advanced the thrust levers, it is estimated that fuel flow reached its minimum value at this time.

(3) From the Wind Shear Warning until just before the tail strike

At around 13:02:58, while the aircraft was descending through around 53ft AGL, the synthetic warning sound of the reactive-type wind shear warning was annunciated. At that time the PF called “Go Around”, and during the period from immediately afterwards until around 13:03:00 he advanced the thrust levers to the maximum take-off thrust position in accordance with the wind shear recovery procedure specified in the AOM. Further, although the rate of descent satisfied the conditions for EGPWS warning annunciation between 13:02:58 and 13:02:59, the EPGWS warning status during this period is indicated as “NOT” in the recordings. It is considered possible that due to the priorities of each warning system, the EGPWS warning was inhibited to allow the reactive wind shear warning to sound.

At around 13:02:59, when the aircraft was descending through around 22ft AGL, the recorded wind speed reached 14kt, and CAS dropped by around 36kt during a period of seven seconds and reached its minimum value prior to the accident of around 117kt, dropping towards the stall speed. The descent rate at that time is recorded as approximately 1,220 ft/min. The first officer’s side stick was almost full back warded to pitch up over the period from 13:03:00 to 13:02:59.

Moreover, the DFDR recording shows that the Captain also pulled back his side stick at the same time as the first officer. It is thought that in the condition that the aircraft was rapidly approaching the ground following a wind shear alert, the Captain acting as a PNF did not have sufficient time to announce to the first officer his intention to take over control of the aircraft and, without utilizing the take-over button on his side stick, also acted to pitch up to recover from the wind shear. As a result of these control inputs, the aircraft’s pitch attitude reached 15.5 at around 13:03:04.

Further, at the time of these pitch up actions, the aircraft’s α Floor Protection function, which is designed that a pitch-up initiates advancing thrust levers to takeoff position automatically without advancing it manually as described in 2.12.4.1 (2), is thought to have not been operating because the flight crew started reactions against the wind shear alert when the aircraft was below 100ft AGL.

At around 13:03:00, the descent rate of the aircraft was still approximately 1,220ft/min.

(4) From the Striking the Ground to the Climb

At around 13:03:01, when the aircraft’s recorded height was minus 4ft AGL and pitch angle had reached 11.2 degrees, it is considered based on the 1.9G recorded vertical acceleration and the sounds of impact recorded on the CVR that the lower part of the aft fuselage of the aircraft struck the ground. The height value of minus 4ft is considered to be the result of the fact that the shock absorbing system of the main landing gear struts was compressed by the touch down.

From that time till around 13:03:02, the pitch input signal from the Captain’s side stick moved from backward to the neutral value. It is thought that the Captain either released his side stick thinking that as the result of the high pitch due to recovery control actions, the aircraft's flight path was able to reach the runway, or he released the side stick after actions to lower the nose thinking that there was the possibility that the aft fuselage might strike the ground if the pitch attitude at touch down were excessive.

At around 13:03:02, recordings from the ground contact sensors installed in each of the aircraft's main landing gears indicate both main gears were on the ground. Further, the aircraft's pitch angle reduced slightly from 11.2 degrees to 10.5 degrees after touch down. This is thought to be the result of either the lower surface of the aft fuselage striking the ground, or due to actions immediately beforehand by the flight crew to prevent the nose rising further that caused pitch angle to decrease slightly. It is estimated that from around this time, engine fuel flow was gradually increasing towards its maximum value, and the aircraft was transiting to a climb.

However, over the two second period from this time till around 13:03:04, the first officer's side stick was almost full forwarded. While it is considered possible that the action to pitch down was to avoid striking the runway due to an excessive pitch up attitude. On the other hand, at the same time as this action by the PF, the input signals from the Captain's side stick indicate pulling the stick backward from the neutral position to pitch up, in the opposite direction to the first officer's control input. Because the magnitude of the first officer's side stick control input was greater than that of the Captain, the aircraft's pitch attitude, which had exceeded 15 degrees pitch up, reduced to approximately 5 degrees by around 13:03:09.

At around 13:03:03, while the aircraft was climbing through around 14ft AGL, CAS increased to 141kt, and the PF commanded the flaps to be raised.

At around 13:03:04, as described in the section 2.12.3, engine fuel flow reached its maximum value. It is estimated that because the first officer's side stick was pulled back from this time, the aircraft had resumed a normal climb attitude and continued to climb from around 13:03:10.

At around 13:03:20, after the aircraft had been configured for climb, the crew reported to Hakodate Tower that a go-around was being executed due to wind shear.

It is estimated that the Captain took over control of the aircraft thereafter.

(Refer to Figs. 2, 8-1 and 8-2)

3.1.5 Forecast Wind Variations

(1) The Weather Conditions on the Day of the Accident

Concerning the weather conditions on the day of the accident, as described in the section 2.7.1, is considered that due to the relationship between a low pressure system developing over the Japan Sea and a high pressure system developing over the east of Hokkaido, the isobar spacing between Hokkaido and the Tohoku Region narrowed and a very high atmospheric pressure gradient was gradually developing. Furthermore, as described in the section 2.7.3 (1), the airport forecast for Hakodate Airport from 12:00 to 18:00, issued at 09:00 by the Hakodate Airport Office of the Hakodate Marine Meteorological Observatory, forecasted a wind direction of 110° and a wind speed of 30kt with gusts of up to 50kt. It is therefore considered that strong wind conditions accompanied gust was expected at Hakodate Airport, and that there was sufficient information that the flight crew should have expected gusts. Further, according to the forecast chart for bad weather shown in Figure 5, it is considered that the forecast weather conditions indicated that as the result of movement of the low-pressure system, Hakodate was expected to fall into the region of bad weather, with moderate turbulence.

At the time just before the accident occurred, although there was not much variation of surface wind direction, the average wind speed was approximately 28kt, with a maximum speed of around 40kt and a minimum speed of around 20kt.

According to the wind condition chart shown in Figure 7, it is considered that this gusty strong wind condition was continued until evening of the day of the accident occurred.

(2) Provision of Weather Information to the Flight Crew

The weather information regarding wind conditions at Hakodate Airport that the flight crew was provided with during the flight is as follows.

According to the ATIS issued at 12:00, the average wind speed was 28kt with no gust information reported.

According to ATIS issued at 12:38, the average wind speed was 29kt with a maximum momentary wind speed of 42kt.

At around 12:56:14, Hakodate Tower reported a wind speed of 28kt with no gust information.

At around 12:59:46, Hakodate Tower reported a wind speed of 28kt with a maximum momentary wind speed of 34kt.

According to ATIS issued at 13:00, the wind speed was 28kt with no gust information reported.

Although some of these reports included gust information while others did not, given that in principle gust information is reported where gusts exceed 10kt, it is considered that even if some reports contained no gust information, wind speed fluctuations could have been expected to some extent judging from the facts that that gust information had been included in previous reports and that the wind speeds were continuously high.

Therefore, while the flight crew did not receive information related to wind shear prior to the accident, it is estimated that because they had received information on strong winds accompanied by gusts, they could have recognized the existence of large fluctuations in wind speed.

Further, regarding the fact that the flight crew received gust information over company radio at around 13:01:07, the flight crew stated in their interviews that they could not have clearly grasped this information because it was received during a period just before landing, while they were concentrating on the landing. However, it is thought that the flight crew should have been able to monitor this information through workload sharing etc, because it is still 3 nm on the final approach course thus the flight crew could have enough time until their landing.

(3) Trigger Conditions of the Wind Shear Warning System

As described in section 2.12.5, the wind shear warning system installed in the aircraft had two types of detection function: predictive and reactive.

In this accident, the reactive detection system issued an aural alert, but the predictive system did not.

The wind shear switch had been set to "AUTO" and the predictive system was enabled.

The weather radar used for the predictive wind shear function has a pulse width of 1.5 μs and cannot detect turbulent air currents of a size less than half a pulse width, 220m, in the direction of flight. The radar has a pencil beam approximately 3° wide, and at a range of 0.5nm (around 930m) from the aircraft the resolution limitations of the equipment mean that it is unable to detect turbulent air currents with a width or height less than the beam width of around 170ft (around 50m) at that distance. In this accident, despite the fact that the predictive wind shear detection system was operative and that rainfall required for detection was existed, it could not be ascertained why the predictive system did not issue an alert. However, it is considered possible that the wind shear could not be detected due to the system's performance limitations, including the possibility that the wind shear could not be detected because of weak reflections due to a low level of precipitation.

Regarding the reactive type system, as described in the section 2.12.2, the synthetic aural alert of "WINDSHEAR, WINDSHEAR, WINDSHEAR" was recorded by the CVR at around 13:02:58. At that moment a wind speed of 14kt was recorded. A maximum wind speed of 47kt was recorded during the 30 seconds immediately prior to this, a difference of 33kt from the wind speed at the time the alert was annunciated. From this variation in wind speed, it is considered that wind shear was detected.

(4) The Crew's Grasp of Information related to Wind Shear

In the event that a preceding aircraft encounters wind shear on approach, or that specified conditions relating to the presence of thunderstorms are satisfied, information that there is the possibility of wind shear is circulated. However, in this accident, no such information was provided.

Moreover, Hakodate Airport was not equipped with a ground radar facility capable of detecting wind shear.

Furthermore, although the predictive wind shear warning system installed on the aircraft was operating normally, as described in (3) above, the warning system did not issue an alert.

Based on these facts, while it is considered that the flight crew could not anticipate the wind shear encounter before the event, it is thought that considering that there were strong winds with large variations in wind speed just before the accident, the crew should have been wary of the range of CAS variation and the amount of wind variation.

(Refer to Figures 3-1, 3-2 and 5)

3.1.6 Final Approach Speed

During the approach on which the accident occurred, while it is considered that the first officer, acting as a PF, was flying the approach in "SELECTED SPEED" mode while controlling the thrust levers manually, the following are thought regarding the establishment of final approach speed at the time:

(1) The Value of the Final Approach Speed Established by the Flight Crew

Regarding the decisions on final approach speed at the time of the accident, according to CVR recordings as described in the section 2.12.2, it is estimated that the flight crew set the final approach speed (V_{LS} +8kt) to 140kt at around 12:31:20 on the basis of the ATIS issued at 12:00 which they had already received. Later, at around 12:33:17, it is estimated that the flight crew set the final approach speed to 142kt in consideration of gusts.

At around 12:50:50, after receiving the ATIS issued at 12:38, the flight crew discussed the existence of gusts but made no mention of final approach speed.

However, as described in section 2.12.6.3, it is thought from the statements of the flight crew immediately after the accident that the final approach speed was set to 143kt.

Moreover, according to DFDR data, the speed value in the "SPD/MACH" window, which is used to set the speed during approach in "SELECTED SPEED" mode, was set to 143kt.

Based on these facts, it is considered that the flight crew set the final approach speed to 143kt during the final stage of the approach on which the wind shear encounter occurred.

(2) Final Approach Speed in Consideration of Gusts less than 10 kt

According to the OM issued by All Nippon Airways, gusts that are less than 10 kt are not a factor to calculate the value of the final approach speed. More over, according to the AOM issued by All Nippon Airways, while the FMGC calculates up to the value of V_{APP} in "SELECTED SPEED" mode, if there are gusts the pilot should add the gust component to the value of V_{APP}. Further, it is specified that a PF should set the final approach speed according to circumstances. The final approach speeds computed in corresponding to the wind conditions communicated including gust less than 10 kt, that are not in accordance with the OM prescribed in subsection 2,12,6.2 (2), to the pilots prior to the accident are as follows:

Time & Source	Avg. Wind SPD	Max Wind SPD	V_{LS}	V_{APP}	Final App SPD
12:00(issued) ATIS	28kt	----	132kt	141kt	141kt
12:38(issued) ATIS	29kt	42kt	132kt	142kt	152kt
12:56:14 HKD TWR	28kt	---	132kt	141kt	141kt
12:59:46 HKD TWR	28kt	34kt	132kt	141kt	147kt(141kt)*
13:00(issued) ATIS	28kt	---	132kt	141kt	141kt
13:01:07 Co. Radio	32kt	40kt	132kt	142kt	150kt(142kt)*

*(speed) indicate the final approach speed not including factor of the gust less than 10 kt.

The flight crew stated that they had not clearly grasped the wind information received by company radio at around 13:01:07 in the above table because they were concentrating on the landing.

From the calculated speeds shown in the above table, it is considered that a final approach speed of 141kt is appropriate if based on the wind reports that did not include gust information, while on the other hand a final approach speed of 147–152kt is considered possible to obtain a speed margin if the calculation is based on the wind reports that did include gust, including less than 10 kt, information. According to the AOM, "the PF makes the decision [on final approach speed] according to the circumstances" based on the computed value, taking into account the wind conditions. It is thought that consideration of the final approach speed including previously received wind information could be result more appropriate flight crew decision making for speed margin advantages when high wind speed and fluctuations; that is, since gusts less than 10kt are not reported, even if no specific gust information is received, it is possible for there to be gusts less than 10 kt and so previous wind reports should also be taken into consideration when determining the final approach speed to obtain an additional speed margin if wind conditions are steady strong. Moreover, while a final approach speed of 152kt is computed in accordance with AOM based on the ATIS issued at 12:38, even if subsequent wind reports indicate that gusts are weakening or do not include gust information, in the case that strong wind conditions remain the same, it is considered appropriate to conduct the approach at a final approach speed based on the larger wind speed value received up to that time. In consideration of this, the final approach speed of 143kt established during the approach on which the wind shear encounter occurred is low, and a final approach speed of 147kt to 152kt is considered appropriate based on the wind information received by the flight crew because of obtaining speed margin advantages.

Further, a final approach speed of 147kt to 152kt is also considered appropriate based on the statements of the air traffic controller as described in the section 2.1.2.3(1) and the actual wind conditions at the time the accident occurred.

However, it is also necessary to consider that the amount of the pitch-up at flare may increase and possible to over shoot the touch down point with increasing final approach speed.

(3) The Method of Calculating the Final Approach Speed used by the First Officer

It is estimated that the first officer established the final approach speed value using the following formula to simplify the calculation method prescribed in the AOM:

Final approach speed = $V_{LS} + \Delta V$

and in consideration of gusts during approach, while intending to select the maximum value of 12kt within the range of his ΔV, he used 11kt and thereby arrived at a value of 143kt by the following calculation:

Final approach speed = V_{LS} + 11kt = 132kt +11kt = 143kt

The value of final approach speed calculated by the first officer is lower than the value computed for conditions with strong winds and gusts using the method specified in AOM and described in section 2.12.6.1. While the method in the AOM distinguishes between a head wind component and a wind speed variation component to add to V_{LS}, it is thought that the PF treated these together in the summation. It is necessary to use the computation formula specified in the AOM to calculate final approach speed.

Also, it could not be clearly determined whether the first officer's use of 11kt as the additional component to the final approach speed in consideration of gusts, rather than the maximum of 12kt, was due to differences in values of V_{LS} is computed by the individual FAC and FMGC computers or was the result of a lapse on the first officer's part.

(4) On Pilots receiving Information on Wind Speed Variations during Approach

Gust information, which is thought to be regarded by pilots as the most important, was included in the reports from Hakodate Tower just before landing. While the computed final approach speed of 143kt was lower than 147kt which is the value obtained following the gust less than 10kt, it is estimated that it should have been considered inadequate from the point of view of ensuring speed margin against the wind based on the wind report issued at around 12:59:46.

Generally, in the case of strong and varying wind speeds where there are large changes in wind speed over time, it is considered that the final approach speed should be selected in order to be able to cope with the largest wind speed changes. Accordingly, it is considered that if there are reports received immediately prior to landing of wind conditions with gusts greater than the wind speeds expected by the flight crew, as in the case of the 12:59:46 wind report, the value previously set in the SPD/MACH window should be changed, or in the case where this cannot be due to the imminence of landing, thrust should be added to increase CAS to counter the change in wind, and if these measures are insufficient to cope with the change in wind speed, the crew should execute a go around without hesitation.

Regarding these matters, given the First Officer's statements that the CAS was fluctuating over a range of around 3kt and was stabilized by adding a little excess power, and that the average CAS from 1,000ft AGL to 177ft AGL was 145kt, it is considered possible that the approach speed was slightly greater than the 143kt value selected.

(5) Establishment of Final Approach Speed in the Accident to be able to Recover from Wind Shear

As described in (2) above, the rules in the AOM specify that the value of the final approach speed be decided by the PF according to conditions.

According to the First Officer's interview statements, as PF he decided the final approach speed considering gusts in accordance with the rules. Although consideration of gusts should result in a greater aircraft speed, as is described in sections 2.12.4.1 (3) and 2.12.6.3 too high a speed results in a nose-down attitude which can impede the proper execution of approach and landing. According to All Nippon Airways' technical information, it is considered that a final approach speed of greater than 149kt, as in the case of this accident, would result in a nose-down attitude. However, in conditions where there is the possibility of a sudden decrease in wind speed following a gust, it is necessary to preserve a speed margin in the final approach speed. However, in the condition to be possible as the wind speed suddenly decreases as following with a gust, the final approach speed should be established with ensuring a speed margin.

Because of this, in this accident it is estimated that the First Officer, as a PF, established the final approach speed as 143kt, calculated as $V_{LS}+$ 11kt, intending to take into account both gusts and the lowering of the nose. This is close to the his maximum value attainable using the formula $V_{LS}+\ \Delta V$ that is thought to have been used by some All Nippon Airways' A321 flight crews based on experience.

This computation method differs from the procedure specified in AOM and, as described in (3) above, gives a low value for final approach speed under conditions of strong winds with gusts. Since the conditions at the time of the accident were such that the final approach speed of 147–152kt could enable to act more appropriately due to speed margin advantages, as described earlier, it is considered that the value of 143kt was slightly low.

Based on the simulator flight test results, if through consideration of a gust component a greater final approach speed had been established than that at the time of the accident, this additional speed alone would have secured a greater margin. Further, there would have been less reduction of thrust to adjust speed than in the accident. It is considered possible in this case that if the value of CAS that suddenly dropped when the head wind suddenly decreased had been able to be maintained at greater than around 144kt until the wind shear warning sounded, the aircraft could have recovered from the same violent wind shear conditions.

Further more, the approach with flap 3 which is thought to be possible to expand the corresponding range that would be made greater final approach speed for wind shear conditions, prescribed in the FCOM on Airbus Industrie, is not specifying about in AOM on ANA.

ANA stated the reason that ANA did not describe a "flap 3 approaches" on the AOM as follows.

"Flaps not in landing configuration warning" on EGPWS was not reflected upon "flap 3 approaches". Thus, "flap 3 approaches" required an over-ride procedure to inhibit EGPWS warnings that are the one of the most important safety warnings.

3.1.7 Wind Shear Recovery Maneuvers and Engine Thrust

(1) The Thrust Reduction by the First Officer prior to the Wind Shear Warning

In the accident, it is estimated that the First Officer, as PF, started to reduce thrust at around 13:02:50 immediately after the increase in CAS, and accordingly the thrust lever angles (TLA) decreased to their minimum values from 13:02:52 to 13:02:55. Subsequently, it is estimated that although TLA began to increase slightly at 13:02:56, fuel flow reached its minimum value of around 1,700lb/hr at around 13:02:57. The wind shear warning was issued at around 13:02:58 with fuel flow was still remaining minimum value.

The following are considered regarding the First Officer's reduction of thrust immediately after CAS increased at around 13:02:50

(i) The First Officer did not recognize the possibility that the aircraft had encountered severe wind shear nor further wind speed reductions. The note "even if sudden airspeed increasing … do not change …" described in sub sentence 2.12.8.2 (2) is only for wind shear but not for gusts.

(ii) The First Officer was training for upgrade to Captain, and was trying to precisely maintain the selected CAS target value in "SELECTED SPEED" mode.

(iii) When a change in wind occurs during the engine response lag time following manipulation of the thrust levers, it is difficult to ascertain in a short period of time whether a change in CAS is the result of the thrust lever operation or a change in wind. In such circumstances, it is difficult to adjust engine thrust appropriately and it is considered possible that a pilot may reduce thrust.

(iv) Because if an approach is made at a high CAS the aircraft assumes a nose-down attitude, there is an effect on the "FLARE" mode, and the flare out requires greater control inputs than normal, the First Officer feared that the approach and landing would become more difficult and over shooting touch down point.

(2) Thrust Lever Operation and Engine Response Lag during the Recovery Maneuvers

Immediately after the wind shear warning sounded, the flight crew initiated recovery maneuvers but although the thrust levers were moved to the maximum take off thrust positions the aircraft had already descended to around 53ft AGL. Although at around 13:03:00 CAS had increased from 117kt to 128kt and fuel flow had reached around 5,500 lb/hr, the aircraft continued to descend and it is estimated that the lower surface of the aircraft's aft fuselage struck the ground at 13:03:01. Given that the minimum value of approach speed during this period was 117kt and that according to simulator test results described in section 2.12.9.2 a fuel flow of around 5,000 lb/hr was required to simply maintain level flight, it is considered that at the time of the accident, nearly maximum take off thrust would have been required to make the aircraft, descending with high inertia, promptly transition to a climb. However, it is estimated that it the engines reached maximum take off thrust at around 13:03:04.

Further, based on the results of simulator tests on engine responsiveness described in section 2.12.9.1, it is estimated that there is a time lag of several seconds between manipulation of the thrust levers and a corresponding change in thrust.

(3) Thrust Lever Operation to enable Recovery from the Encountered Wind Shear

Based on the results of simulator tests as described in section 2.12.9.4, if the First Officer had not reduced thrust in order to maintain the CAS at the target value when it had increased following a sudden increase in wind speed, or if he had moderated the reduction in thrust to maintain the increased CAS at above 144kt until the wind shear warning sounded, it is considered that wind shear recovery may have been possible.

In this regard, although the flight crew had not recognized the possibility of a wind shear encounter, it is considered they should have been cautious of the fact that when making an approach in strong winds with gusts, in the event that thrust is reduced in response to an increase in CAS and immediately afterwards the head wind decreases resulting in a reduction in CAS and lift, and consequently an increased rate of descent, even if the thrust levers are advanced promptly it may not be in time to prevent a descent due to a time lag of several seconds before a corresponding increase in thrust.

3.1.8 Flight Crew Coordination

The aircraft was being operated by two flight crewmembers; the Captain and the First Officer, who was training for upgrade to Captain. The Captain performed the duties of PNF from the left commander's seat, and the First Officer performed the duties of PF from the right co-pilot's seat. The following are considered regarding the coordination between the flight crewmembers related to the accident:

(1) The Decision on Final Approach Speed

As described in section 3.1.6, the First Officer, acting as PF, calculated the final approach speed using a simple method thought to be used by some ANA A321 flight crews based on experience, but which differs from the procedure specified in the AOM. As a result, he decided on a final approach speed of 143kt in consideration of gusts.

In interview statements made immediately after the accident, the Captain stated that although the computer was indicating a V_{APP} value of 140kt as V_{LS} + 8kt, because there is a tendency to land nose-first if final approach speed is too high a further three knots were added in consideration of gusts to give a final increment of 11kt and a final approach speed of 143kt. Further, as described in section 3.1.6 (4), it is considered that the final approach speed was set to 143kt based on the recording of the value set in the

SPD/MACH window.

However, based on the CVR recording, although the Captain and the First Officer discussed setting the final approach speed as plus 10kt at around 12:33:17, there was no clear verbal confirmation regarding a change of final approach speed. Given that there were strong winds with large wind speed variations at the time of the accident, it is considered desirable that crews should mutually confirm their intent clearly regarding the decision on final approach speed, which is a large factor for ensuring flight safety.

(2) Possibility of Go Around

At around 13:00:03, while the aircraft was on final approach and just after Hakodate Tower had reported strong winds accompanied by gusts, the First Officer as a PF, carried out a confirmation briefing on the go-around procedure with the Captain. It is considered that this briefing was performed during final approach because it was thought that the wind and any other conditions at that time would make the landing difficult and that it was possible that there would be a go-around.

(3) Simultaneous Side Stick Operation

During the time from the wind shear recovery operations until the aircraft began to climb, there were simultaneous control inputs made to the Captain's and First Officer's side sticks, including momentarily opposing inputs. The Airbus A321's side sticks are small and since the left-seat's side stick is on the left and the right seat's side stick is on the right, are also well separated. It is considered that this made it difficult for the Captain to grasp the control inputs made by the First Officer. Furthermore, it is considered that the Captain felt that there was not sufficient time to inform the First Officer of his intention to take over control of the aircraft. However, it is considered that the Captain should have clearly assumed control by pressing the take-over push button and by the "I have" and corresponding "You have" calls, even though it is considered that simultaneous side stick in puts are not major factors in this accident.

(Refer to Figure 8-2.)

3.1.9 Approach and Landing Training and AOM Procedures

3.1.9.1 The Decision on Final Approach Speed

In this accident, the First Officer, acting as PF, calculated the final approach speed using a simple method which differed from that specified by the AOM. It is considered that the reason for his using the simple method was not only the fact that he had used it previously based on experience, but also possibly because he feared that if the aircraft assumed a nose-down attitude if an approach were made at high CAS, a greater amount of control input that normal would be required to flare the aircraft and this would make the landing difficult. To the extent that these fears remained, he would not in actual operations decide on the final approach speed for approaches in strong winds with large wind speed changes in accordance with the AOM, resulting in the selection of a low final approach speed.

Operators should grasp the actual operational practices of pilots and, while considering means of addressing concerns and fears of pilots, should adapt procedures and rules to be suited for actual line operations and in addition, should thoroughly train pilots to follow procedures.

3.1.9.2 Thrust Control in Conditions of Strong Wind with Large Wind Speed Variations

In this accident, the First Officer reduced thrust immediately after the CAS increased at around 13:02:50. However, as described in section 2.12.9.2 (2), the AOM procedure for the case where there is a possibility of encountering wind shear has a cautionary note that if there is a sudden increase in airspeed thrust should not be greatly reduced as there is the possibility that airspeed will subsequently drop. If the First Officer had heeded this under the conditions of strong wind with large wind speed variations, it is considered that the he would have reduced the thrust less than he did at the time of the accident.

It is considered that this description in the AOM is important for preventing recurrence of accidents of this type and should be emphasized. Further, while AOM describes procedures for the cases of possible and actual wind shear encounter, because the existence of wind shear can be difficult to forecast, it is considered appropriate that these procedures be considered normally applicable for approaches and landings in conditions of strong wind with large wind speed variation. It is also necessary to thoroughly train crews regarding the cautionary note.

3.1.9.3 Mode Selection for Approach and Landing

(1) Problems of “SELECTED SPEED” Mode for Approach and Landing

As described in section 2.12.6.1, the maximum final approach speed that should be set in SELECTED SPEED mode is V_{REF} + 20kt. In the case of this accident, the maximum value is 132 + 20 = 152kt. However, if aircraft were actually operated at this high speed it would always cause excessive lowering of the nose. This would affect “FLARE” mode, and the amount of control input necessary to flare would be larger than for a nose-up pitch attitude. As a result, is possible that it would be difficult to control the landing.

It is thus estimated that there are limits to carrying out a positive approach and landing under manual control in “SELECTED SPEED” mode in conditions of strong wind with severe wind speed variations.

Regarding this matter, as described in section 2.12.8.3 the Airbus Industrie FCOM states that in conditions of severe wind speed variation it is important to consider carrying out the approach and landing with flap 3 instead of full flap.

(2) The Operating Procedures of Airbus Industrie and All Nippon Airways

As described in section 2.12.8.1 (2), the Airbus Industrie FCOM recommends the use of “MANAGED SPEED” mode for ILS approaches.

On the other hand, All Nippon Airways’ AOM specifies that for approaches with manual thrust lever control, “SELECTED SPEED” mode should be used for final approach, and there is no procedure for “MANAGE SPEED” mode. Further, even for approaches using autothrust, while “MANAGED SPEED” mode is mentioned in the AOM there are no standards for judgment of its use.

While details on the circumstances of the adoption of “SELECTED SPEED” mode at the introduction of the A321 aircraft to All Nippon Airways are not clear, it is considered that there were differences in the way of thinking between the manufacturer Airbus Industrie and the operator All Nippon Airways.

For All Nippon Airways, there were large differences between some of the operating procedures for the aircraft types they had already operated for a long time and the newly introduced Airbus type. When the Airbus aircraft were introduced, the descriptions of “MANAGED SPEED” mode in the All Nippon Airways AOM were limited to what was considered the necessary minimum in consideration of the opinions of the pilots and operational experience.

Further, although judgment standards on the use of MANAGED SPEED mode during approach are not specified in the AOM, All Nippon Airways’ AOR states that “MANAGED SPEED” mode is effective for approaches made in strong winds etc., and describes its characteristics and detailed operating procedures. However, because the AOR is not part of the formal operating procedures manuals, it is considered pilots were hardly using this mode for approach and landing in actual line operations.

Regarding the differences in content between the FCOM and AOM, it is considered that it was necessary for All Nippon Airways as the operator to understand the background and rationale of “MANAGED SPEED” mode in the manufacturer’s FCOM and, having considered the issues in applying it to its own operations, it should have carried out an adequate technical study on whether to incorporate it into its own AOM. Furthermore, it is considered that it would have been effective for such a technical study to confirm the effects on aircraft flight characteristics and pilot operations by flight simulation as necessary. Also, it is considered appropriate that matters that are thought to have a large impact on flight safety should be described in the AOM that constitutes part of the formal operating procedures documentation.

(3) The training for the establishment of use of “SELECTED SPEED” mode

Regarding All Nippon Airways’ continued operation of “SELECTED SPEED” mode on A321 aircraft, it is considered by All Nippon Airways that when pilots convert to another type of aircraft, the training will be proceed more smoothly if the concepts of operating procedures for the same mode are the same between pilots’ currently rated aircraft types and the new type.

It is considered that if an operator establishes operating procedures that differ from those of the manufacturer, such as the use of “SELECTED SPEED” mode in this accident, adequate studies should be carried out on factors that may have an affect on pilot operations, for example a delay in engine thrust response and a pitch attitude associated approach speed. It is considered that if there are matters in the operating procedures that require special attention such as to not reduce thrust greatly in gusts and the fact that high approach speed causes a nose-down attitude, the operator should study instilling common pilot knowledge and conducting thorough training as necessary. If there had been such common knowledge and training, it is thought that the crew would have responded appropriately in this accident.

(4) The Effectiveness of “MANAGED SPEED” Mode.

From the point of view of preventing recurrence of this type of accident, the following improvements are considered when comparing approaches and landings flown in “MANAGED SPEED” mode to those flown in “SELECTED SPEED” mode:

(i) Automatic on-board computer calculation of final approach speed.

(ii) Even if CAS increases there should not be an excessive reduction of thrust to maintain a fixed ground speed during approach and landing.

Further, as described in section 2.12.9.3, regarding maneuvers to recover from wind shear during approach and landing using “MANAGED SPEED” mode, the result of flight simulator tests assuming similar conditions as at the time of the accident showed that wind shear recovery would have been possible and confirmed that using “MANAGED SPEED” mode would have been effective.

3.1.10 Regarding the Wind Shear Encounter

Based on flight crew statements and analysis of the DFDR data, it is estimated that while the aircraft was on final approach at a distance of 250m from the approach end of the runway, there was an abrupt descent from a height of approximately 100ft AGL, two seconds after which the wind shear warning sounded.

According to flight crew interview statements and the weather information described in section 2.7, the possible existence of weather phenomena capable of causing wind shear, such as fronts, clouds potentially associated with microburst or temperature inversion, was not recognized in the vicinity of the ground around Hakodate Airport.

Judging from the near-ground wind speed measurements along the approach course to Hakodate Airport recorded between the approach on which the wind shear encounter occurred and the second approach of the same aircraft, shown in Figure 9, regarding wind conditions that would cause an aircraft to abruptly descend and trigger a wind shear warning, it is considered that there was localized air mass with a wind speed 10kt greater than the surroundings from 250–100ft above ground level, and below 100ft AGL there was a wind shear with a marked decrease in wind speed with decreasing altitude. It is considered possible that wind conditions like these arose due to a combination the strength and direction of a wind passing over the terrain in the vicinity of the airport at the time affecting the surface boundary layer that was developing along ground surfaces.

Depends on the DFDR Data, it is considered that intensity of the wind-shear in this accident could be designated as "severe" that was described in a ICAO Circular 186-AN/122 titled WIND SHEAR.

(Note: While winds generally weaken near the ground due to friction with surface, they in particular they can suddenly weaken at heights close to ground level such that there is in no wind at the ground surface. The height range over which this severe change of wind speed occurs is called the surface boundary layer.)

(See Figs. 6, 9 and Photo 1)

3.1.11 The Impact Absorption Characteristics of Cabin Attendant Crew Seats

Although a vertical acceleration of approximately 1.9G occurred when the lower surface of the aft fuselage struck the ground, no injuries were sustained by the passengers or flight crew.

On the other hand, three of the four CAs sustained minor injuries such as lumber sprains, etc. It is estimated that the reason that only CAs sustained minor injury, as described in section 2.12.10, is that the CA crew seats had inferior impact absorption characteristics, with the thickness of the cabin attendant seat cushions being less than one third that of the passenger seat cushions and the reclining angle of a CA seat was almost vertical with no armrest might be factors on this accident.

4 PROBABLE CAUSES

In this accident, it is estimated that while on final approach at a height of approximately 100ft AGL, the aircraft encountered severe wind shear and although recovery actions were taken, a sufficient rate of ascent was not attained in time to prevent the lower surface of the aft fuselage striking the runway, resulting in damage to rear frames and the aft pressure bulkhead.

Further, the following factors are considered to have contributed to this accident:

(1) A delay in engine thrust response to the thrust levers being advanced to recover from the wind shear, combined with a reduced approach speed, meant that an increase in speed could not be obtained immediately. These factors contributed to the fact that sufficient rate of ascent could not be attained in time to prevent the tail strike.

(2) Factors contributing to the reduced approach speed were the fact that the first officer, acting as PF, had selected a slightly low value for the final approach speed, and that he reduced thrust in response to an increase in headwind.

(3) Factors in the reduction of engine thrust in response to the increase in headwind were that because the pilot was operating the thrust levers manually in “SELECTED SPEED” mode he was attempting to maintain a constant CAS, and that the flight crew had not adequately anticipated a increasing followed by a continuing drop in wind speed.

(4) Regarding the selection of a slightly low value for final approach speed, appropriate consideration was not given to wind speed, and there were concerns over touch down attitude related to high approach speeds.

(5) Regarding the fact that appropriate consideration was not given to wind speed, the first officer used a simple calculation formula that did not separately consider the additional airspeed margins to take account of wind speed changes and the head wind component, but that treated these together.

(6) Regarding the concerns over aircraft touch down attitude at high approach speeds, the measures described in the operator’s AOM for dealing with a nose-down attitude assumed only the case of full flap landings, and the First Officer considered difficulty to land an aircraft with a nose-down attitude.

It is considered possible that the low-level wind shear had originated due the effects of ground topography on the surface boundary layer under conditions of strong winds accompanied by gusts.

5 FINDINGS

5.1 Flight Crew Training and the Development of Standards related to Wind Shear

(1) In flight crew wind shear training, it is necessary for operators to draw attention to not only downbursts but also to other causes of wind shear including the effects of topography on the surface boundary layer.

(2) Since it is sometimes difficult to forecast wind shear, flight crews should be aware of the possibility of encountering wind shear during approaches and landings where there are strong winds accompanied by large wind speed fluctuations, and should be thoroughly trained to give priority to safety in setting the approach speed, engine thrust etc.

(3) Operators should thoroughly train flight crews to determine approach speed by following the specified rules, rather than by using simple computation methods as in this accident. Further, operators should grasp line operating practices while considering means of addressing flight crews' concerns and misgivings. Thence, operator should notify these points to their flight crews whenever required.

(4) Under conditions of strong winds accompanied by large wind speed fluctuations, as at the time of the accident, it is desirable for flight crew members to confirm with each other clearly and positively their intentions regarding the setting of final approach speed, which is considered to be a large element for ensuring flight safety during approach and landing. It is also considered that this point should be emphasized in flight crew training.

(5) Regarding procedures to deal with possible wind shear encounter, the AOM issued by the operator contained a cautionary note that "Thrust should not be greatly reduced even in the event of a sudden increase in airspeed, because of the possibility that airspeed may subsequently decrease". It is considered necessary that this cautionary note be emphasized, since is important for preventing recurrence of accidents of this kind. Furthermore, it is considered appropriate to always consider this caution when conducting approaches and landings under conditions of strong winds with large wind speed fluctuations. Moreover, it is necessary that this point be thoroughly driven home by flight crew training.

5.2 Technical Study on the Establishment by Operators of Operating Procedures different from those recommended by the Aircraft Manufacturer

(1) In connection with this accident, regarding the establishment of approach speed for A321 aircraft under the management of "SELECTED SPEED" and "MANAGED SPEED" modes, if the procedure for determining the approach speed in aircraft operations differs from that recommended by the manufacturer, it is considered necessary that operators should decide on the establishment of procedures based on adequate technical studies on the problems etc. of each procedure relating to company operations while grasping the background and rationale of the manufacturer's recommended procedure. It is considered that the effects of each considered procedure on the pilots' workload and actions be adequately examined, with examination of the adequacy of pilot common-knowledge information and training as necessary.

(2) In particular, when pilots transition to an aircraft with markedly different operating procedures than their currently qualified aircraft, it is considered that sufficient flight crew training be conducted on actual operating procedures based on a grasp of the background and rationale of the manufacturer's recommended procedures.

5.3 Shock Absorption Characteristics of Cabin Attendant Crew Seats

Although in this accident there were no injuries to passengers or the flight crew due to the shock of the lower surface of the aft fuselage striking the ground, three of the four CAs sustained minor injuries. The fact that the thickness of the seat padding of the cabin crew seats was less than one third of that of passenger seats and the reclining angle of a CA seat was almost vertical with no armrest might be considered a contributory factor in this accident.

Given the safety role of cabin crew in guiding passenger evacuation etc. in emergencies, it is considered necessary to study the means to reduce the possibility of injuries to CAs.

6 REFERENCE MATTERS

6.1 Investigations on the use of “MANAGED SPEED” Mode Overseas

All Nippon Airways visited several operators of A320 family aircraft between 2–8 June 2002 and asked questions regarding the use of “MANAGED SPEED” mode in establishing approach speed in the operation of same-model aircraft. The findings are summarized as follows:

(1) In-Service Use of “MANAGED SPEED” Mode.

All operators interviewed had used “MANAGED SPEED” mode since its introduction.

(2) Flight Crew Resistance to the use of “MANAGED SPEED” Mode.

All operators reported initial resistance from flight crews at the introduction, but this disappeared as understanding developed.

Similarly, there was initial resistance from flight crews converting from other types regarding differences relating to “MANAGED SPEED” mode and auto-thrust, but this disappeared as understanding developed.

(3) Use of “MANAGED SPEED” mode.

Each operator understood that Airbus recommends use of “MANAGED SPEED” mode as standard procedure, even for runways 2,000m or less in length.

(4) Use of Auto-Thrust.

While each operator understood that Airbus recommends use of auto-thrust as standard procedure, some operators that did not use auto-thrust as standard procedure. All operators recognized the manual control of thrust to maintain flying skills.

6.2 Measures, relating to operational procedures, to be implemented by All Nippon Airways

Based on the overseas study described in section 6.1 above, All Nippon Airways examined measures to prevent recurrence of the accident and intends to make phased revisions to its aircraft operating manual.

(1) Introduction to Actual Operations.

Build experience by flight simulator training in order to deepen flight crews’ understanding of “MANAGED SPEED” mode and auto-thrust, and plan to instill pilot common knowledge about these systems’ characteristics, rationale and standards for judgment regarding their use in actual operations.

(2) AOM Revisions.

(i) Use of Auto-Thrust during Landing

Use of auto-thrust during the landing will be at the discretion of the PF. However, use of auto-thrust will be strongly recommended when wind shear is expected.

(ii) Use of "MANAGED SPEED" mode

After pilot common knowledge has been established by the measures described in (1) above, a description will be added to the AOM section on Target Approach Speed that while use of Managed Speed mode will be standard procedure, Selected Speed mode may be used as necessary, subject to the judgment of the PF.

6.3 Notifications on the local weather information at Hakodate Airport

After this accident, ANA described in their Weather Handbook that the low-level wind shear effects of ground topography on the surface boundary layer at Hakodate Airport to notice flight crews.

Figure 1:　Topography around Hakodate Airport

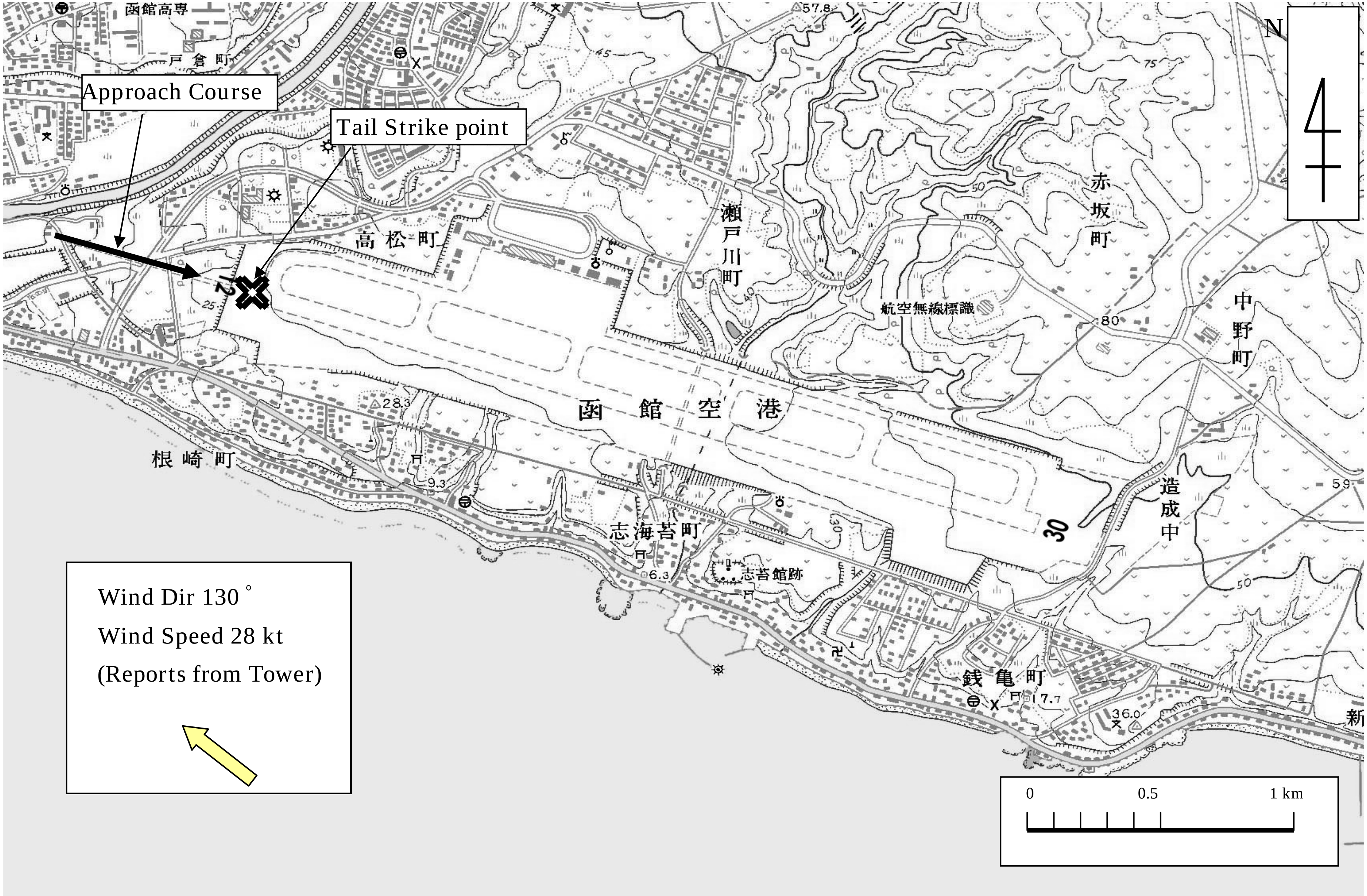


Figure 2: Three angle view of AIRBUS A321

Unit: m

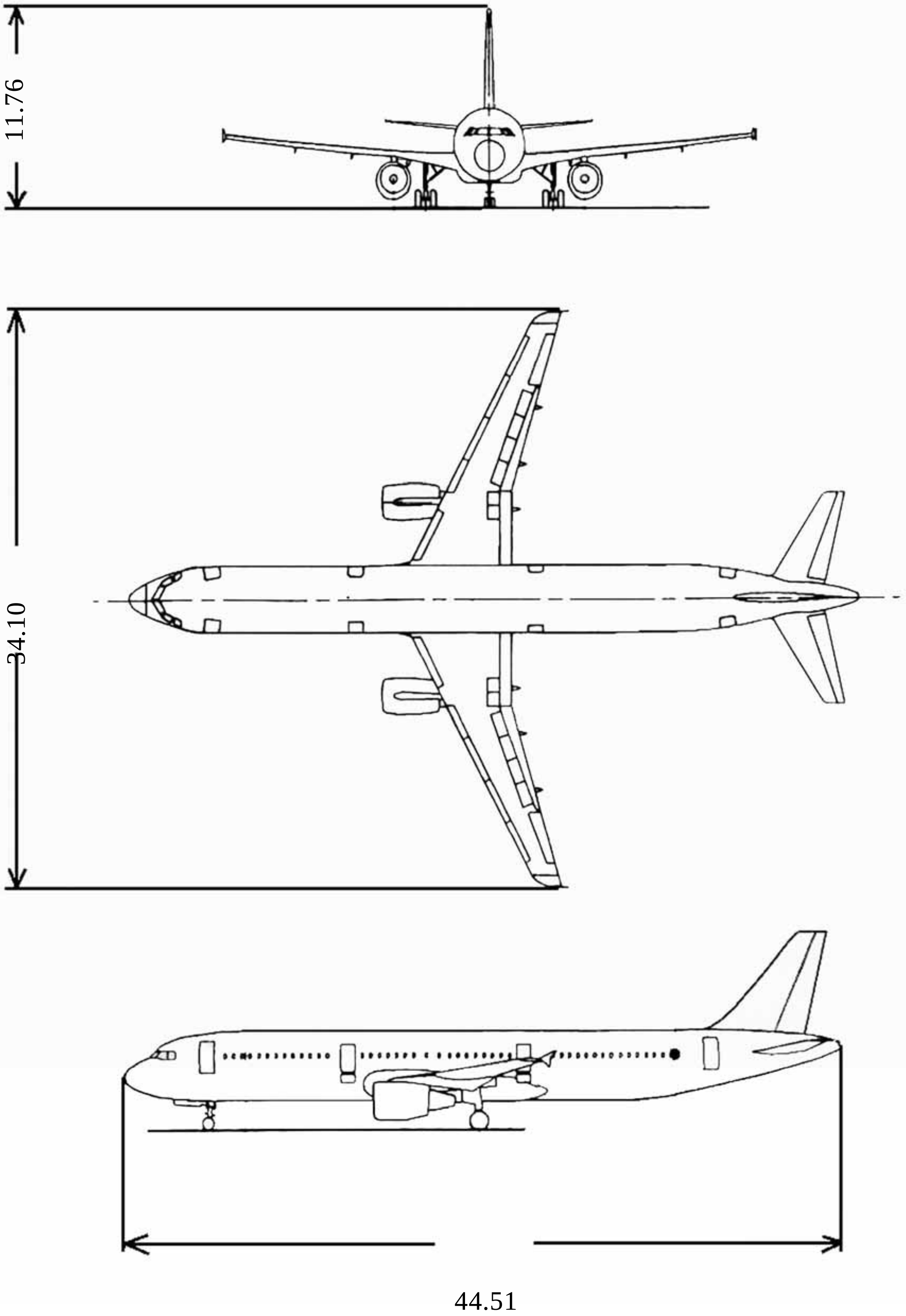


Figure 3-1: Weather Map (0900 JST, 21 JAN 2002)

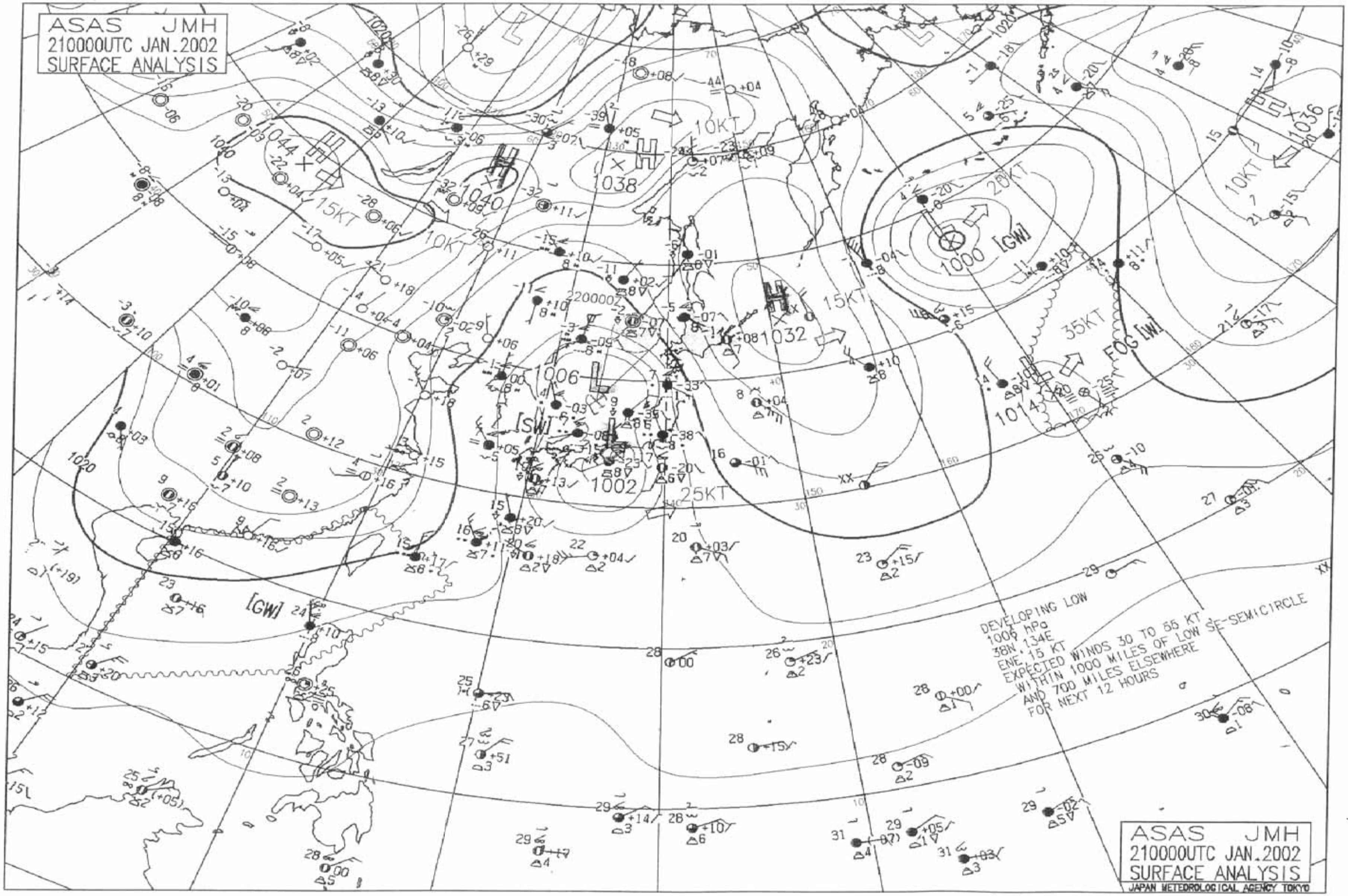


Figure 3-2: Weather Map (1500 JST, 21 JAN 2002)

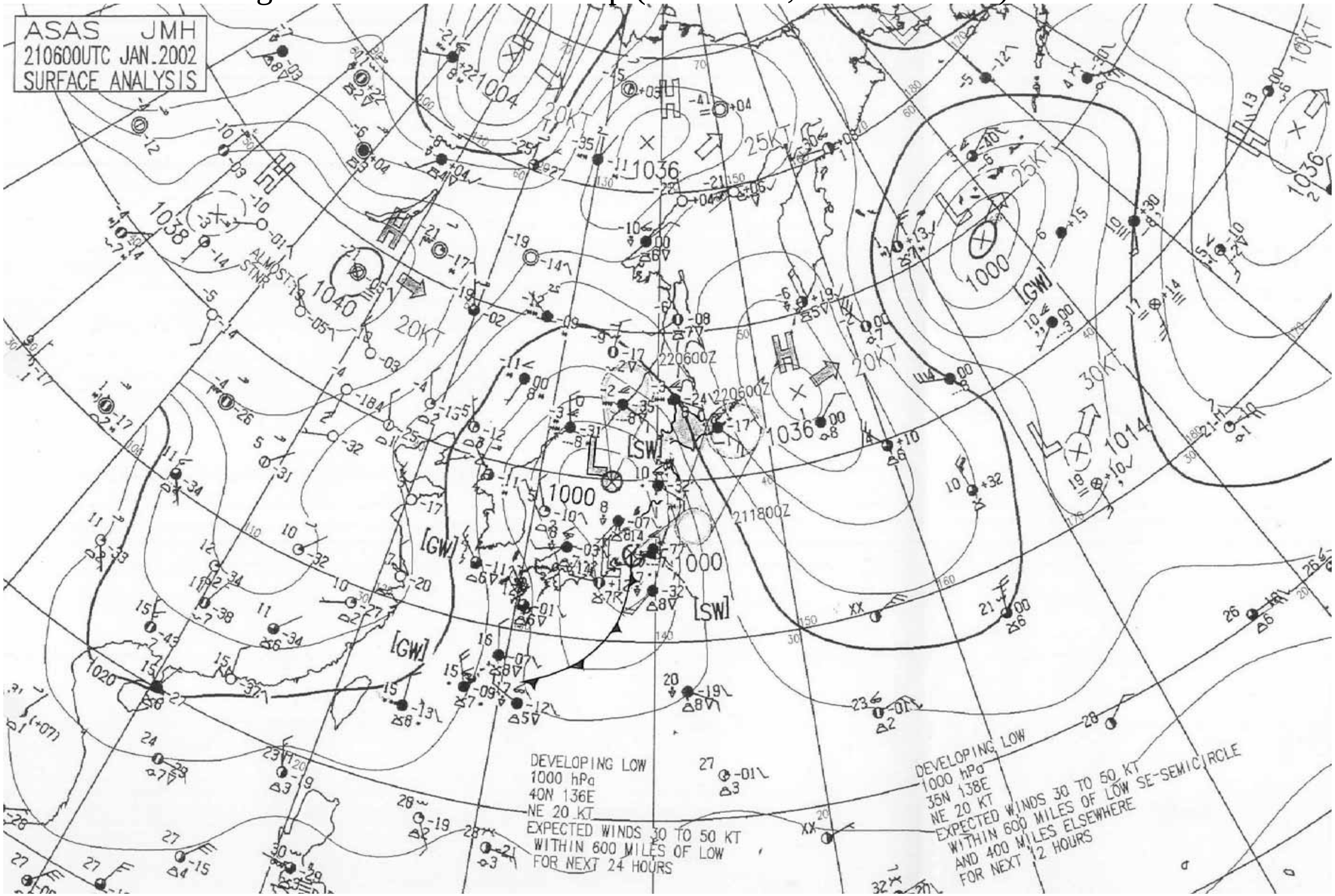


Figure 4:　Clouds Information Chart (1200JST, 21 JAN 2002)

TSFE1　　RJTD

210300UTC JAN 2002

Cloud Information Chart

対応記号	位置	移動	変化傾向
ⓐ	33.7N,136.5E	NE 19KT	変化なし
	紀伊半島付近の低気圧対応下層渦、周辺にCbを伴う		
ⓑ	36.0N,126.0E	ESE 19KT	変化なし
	朝鮮半島西海上のトラフ対応上層渦		
①	43.6N,140.6E	NNE 21KT	H=0,A=+
	日本海北部から北海道地方の厚い雲域		
②	39.4N,135.8E	NNE 16KT	H=0,A=0
	日本海中部の厚い雲域		
③	39.3N,141.0E	NE 17KT	H=0,A=+
	東北地方のCbを含む対流雲域		
④	34.4N,138.5E	NNE 13KT	H=+,A=+
	東海沖から東海・関東地方南部のCbを含む対流雲域		
⑤	36.0N,136.0E	NE 15KT	H=0,A=0
	近畿・北陸地方のCbを含む対流雲域		
⑥	33.9N,131.1E	E 15KT	H=0,A=-
	九州北部・中国地方西部の対流雲域		
⑦	27.7N,128.3E	E 14KT	H=+,A=0
	南西諸島付近のCgを含む対流雲域		

上層雲域
中層雲域
曇天域
積雲域
霧域
Cb域
Cg域
暗域
WV.TBB等値線

トランスバースライン
シーラスストリーク
上層トラフ
強風軸
対流雲列
下層渦　αスケール　βスケール
上層渦
波状雲
台風及びTD中心
雲頂高度　移動
風ベクトル　上層　下層

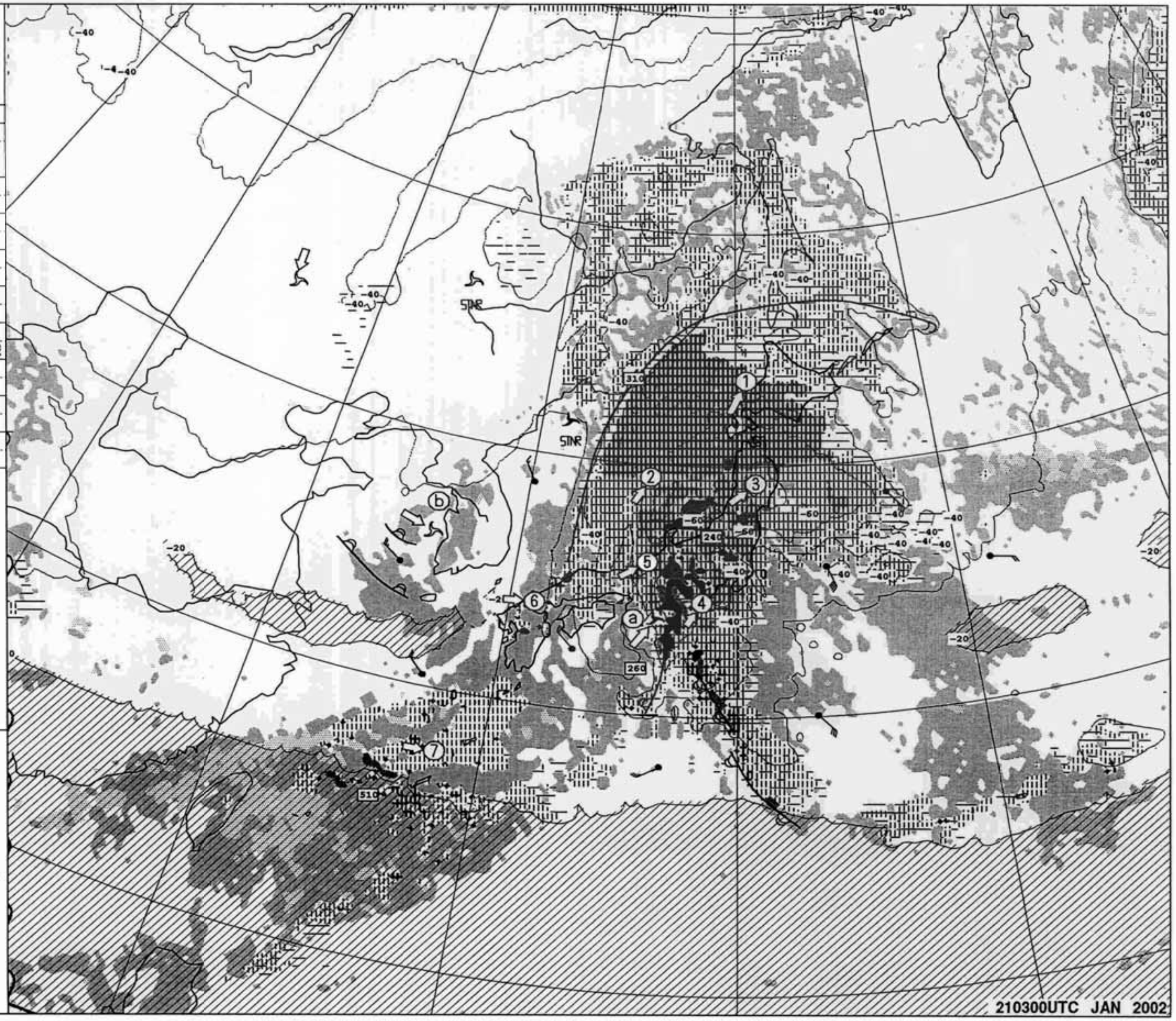


Figure 5: Area Meteorological Advisory Chart (1500JST, 21 JAN 2002)

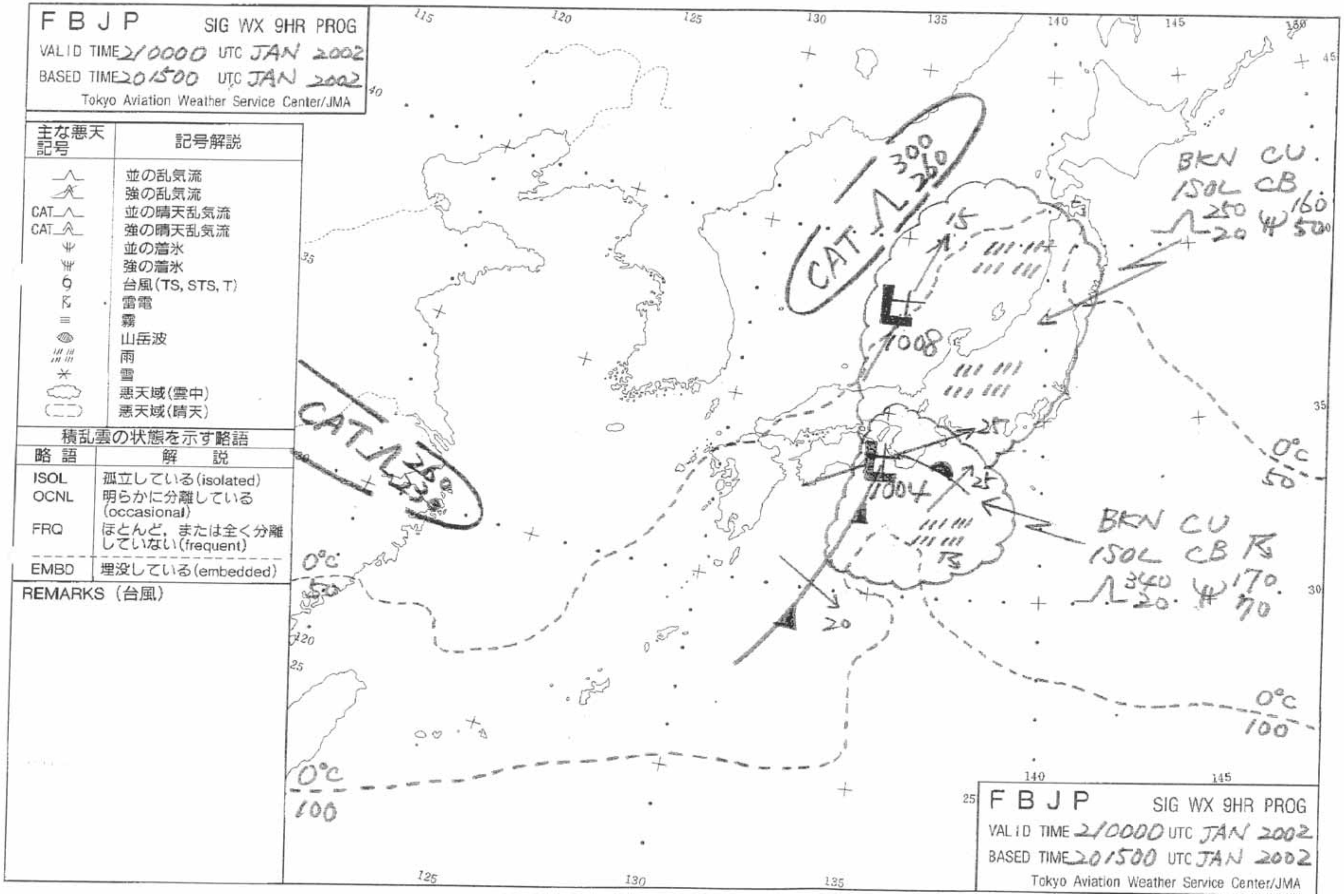


Figure 6: Weather Radar Chart for Western Hokkaido

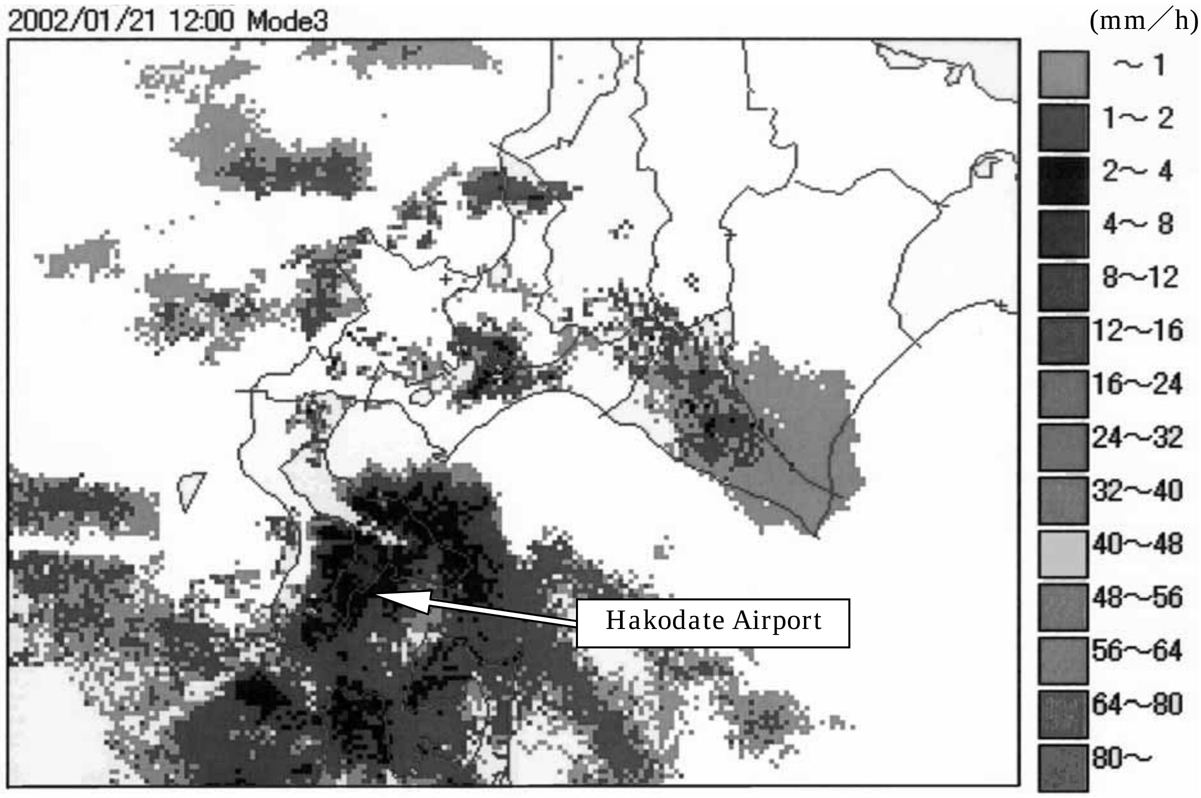


Figure 7: Wind Dir and Speed Information (RWY 12)

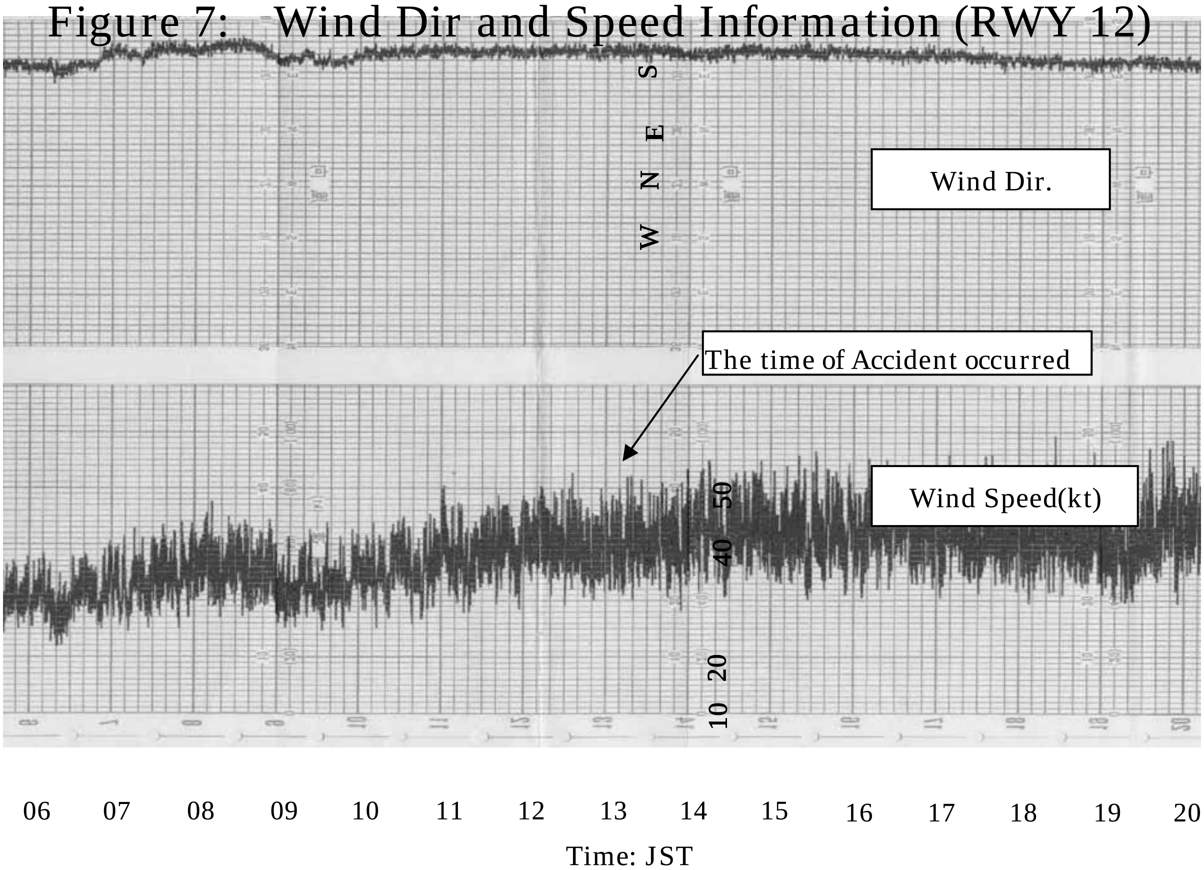


Figure 8-1 DFDR Recording-1

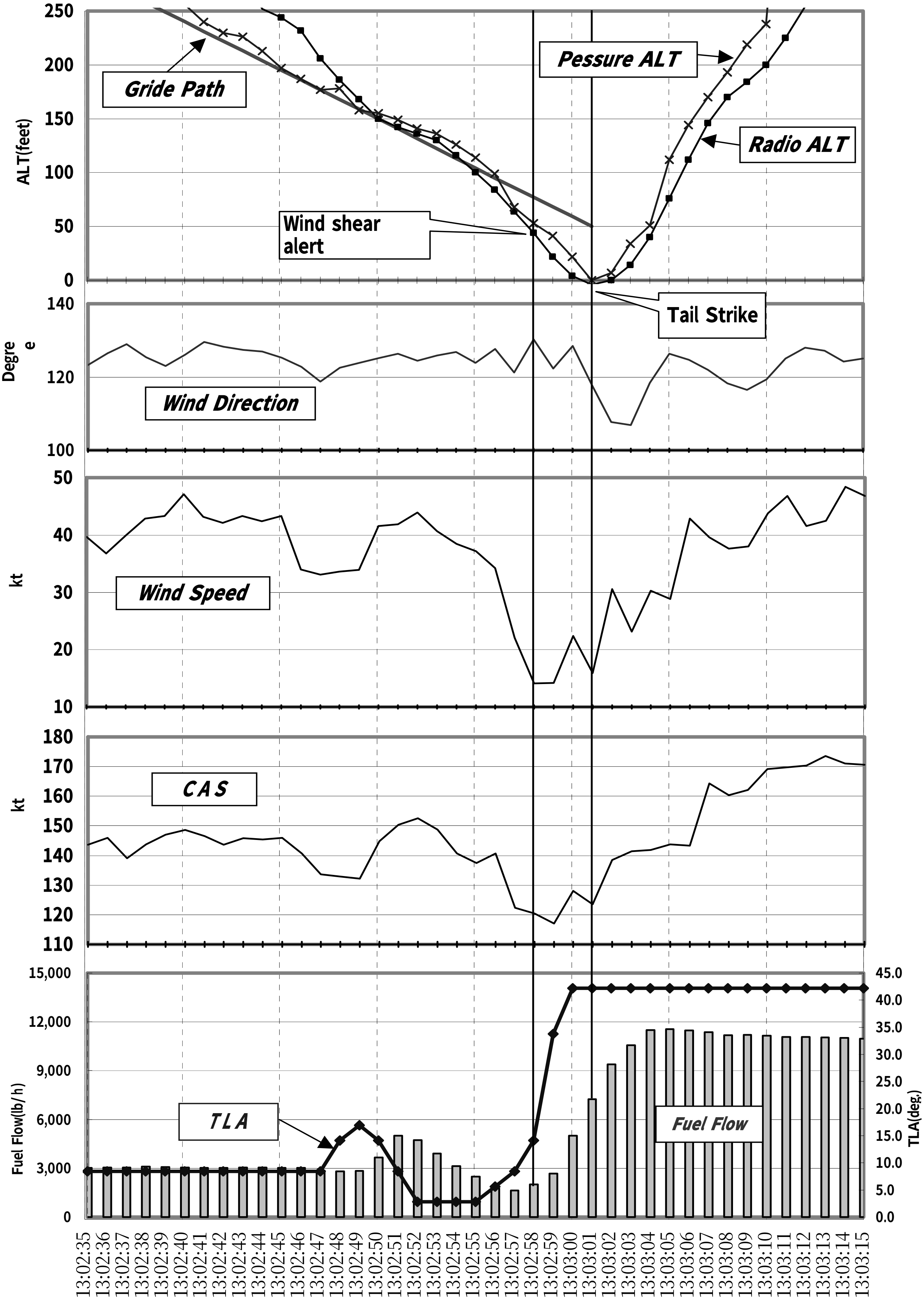


Figure 8-2 DFDR Recording-2

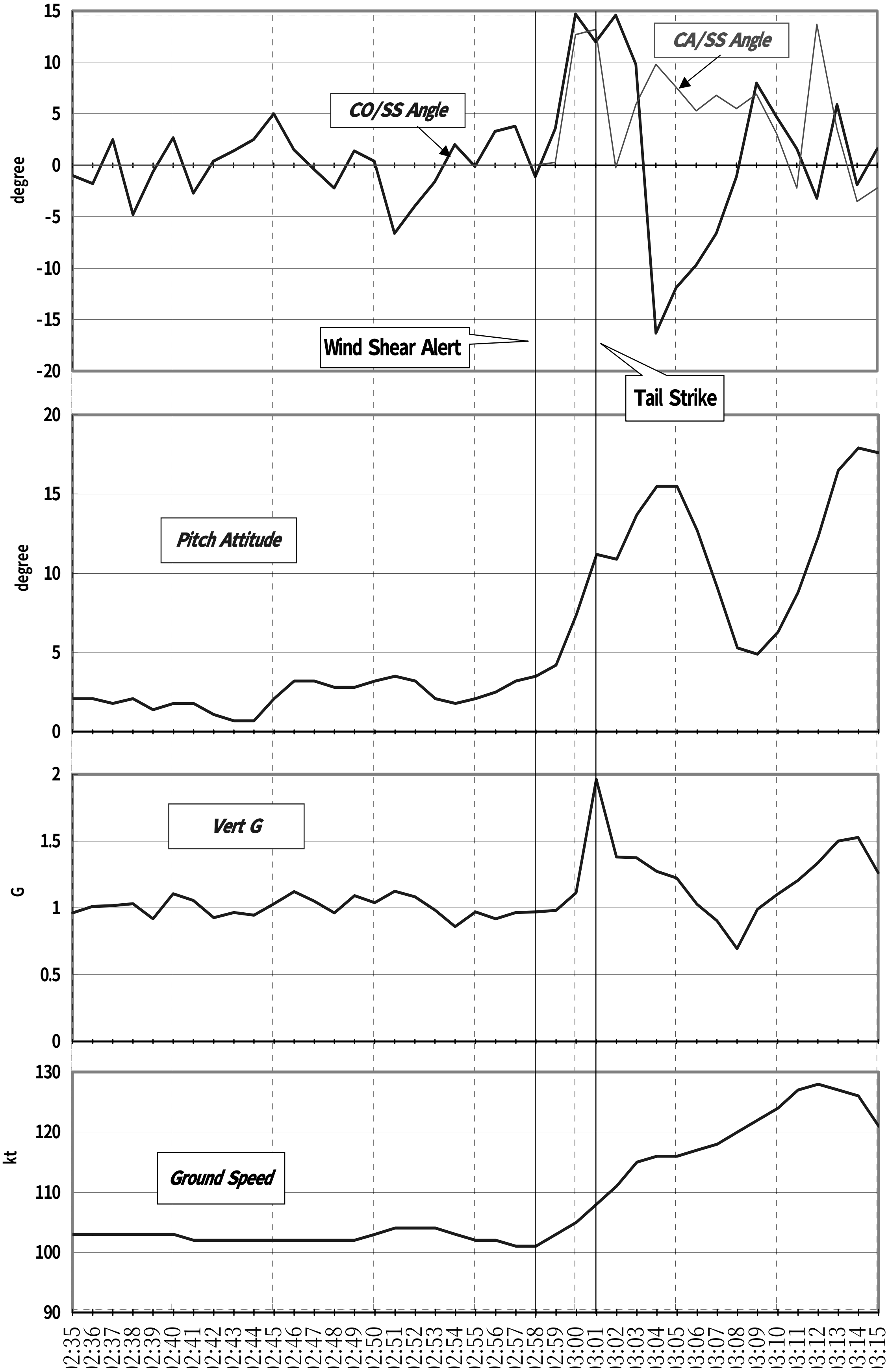
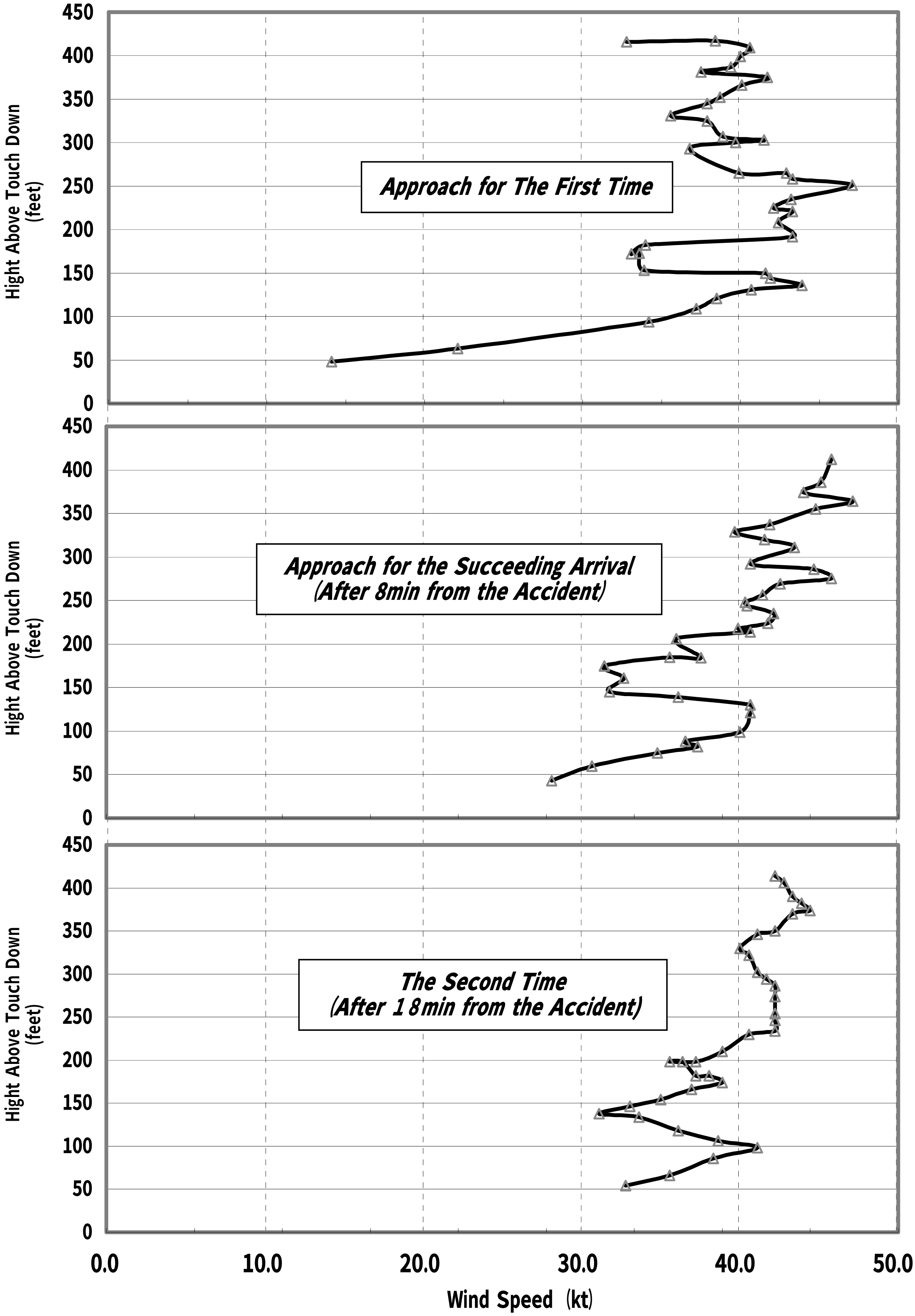
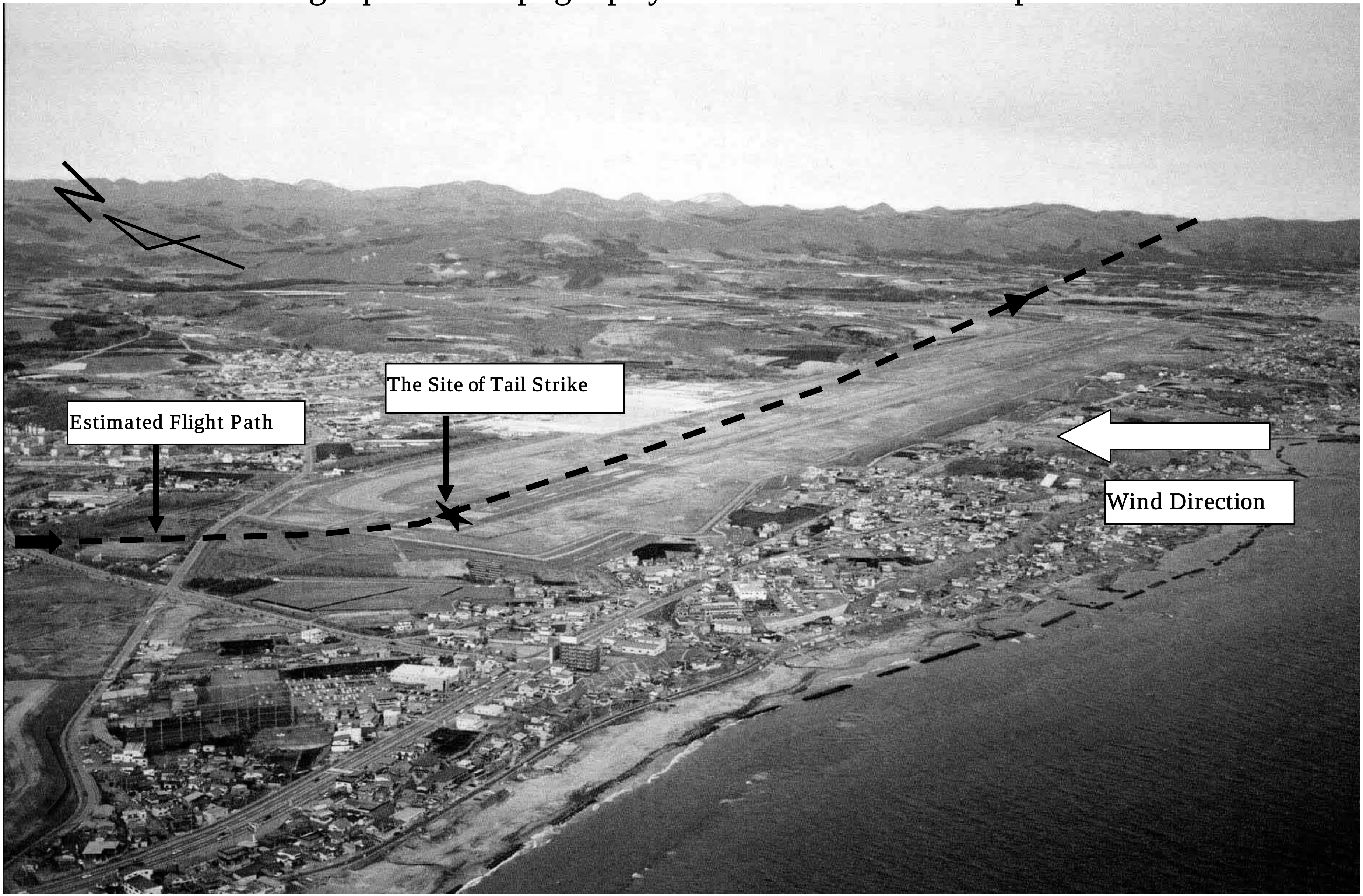


Figure-9 Wind Speed on the Final Approach

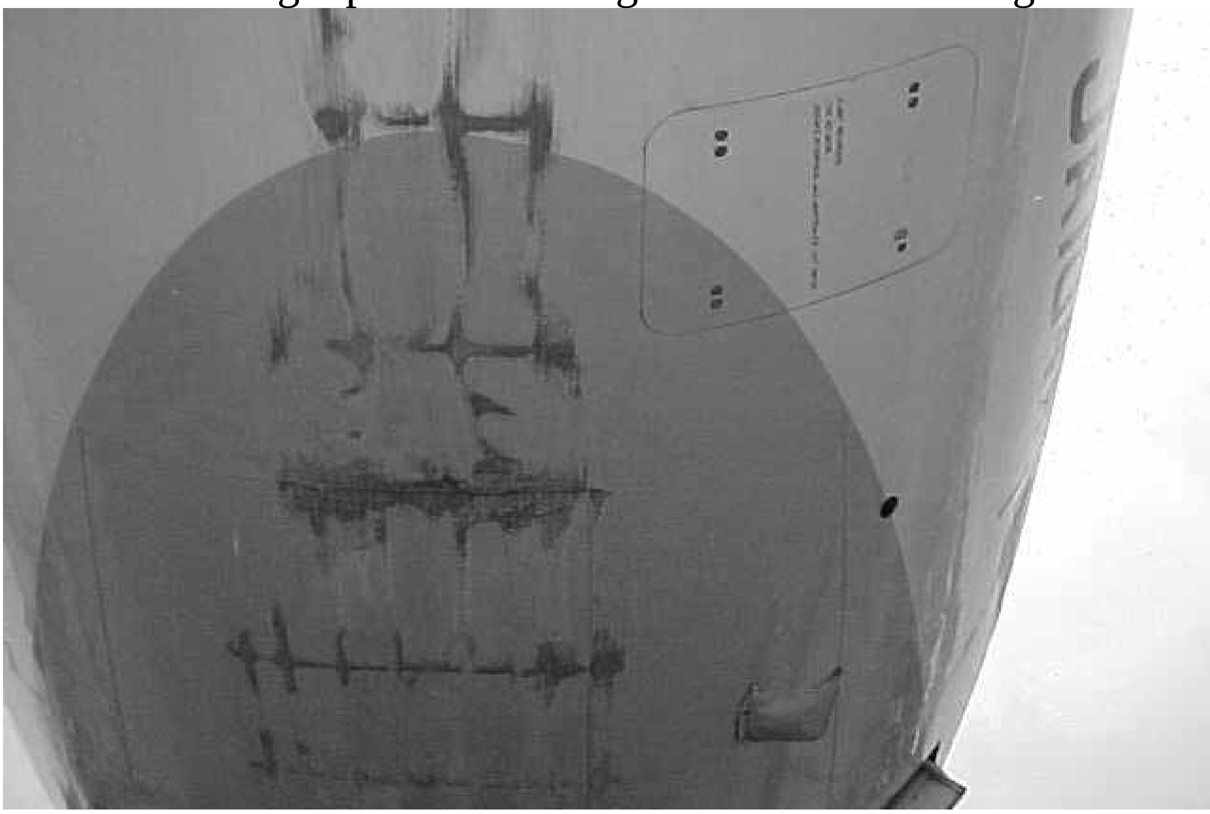


Photograph-1:　Topography around Hakodate Airport

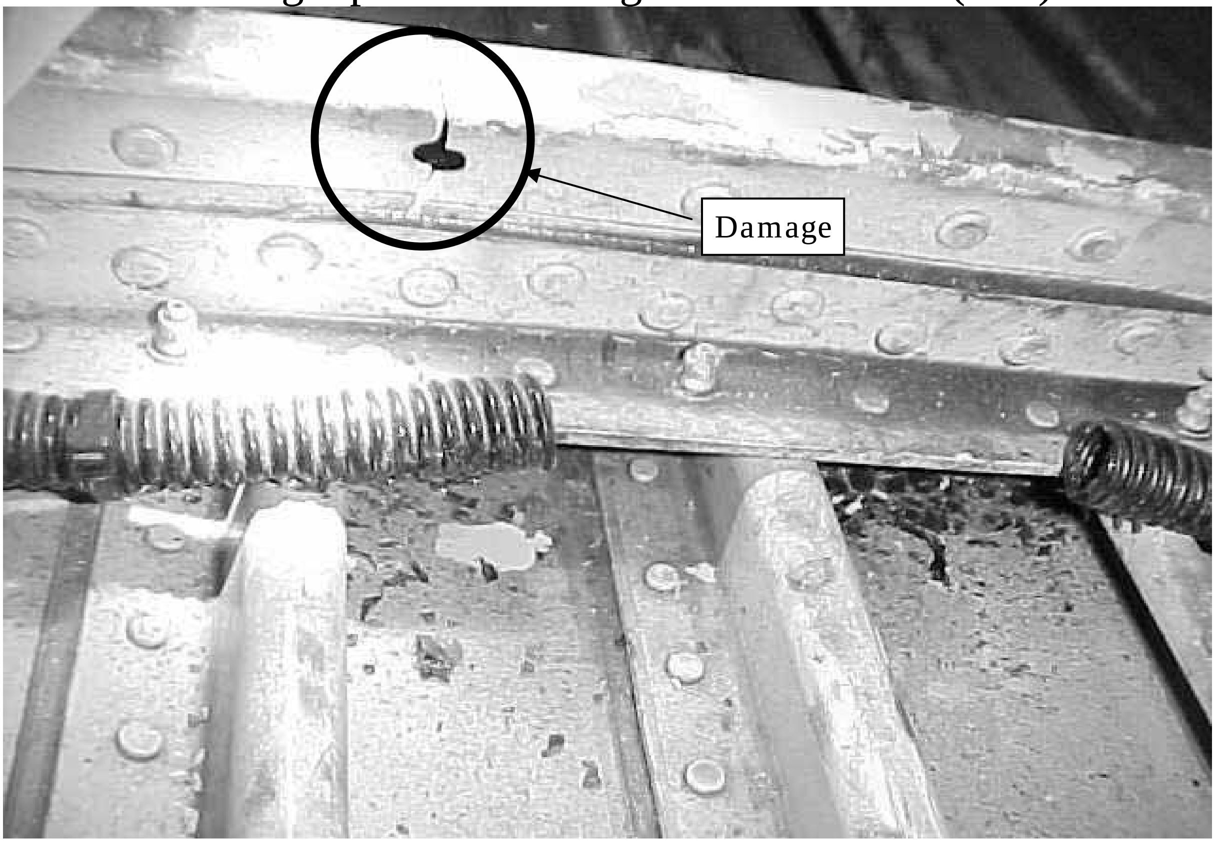


Photograph-2: The scrape marks on RWY 12

Photograph-3: Damage of the Aft Fuselage



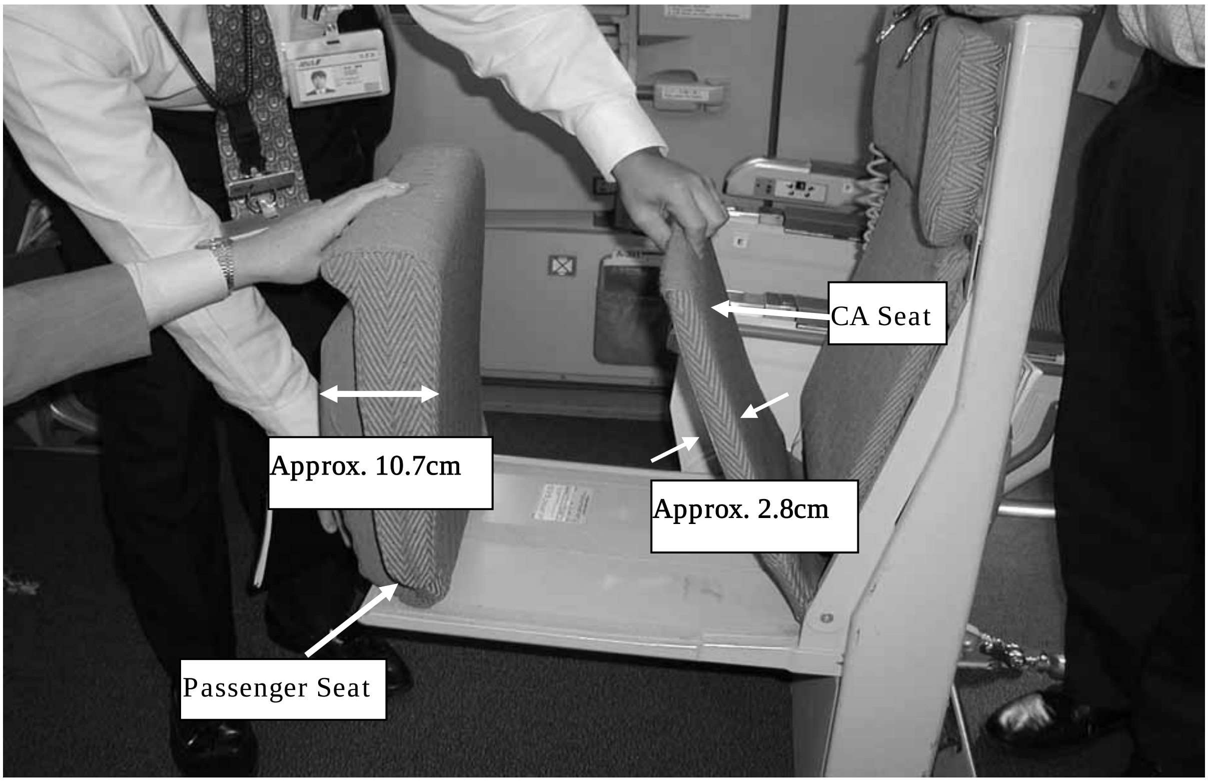
Photograph-4: Damage of the Frame (#67)



Photograph-5: Damage of the Aft Bulkhead

Photograph-6: Cabin Attendants Seat

Photograph-7: Seat Comparison of CA with Passenger



APPENDIX: Analysis of CVR Recording

The outlines of the conversations in the cockpit recorded on the aircraft's CVR before and after the approach on which the wind shear encounter occurred are as follows:

Approx. Time	
12:31:20	Flight crew dialogue on flying the approach at V_{APP} 140kt (V_{LS} 132kt + 8kt).
12:32:37	Flight crew dialogue on approaching runway 12 using radar vectors then ILS because of 12:00 ATIS information of a strong southeast wind and a 12–13kt crosswind component.
12:33:17	Flight crew dialogue on flying the approach at Target Approach Speed plus 10kt using the PFD.

Subsequent recordings contain communications with ATC for descent 4,000ft and radar vectors to intercept the ILS.

12:50:50	Flight crew dialogue on the latest ATIS, issued at 12:38, QNH 29.92 inHg and ground visibility 4,500m with gusty wind condition.
12:54:53	Flight crew dialogue confirms to capture the localizer.
12:56:14	Hakodate Tower issues clearance to land, reports wind at 130°/28kt.
12:58:22	Landing gear extended and confirmed as down and locked.
12:59:46	Aircraft requests current winds from Hakodate Tower. Tower reports wind at 130°/28kt with a maximum instantaneous speed of 34kt.
13:00:03	The First Officer conducts a briefing to confirm go-around procedures with the Captain.
13:00:32	PNF announces that he has the approach lights in view. PF acknowledges this.
13:00:43	Hakodate Tower reports an altimeter setting of 29.91 inHg. Flight crew dialogue confirms correcting the altimeter setting.
13:01:07	Company radio reports winds of 140°/32kt with a maximum instantaneous speed of 40kt, and a crosswind component of 11kt.
13:01:23	PNF calls 1,000ft.
13:01:40	Flight crew dialogue on switching auto-thrust to manual mode.
13:02:11	Flight crew dialogue on disconnecting the autopilot (AP). Sound of aural AP disconnects warning.
13:02:16	PNF calls 500ft.
13:02:34	The middle marker aural indicator starts sounding.
13:02:43	PNF calls decision height. PF declares landing.
13:02:47	PNF calls “AIRSPEED”.
13:02:55	Synthetic voice callout of “One hundred” feet.
13:02:57	PNF calls “AIRSPEED, AIRSPEED”.
13:02:58	Synthetic voice warning “WINDSHEAR, WINDSHEAR, WINDSHEAR”. PNF simultaneously calls “GO-AROUND”.
13:03:01	Sounds of impact.
13:03:03	Flight crew dialogue to set flap up.
13:03:08	Flight crew dialogue to retract the landing gear.
13:03:20	PNF reports go-around due to wind shear to Tower. Tower instructs aircraft to follow go-around procedure.