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AIRCRAFT SERIOUS INCIDENT INVESTIGATION REPORT

AIR NIPPON NETWORK CO., LTD.
BOMBARDIER DHC-8-402, JA841A
KOCHI AIRPORT,
NOVEMBER 21, 2004

March 30, 2007

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 serious incident of AIR NIPPON NETWORK CO., LTD. BOMBARDIER DHC-8-402, JA841A 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.

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Norihiro Goto,
Chairman,
Aircraft and Railway Accidents Investigation Commission

AIRCRAFT SERIOUS INCIDENT INVESTIGATION REPORT

**AIR NIPPON NETWORK CO., LTD.
BOMBARDIER DHC-8-402, JA841A
KOCHI AIRPORT,
AROUND 14:27 JST, NOVEMBER 21, 2004,**

February 21, 2007

**Adopted by the Aircraft and Railway Accidents Investigation Commission
(Aircraft Sub-committee Meeting)**

Chairman	Junzo Sato
Member	Yukio Kusuki
Member	Susumu Kato
Member	Yukiko Kakimoto
Member	Akiko Matsuo

1. PROCESS AND PROGRESS OF AIRCRAFT SERIOUS INCIDENT INVESTIGATION

1.1 Summary of the Serious Incident

The event covered by this report is classified as a serious aircraft incident under the category of “running off the side of a runway (in case the aircraft cannot move by itself)” as stipulated in Clause 3, Article 166 - 4 of the Civil Aeronautics Regulations of Japan.

On November 21, 2004 (Sunday), a Bombardier DHC-8-402, JA841A, operated by Air Nippon Network Co., Ltd. took off from Osaka International Airport at 13:51 Japanese Standard Time as All Nippon Airways Flight 1617 on a regularly scheduled service under the arrangement of joint business of transportation. When the aircraft landed on Runway 32 of Kochi Airport, the destination, the right main wheels ran off the side of the runway and the aircraft stopped there.

There were 19 people on board, consisting of the pilot in command (PIC), three other crewmembers, and 15 passengers. There were no injuries.

1.2 Outline of the Serious Incident Investigation

1.2.1 Investigative Organization

On November 22, 2004, the Aircraft and Railway Accidents Investigation Commission assigned an investigator-in-charge and two investigators to the serious incident.

1.2.2 Accredited Representative Participating in the Investigation

An accredited representative of Canada, the state of design and manufacture of the aircraft involved in this serious incident, participated in the investigation.

1.2.3 Implementation of Investigation

November 22 and 23, 2004	Investigation at the serious incident site
November 24, 2004 - February 28, 2005	Analysis of data recorded by digital flight data recorder and cockpit voice recorder
November 26, 2004	Interviews
February 3 and 4, 2005	Investigation of aircraft equipment
December 15 and 16, 2005	Investigation of aircraft

1.2.4 Status Report of Investigation

On November 25, 2005, the status report of investigation was submitted to the Minister of Land, Infrastructure and Transport based on the result of fact finding investigation to that date, and made public.

1.2.5 Interviews with Relevant Organizations' Personnel

Interviews were conducted with personnel of the organizations relevant to the cause of the serious incident.

1.2.6 Comment from the State of Design and Manufacture

Comments were invited from the state of design and manufacture of the aircraft involved in the serious incident.

2. FACTUAL INFORMATION

2.1 History of the Flight

On November 21, 2004, a Bombardier DHC-8-402, JA 841A, (hereafter called “the aircraft”) operated by Air Nippon Network Co., Ltd. (hereafter called “the company”) took off from Osaka International Airport at 13:51 Japanese Standard Time (JST) bound for Kochi Airport as All Nippon Airways Flight 1617 on a regularly scheduled service under the arrangement of joint business of transportation*1.

The flight plan submitted to the JCAB Osaka Airport Office was as outlined below.

Flight rules:	Instrument Flight Rules (IFR)
Departure aerodrome:	Osaka International Airport
Estimated off-block time:	13:45
Cruising speed:	305 knots
Cruising altitude:	FL160
Route:	SUMAR (reporting point) - Y30 (airway) - SETOH (reporting point) - KTE (Kagawa VOR/DME) - V53 (airway) - KRE (Kochi VOR/DME)
Destination aerodrome:	Kochi Airport
Time to destination:	0 hr and 39 min
Endurance by loaded fuel:	2 hrs and 38 min
Alternate aerodrome:	Osaka International Airport

There were 19 people on board the aircraft, consisting of the pilot in command (PIC), three other crewmembers, and 15 passengers. In the cockpit, the PIC took the left seat as Pilot Flying (primarily responsible for aircraft maneuvering) while the first officer took the right seat as Pilot Not Flying (primarily responsible for non-maneuvering tasks).

The flight history of the aircraft after it started communication with Kochi Tower (hereafter called “the tower”) is as outlined below. It was determined from the records in the digital flight data recorder (DFDR) and the cockpit voice recorder (CVR), the air traffic control communications records, and the statements of crewmembers.

2.1.1 Flight History Determined from DFDR, CVR, and ATC Communications Records

(All the times below are JST.)

14:19:02 The tower notified to the aircraft of wind 020 degrees at 14 knots for

*1 “Arrangement of joint business of transportation” refers to an arrangement whereby a domestic airline transportation service is jointly provided by two Japanese operators, which are jointly responsible to passengers or freight owners for transportation (including liability to customers for damages) in conformity with a Circular issued by the Director of the Aviation Industries Division, Administration Department, Japan Civil Aviation Bureau, the Ministry of Land, Infrastructure and Transport.

Runway 32 of Kochi Airport, and gave landing clearance.

- 14:23:11 The tower notified to the aircraft of wind 010 degrees at 14 knots.
- 14:24:16 The aircraft passed over the threshold of the runway at 37 feet radio altitude and at 122 knots CAS*².
- 14:24:25 The right main wheels touched down on the runway at 112 knots CAS and 108 knots GS*³.
- 14:24:26 The left main wheels touched down on the runway at 110 knots CAS and 106 knots GS.
- 14:24:28 The rudder started moving slowly to the nose left, but the aircraft heading started drifting to the right.
- 14:24:29 The nose wheels touched down on the runway at 93 knots CAS and 89 knots GS.
- 14:24:30 The nose wheels became an “in air “ condition.
- 14:24:31 The rudder deflection reached a maximum of approximately 18 degrees to the nose left, but the heading was continuing to drift to the right.
- 14:24:34 The nose wheels touched down on the runway again. The master caution light came on and, at the same time, the one-time aural warning sounded in the cockpit. The heading continued to drift to the right. The PIC started moving the power lever to the reverse position. The aircraft speed at this time was 70 knots CAS and 67 knots GS.
- 14:24:37 The first officer started applying the left wheel brake at 61 knots CAS and 58 knots GS.
- 14:24:41 Vertical accelerations of approximately 1.3 - 0.7G were recorded. The aircraft speed was 43 knots GS.
- 14:24:43 The PIC terminated the propeller reverse. The aircraft speed was 30 knots GS.
- 14:24:44 The first officer terminated the left wheel brake application at 25 knots GS.
- 14:24:45 The right propeller speed (Np) began to decrease following the termination of the propeller reverse. Three seconds later, the Np of the left propeller began to decrease.
- 14:24:57 The PIC began to apply the left wheel brake.
- 14:24:59 The aircraft came to a stop with the heading at approximately 324 degrees.
- 14:25:02 The PIC requested the tower to send a towing tractor due to steering trouble.

*² “CAS” stands for Computed Air Speed.

*³ “GS” stands for Ground Speed.

- 14:25:26 The PIC terminated the left wheel brake application.
The rudder returned to the neutral position.
- 14:25:37 The PIC announced to the passengers that the aircraft had stopped due to steering trouble and that it would be towed to the parking spot, and he requested the passengers to remain seated with their seatbelts fastened until further announcement.
- 14:25:43 The master caution light went out.
- 14:25:05 The first officer proposed to the PIC to turn off and on (recycle) the nose wheel steering switch (hereafter called “the steering switch”) and use the right engine power in order to return the aircraft on to the runway pavement.
- 14:26:29 The PIC recycled the steering switch.
- 14:27:12 The aircraft started advancing.
- 14:27:20 The first officer reported to the tower that the nose wheel steering (hereafter called “the steering”) had returned to normal and that the aircraft would taxi to the parking spot by way of the T-4 taxiway.
- 14:27:23 The aircraft came to a stop again with the heading at 305 degrees.
- 14:28:50 The PIC informed the company’s operation support staff (at Kochi Airport), who came from a company by contract with the company (hereafter called “the operation support staff”) that the aircraft ran off the runway due to steering trouble, and he asked them to send a towing tractor.

All passengers deplaned between 14:42 and 14:44. The runway was closed until 17:16 that day due to the occurrence of this serious incident.

2.1.2 Crewmembers’ Statements

(1) PIC

I received a briefing from the dispatcher at Osaka International Airport, who did not mention any problem about weather and aircraft, and I did not find anything abnormal during the walk around inspection of the aircraft. Furthermore, the mechanic on the ground reported to me that the aircraft had no problem.

I taxied the aircraft from the parking spot without problem and flew from Osaka International Airport to Kochi Airport. After the runway of Kochi Airport was in sight, I requested a visual approach to Runway 32 and received landing clearance.

I was informed by the operation support staff of the reported presence of downdraught on the short final. To take the wind into account, I decided target speed (V_{TG}) of 118 knots by adding 10 knots to the landing reference speed (V_{REF}) of 108 knots for 46,000 pounds of aircraft weight.

After aligning the aircraft with the (extended) runway centerline at an altitude of 1,500 feet on final to Runway 32, I made the gear down, the flaps 15 degrees, and placed the condition lever*⁴ in MAX position. With crosswind from the right, I used ‘crab method’*⁵ at first, then changed gradually to wing low method*⁶ approaching the threshold, thereby landed the aircraft on the touchdown zone markings with the right main gear (windward side) first, the left main gear second and the nose gear third. On the short final, I believe the precision approach path indicator (PAPI) showed three red lights and one white light.

Upon touch down of both main wheels, with my right hand I placed the power lever in “FLT IDLE” position, then in “DISC”*⁷ position. In order to remain on the runway centerline, I kept heading by rudder control as usual. Initially, the aircraft was running straight, then I felt that it was deviating from the centerline. To correct the course, I applied full rudder, but the deviation did not stop to increase. Judging that the aircraft was in danger of deviating from the runway, I intentionally operated the steering control handle (hereafter called “the handle”) to the left while placing the power lever in the reverse position with my right hand. The handle moved freely without any reaction of aircraft. Although I have a habit to use the handle only after the aircraft speed has dropped to taxiing speed, I intentionally operated the handle when I believed the aircraft would deviate from the runway unless I took some action. In an attempt to prevent the aircraft from deviating from the runway centerline and to maintain directional control, I applied force on the left rudder pedal and brake. However, this action did not stop the rightward drift of the aircraft heading, so I used differential propeller reverse.

In usual landings, I put both my feet almost uniformly on rudder pedals. In crosswind, I bring aircraft to touchdown using ‘wing low method’ and apply force on leeward rudder pedal even after nose wheels have touched down. I do not usually need a large amount of rudder pedal movement to keep the aircraft on the centerline. I have a habit to correct deviation from the centerline, but I felt it strange that the required amount of rudder movement was somewhat larger than usual.

Despite my efforts to maintain the aircraft within the shoulder of the runway, I felt the right main wheels had entered the grass area.

When the aircraft came to a full stop, I thought that the engines were in normal

*⁴ “Condition lever” is a lever that is used to adjust and cut off the fuel flow to the engines. It allows adjustment of the propeller speed between 850 and 1,020 rpm without use of the power lever.

*⁵ “Crab method” is an approach technique used when there are crosswinds on runways. The aircraft is flown without any bank and with the heading turned toward the wind by an angle necessary to counter the drift caused by the crosswind.

*⁶ “Wing low method” is an approach technique used to avoid crosswind-caused drift of the aircraft by lowering the wing on the upwind side. The “wing low” attitude is taken when the aircraft is on the extension of the runway centerline, and it is maintained while the aircraft is flown in alignment with the runway centerline.

*⁷ “DISC” is a power lever position at which hydraulic control brings the propeller blades to the zero-degree pitch position. In the zero-degree pitch position, the propellers act as discs that increase air resistance and create a braking effect.

condition, as the aircraft did not experience any shock that would have caused damage to the airframe and it remained in wing level attitude.

Using the passenger address system, I announced to the passengers that the aircraft had stopped where it was because of steering problem, asked them to remain seated with their seatbelts fastened, and told them that the aircraft would be moved by a towing tractor.

I didn't notice if the 'steering light'*⁸ came on during the landing roll. But I noticed the illuminated steering light after the aircraft had stopped. Based on our experience, I turned off the steering switch then turned it on, then the steering light went off. I operated the handle as a test. The handle recovered its normal responsiveness, and I thought the wheel steering function was restored, then I tried taxiing the aircraft. I could taxi the aircraft a little, taking care of not damaging any runway light. My intention was to turn the steering handle sharply to the left if the aircraft was able to continue moving, but the aircraft stuck and I gave up taxiing. When the aircraft moved, the first officer advised me to use only the right engine. However, I used both engines evenly to avoid a risk of damaging runway lights by the wheels.

I subsequently requested the operation support staff to send a towing tractor and shut down the engines.

Usually I perform rudder operation during landing with my heels in contact with the cockpit floor. As I had to use full rudder to maintain the direction in case of this incident, I performed simultaneous rudder and brake operations without a chance to change my foot position on the brake pedal. As a result, I think braking effect was not sufficient.

(2) First officer

The approach was stable, passing over the threshold at 118 knots, nearly the same speed as the V_{TG} . The descent below 100 feet was also normal, and the landing was smooth with adequate flare.

I think the aircraft touched down at a speed of 113 knots, i.e. V_{REF} plus 5 knots. It seemed to me that both main wheels touched down on the runway simultaneously. The aircraft remained wing level and didn't bounce. The touchdown point was on the runway centerline and on the big mark (touchdown zone marking), which is located approximately 1,050 feet (315 meters) beyond the threshold. After touchdown of the nose gear, the aircraft ran straight along the centerline to a point just before the T-3 taxiway. Until that point, I felt nothing abnormal and thought the landing roll normal. When the aircraft speed had decreased, the aircraft heading started deviating to the right from the centerline. I felt this strange and looked at the captain's face, thinking that the captain might be going to use the T-3 taxiway to exit the runway. When I saw the T-3 taxiway on the right hand, I saw the

*⁸ "Steering light" refers to the nose steering caution light. It comes on when the steering control unit (SCU) has failed with the steering switch in the "STEERING" position and when any hydraulic pressure is sensed with the steering switch in the "OFF" position.

captain violently moving the handle with his left hand. It was not until then that I realized that some abnormal condition had happened in the aircraft. However, the captain told me nothing about that. The aircraft still continued drifting to the right when it was passing the T-3 taxiway. Then a row of runway lights appeared directly ahead of the aircraft, and I instantly applied left rudder and also strongly left brake. My actions at that time were instinctive, neither following captain's order nor helping the captain's operation. I felt a small decrease in the aircraft's rightward drift, which might be due to my actions, but immediately after that, the right main wheels ran off the pavement and the aircraft stopped.

The engines were operating normal, and I found no abnormality other than that the steering light came on. This light went out after that the captain recycled the steering switch. Realizing that steering function was restored, I thought it possible for the aircraft to return to the runway by using differential power between the right and left engines, so I advised the captain accordingly, saying, "Use only the right engine, please."

However, the captain used both engines' power. The aircraft moved a little but soon stopped. Judging from the situation, I suspected burst of wheel tires, so I asked a cabin attendant, using the interphone, to check the wheels visually and let me know the result.

(3) Cabin attendant

After touchdown, I heard the engines making an unusually loud sound accompanied by a strange whining sound rather than their usual growling sound. Also, the aircraft shook significantly, making me think it was being affected by strong winds.

After landing, I made an announcement over the passenger address system, saying, "We have arrived at Kochi Ryoma Airport." However, the aircraft then came to a stop. Thinking it strange, I made another announcement, saying, "The aircraft has temporarily stopped here but will be moving to parking spot. Please wait in your seats." This announcement was followed by an announcement from the captain saying, "Due to steering trouble, the aircraft will be moved by a towing tractor to the parking spot."

When the aircraft subsequently came to a stop again, I received via interphone a request from the first officer, who said, "Would you check visually the right main wheels?" I did it through a window and reported that, "The tires have stuck in the earth." The captain immediately informed the passengers of the situation using the passenger address system, so the passengers stayed calm.

The serious incident occurred on Runway 32 of Kochi Airport, at a point approximately 1,215 meters beyond the threshold at about 14:27 on November 21, 2004.

(See Figures 1, 2, 4-1, 4-2, 4-3 and 5 and Photos 1, 2, 3 and 4.)

2.2 Injury to persons

None

2.3 Damage to Aircraft

None

2.4 Damage to Objects other than Aircraft

One taxiway light was broken.

2.5 Pilot Information

(1) PIC	Male, Age 53 years	
Airline Transport Pilot License (Airplane)		December 16, 1988
Type rating: De Havilland DHC8		August 27, 2003
1st class Aviation Medical Certificate		
Validity		Until May 14, 2005
Total flight time		14,530 hrs and 37 min
Flight time in the last 30 days		38 hrs and 35 min
Flight time on the type of aircraft		525 hrs and 0 min
Flight time in the last 30 days		38 hrs and 35 min
(2) First officer	Male, Age 33 years	
Airline Transport Pilot License (Airplane)		July 12, 2004
Type rating: De Havilland DHC8		July 12, 2004
1st class Aviation Medical Certificate		
Validity		Until January 23, 2005
Total flight time		3,684 hrs and 28 min
Flight time in the last 30 days		28 hrs and 30 min
Flight time on the type of aircraft		88 hrs and 40 min
Flight time in the last 30 days		28 hrs and 30 min

2.6 Aircraft Information

2.6.1 Aircraft

Type	Bombardier DHC-8-402
Aircraft serial number	4080
Date of manufacture	June 21, 2003
Certificate of airworthiness	No. Dai-16-231
Validity	Until July 23, 2005
Category	Airplane, Transport category
Total time in service	1,865 hrs and 31 min
Time in service since last regular inspection (Annual inspection on July 21, 2004)	565 hrs and 04 min
(See Figure 3.)	

2.6.2 Weight and Balance

It is estimated that the weight and center of gravity of the aircraft at the time of the serious incident were 45,870 pounds and 25.9 percent mean aerodynamic chord (MAC), respectively. It is estimated that both of them were within the allowable limits (61,750 pounds is the maximum landing weight and 15.7 - 34.1 percent MAC corresponding to the weight at the time of the serious incident).

2.7 Meteorological Information

2.7.1 The instantaneous wind direction and velocity measured at three-second intervals derived from the aero vane installed near the touchdown zone of Runway 32 were as follows.

14:24:06	004 degrees;	15 knots
14:24:09	360 degrees;	15 knots
14:24:12	003 degrees;	14 knots
14:24:15	007 degrees;	13 knots
14:24:18	004 degrees;	12 knots
14:24:21	010 degrees;	13 knots
14:24:24	028 degrees;	14 knots
14:24:27	024 degrees;	12 knots
14:24:30	024 degrees;	12 knots
14:24:33	016 degrees;	12 knots
14:24:36	023 degrees;	14 knots
14:24:39	023 degrees;	13 knots
14:24:42	019 degrees;	12 knots

2.7.2 The aviation routine weather report (METAR) data at around the time of the serious incident at Kochi Airport were as follows:

14:00	Direction of wind ... 030 degrees; Velocity of wind ... 15 knots; Prevailing visibility ... 25 kilometers; Clouds: amount ... 1/8, type ... cumulus, Ceiling ... 3,000 feet; Temperature ... 17°C; Dew point ... 3°C; Altimeter setting (QNH) ... 30.09 inches Hg
15:00	Direction of wind ... 020 degrees; Velocity of wind ... 15 knots; Prevailing visibility ... 25 kilometers; Clouds: amount ... 1/8, type ... cumulus, Ceiling ... 3,000 feet; Temperature ... 17°C; Dew point...2°C; Altimeter setting (QNH) ... 30.10 inches Hg

2.8 Information on DFDR and CVR

The aircraft was equipped with a Digital Flight Data Recorder (DFDR)

manufactured by the Honeywell Inc. (part number 980-4700-027), in the U.S.A. and had a Cockpit Voice Recorder (CVR) manufactured by the Allied Signal Inc. (part number 980-6022-011), in the U.S.A.

The DFDR retained records from the time the aircraft departed Osaka International Airport, to the time electric power was turned off after the serious incident had occurred and the aircraft had come to a full stop. The precise time of DFDR recording was determined by comparing time of the DFDR's record of the VHF transmission key (used during communications between the crew and the ATC) with the time of the ATC communication records.

The aircraft's CVR is able to record audio data for at least two hours before the equipment stops itself. The CVR retained the data before and after the serious incident.

2.9 Serious Incident Site Conditions

Kochi Airport has a 2,500-meter-long, 45-meter-wide runway that is oriented in the 14/32 direction and is grooved over a 2,500-meter-long, 30-meter-wide area.

The aircraft stopped approximately 35 meters short of the runway half-length marking on a heading of approximately 305 degrees. The right main wheels had mired into the earth to a depth of one third of their diameter, but the nose wheels and left main wheels remained on the shoulder of the runway.

Tire skid marks, left on the runway by the right main wheels, started at about the 850-meter point (all distances mentioned in Section 2.9 are distances beyond the threshold) as a slightly right-biased straight line. From about the 920-meter point the marks on the runway significantly biased to the right and entered the grass area at about the 1,100-meter point. The line continued parallel to the runway to where the aircraft stopped. Tire skid marks made by the left main wheels started at about 980-meter point on the runway, entered and its shoulder, and ended where the aircraft stopped.

In addition, there was a faint tire mark on the runway shoulder at about 1,200-meter point, apparently made when the aircraft's steering function was restored and the nose wheels returned to the neutral position.

(See Figure 2 and Photo 3.)

2.10 Tests and Research for Fact-Finding

2.10.1 Outline of the Steering System

According to the explanation of the company's airplane operations manual, principal components of the steering system of the aircraft include a steering control unit (hereafter called "SCU"), a steering motor, steering actuators, a steering switch, a pilot hand control (a handle), and rudder pedals. Displacement of handle or rudder pedals is converted into an electric signal, which is sent via SCU to steering motor, moving the steering actuators

proportionally. There is no mechanical linkage between the handle or rudder pedals and the steering actuators.

The steering actuators operate on pressure from the No. 2 hydraulic system.

With steering switch ON, and nose wheels on the ground the nose wheels can be steered up to eight degrees left and right using rudder pedals during high-speed taxiing, takeoff roll or landing roll, and can be steered up to 70 degrees left and right using the handle during low-speed taxiing. With the steering switch OFF the nose wheels are in caster mode*⁹, in which they can be steered up to 120 degrees left and right. (See Attachment.)

In any of the following cases, where the nose wheels are in caster mode the steering light and master caution light illuminate, and an audible warning (single chime) is activated.

- (1) With the steering switch in the “STEERING” position, when hydraulic pressure to steering motor drops.
- (2) With the steering switch in the “OFF” position, when hydraulic pressure is applied to steering motor.
- (3) When nose wheels are steered left or right beyond 70 degrees.
- (4) When SCU fails.
- (5) When SCU senses failure in any of the steering system components.
- (6) When handle is turned in excess of 8 degrees left or right with the nose gear shock strut not sufficiently compressed (i.e. nose gear’s weight-on-wheel sensors (hereafter called “WOW sensors”^{*10}) detecting an ‘in-air’ condition).
- (7) When handle is turned in excess of 8 degrees left or right within one second of compression of the nose gear shock strut (i.e. WOW sensors detecting an ‘on-ground’ condition).

The SCU has built-in test equipment (hereafter called “BITE”), which registers a fault code when the steering system fails, to facilitate troubleshooting.

The STEERING SYSTEM section of the company’s MAINTENANCE TRAINING MANUAL contains a description that is summarized below.

During takeoff, when the nose gear WOW sensor signal changes from ‘on-ground’ to ‘in-air’, the SCU ignores all signals from the handle and rudder pedals and sends a neutral command to the servo valve to cause the nose wheels to be hydraulically centered. Five seconds later, the hydraulic pressure is cut and the nose wheels enter caster mode.

*⁹ “Caster mode” is one of the SCU’s modes. When the SCU is in this mode, nose wheels can be steered neither by rudder pedals nor by steering handle, but their direction changes freely up to 120 degrees left and right according to side force acting on the tires.

*¹⁰ “WOW sensors” are installed on the nose gear and on the left and right main gears. Each WOW sensor senses compression of the shock strut resulting from the aircraft’s weight placed on the gear when the aircraft is on the ground. The sensors thus detect whether the aircraft is on the ground or in the air.

During landing, when the nose gear WOW sensor signal changes from 'in-air' to 'on-ground', hydraulic steering using rudder pedals or the handle starts with a one-second delay.

2.10.2 Investigation of the Brake System

On November 22, 2004, on-site investigation was conducted on the functions of the brake and anti-skid systems. This investigation revealed that all the functions were normal.

2.10.3 BITE Check and Steering System Check Conducted after Occurrence of the Serious Incident

- (1) BITE check (The SCU fault codes are shown in boxes hereinafter.)

When a BITE check was conducted after the serious incident, **EHVS** (indicating a fault related to the electro-hydraulic servo valve coil) and **PHC** (indicating a pilot-hand-control-related abnormalities or operation of the handle with the aircraft in-air condition) codes were found registered. The **EHVS** code is automatically registered every time the SCU power is turned on and does not always mean detection of a fault.

- (2) Steering system check

Since the steering light had been illuminated after the serious incident occurred, inspection was conducted to determine whether the aircraft's steering function was normal. In order to simulate the conditions during aircraft landing, the aircraft was raised with jacks, an external electric power supply was connected and the No. 2 hydraulic system was pressurized by an external hydraulic source. The operation of the rudder pedals and handle was conducted according to the maintenance manual, and no abnormality in the steering function was found.

Simulation was also conducted for the steering function in the aircraft operation before the occurrence of the serious incident, i.e. pre-takeoff taxiing, takeoff roll, and in-flight; no abnormalities were detected.

2.10.4 Investigation on Pilot Hand Control Assembly and SCU

Although the check for inoperative steering and the simulation of each wheel's "on-ground" and "in-air" conditions were conducted as mentioned in Section 2.10.3 (2) of this report, it was not possible to detect or reproduce any failure of the steering system function. To determine the cause of illumination of the steering light, detailed investigation on the pilot hand control assembly and SCU, which are major components of the steering system, was conducted, under the witness of Canadian accident investigators, on February 3 and 4, 2005 at the repair company.

- (1) Investigation on Pilot Hand Control Assembly

In accordance with the PILOT HAND CONTROL ASSEMBLY COMPONENT MAINTENANCE MANUAL, output DC voltage corresponding to each angle of the handle (pilot hand control) was checked and found normal, i.e. the outputs were within the specification.

(2) Investigation on SCU

In accordance with the STEERING CONTROL UNIT COMPONENT MAINTENANCE MANUAL, insulation tests and inspection to see whether the SCU was communicating properly with the associated units were conducted. No abnormalities were detected.

2.11 Other Relevant Information

2.11.1 Steering System Problems Experienced by the type of Aircraft

As of February 1, 2005, the company owned and operated seven (7) Bombardier DHC-8-402 aircraft including the one involved in the serious incident. Up to January 19, 2005, the following steering malfunctions were experienced on three of these airplanes (No. 1 (the aircraft), No. 2 and No. 4).

(1) The aircraft (manufactured on June 21, 2003)

September 24, 2003

(Problem) The steering light came on after the flight crew started the engines and turned on the steering switch.

(Action) As a result of BITE check, **EHVS** fault code was recorded. The connector of the electro-hydraulic servo valve was cleaned, and the steering system function was confirmed normal. The system was normal during subsequent aircraft operation.

December 10, 2003

(Problem 1) The steering became inoperative when taxi was commenced, but the master caution light did not illuminate.

(Action 1) Recycling the steering switch restored normal steering operation. A BITE check was conducted, but there were no fault codes recorded.

(Problem 2) Steering was inoperative during taxi.

(Action 2) A BITE check was conducted on the SCU, but there were no fault codes recorded. Recycling the steering switch restored normal steering operation.

December 16, 2003

(Problem) Reliability of steering was degraded (reported verbally).

(Action) Treated as malfunction considering former malfunction records. A conductivity check from steering switch to SCU was performed, a steering switch power check, and a BITE check on SCU were conducted with

normal results. However, the SCU was replaced (with the one that was installed at the time of the serious incident).

October 3, 2004

(Problem) The steering light illuminated when the handle was operated during landing roll.

(Action) Recycling the steering switch restored normal steering operation. As a result of a BITE check, **EHVS** and **PHC** fault code were recorded. The SCU was inspected, but no abnormalities were found.

October 21, 2004

(Problem) The handle felt heavy and sometimes sticky during taxi.

(Action) The mechanical components of the handle were lubricated. The function was confirmed normal.

(2) No. 2 airplane (manufactured on September 9, 2003)

November 29, 2003

(Problem) After landing touchdown, the steering light came on and the steering was inoperative.

(Action) Recycling the steering switch restored normal steering operation. As a result of a BITE check on the SCU, **EHVS**, **PHC** and **PED** (rudder-pedal-related fault) fault codes were recorded. The SCU was inspected, but it was found to be normal.

December 17, 2004

(Problem) During pre-flight check by the flight crew, the steering system was inoperative.

(Action) As a result of a BITE check on the SCU, at least **EHVS**, **PHC**, **SCU** and **PED** fault codes were recorded. The handle and rudder pedals were operated to test the steering system, however, the result showed normal steering.

(3) No. 4 airplane (manufactured on April 27, 2004)

November 7, 2004

(Problem) During pre-flight check by the flight crew, the steering system was inoperative.

(Action) Recycling the steering switch restored normal steering operation. It was confirmed that the system functioned normally. As a result of a BITE check on SCU, at least **EHVS**, **SCU** and **PHC** fault codes were recorded. Monitoring was continued during flight operation, and another BITE check on the SCU was conducted, however, showed that no faults were recorded.

November 23, 2004

(Problem) When the airplane taxied on the ramp, the steering occasionally did not respond to handle inputs.

(Action) A steering operation test showed normal result. No fault codes were registered in a BITE check performed on the SCU.

December 7, 2004

(Problem) After landing, the steering handle was operated at 20 knots GS, but the steering did not respond to the handle inputs. The steering suddenly started responding after a while.

(Action) A BITE check on the SCU did not show any fault codes recorded. A steering operation check could not reproduce the faulty condition. After the SCU, steering switch, handle, nose wheel system manifold assembly and steering motors were replaced, function of the steering system was confirmed normal.

January 19, 2005

(Problem) After touchdown, rudder pedals were operated for steering, but there was no response to the pedal inputs. To counter the drift to the left, heading correction by rudder pedals was not effective. Directional correction but could be made by steering handle operation.

(Action) As a result of a BITE check of the SCU, **EHVS** fault code was recorded. Steering operation test was normal, and the nose wheel tire pressure was normal.

2.11.2 All Operator Message No. 016 Issued by the Manufacturer

The manufacturer of the aircraft issued the All Operator Message No. 016 (hereafter called "AOM No. 016") dated February 7, 2001, titled "Inoperative Nose Wheel Steering following Landing" to all DHC-8-Q400 Operators.

Several Operators have reported recurring incidents in which the nose wheel steering failed to operate following landing. Investigation has determined that the nose landing gear shock strut may not be compressing sufficiently to allow the weight-on-wheel (WOW) sensors to register. This problem is more prevalent when the aircraft is light, with an aft center of gravity. The nose wheel steering system requires three conditions to operate; nose landing gear WOW 1, nose landing gear WOW 2 and nose gear down and locked. Without these conditions the steering system will not be activated.

To ensure that the nose wheel steering system is operational after landing, the following procedure is recommended. During the landing rollout, when the aircraft speed has decreased to 60 knots, apply forward control column movement,

and moderate braking. This will ensure positive loading on the nose gear to compress the shock strut and allow use of the nose steering.

Steering system operation will experience the normal delay, due to the bite test, if the steering arm switch is recycled.

With regard to the above recommendation, the manufacturer remarked that “applying forward movement to the control column when the aircraft speed is in excess of 60 knots could overload the nose wheel structure.”

2.11.3 Handling of “AOM No. 016 Issued by the Manufacturer”

Both the company and Air Nippon Co., Ltd. (hereafter called “Air Nippon”), to which the company contracts out management of aircraft maintenance (and fundamental jobs for aircraft operations), had received from the manufacturer AOM No. 104 (dated September 2, 2003) and later-numbered AOMs when the company introduced the type of aircraft. Past Service Bulletins, AOMs and other necessary information are available from the manufacturer’s website. The maintenance and operation personnel of Air Nippon had actually accessed the website in the event of irregular operations and system failures.

However, until the time of occurrence of the serious incident, the company and Air Nippon did not realize that “AOM No.016 issued by the manufacturer” was applicable to all airplanes of the type and remained in effect.

2.11.4 Extracts from the Company’s Airplane Operations Manual (1)

Section 3-9-3 LANDING ROLL PROCEDURE in Chapter 3 NORMAL PROCEDURE of the company’s airplane operations manual contains the following description.

PF	PNF
POWER lever FLT IDLE	
POWER lever DISC BRAKE APPLY	Monitor engine instruments. Check that PROPELLER GROUND RANGE advisory light is ON.
Check that ROLL OUTBD and ROLL INBD SPOILER advisory lights are ON upon touchdown of main wheels.	
	Call “Sixty” when 60 kts is reached.
Order “Control Lock ON” at 60 kts or lower speed.	With PF’s order, place control lock in ON position and confirm control is properly locked.

NOTE: Reverse pitch may be used if necessary. Be sufficiently careful in directional control when reverse pitch is used.

2.11.5 Extracts from the Company's Airplane Operations Manual (2)

Section 2-2-13-(5) of "NOSEWHEEL STEERING" in Chapter 2 NON-NORMAL PROCEDURE of the company's airplane operations manual contained the following description.

Condition: NOSE STEERING caution light illuminated.

Steering Handle CENTER PF [PNF]

If caution light remains illuminated:

Nosewheel STEERING SwitchOFF PF [PNF]

NOTE: Taxi using differential braking and power.

2.11.6 Extracts from the Company's Airplane Operations Manual (3)

After the date of occurrence of the serious incident, the description shown in Section 2.11.5 of this report was revised (dated 2005, JUL. 25) as follows.

Condition: NOSE STEERING caution light illuminated.

Steering HandleCENTER PF [PNF]

If caution light remains illuminated:

Nosewheel STEERING SwitchOFF PF [PNF]

NOTE: To control the aircraft direction during landing roll with nosewheel steering inoperative, depending on crosswind condition, differential brake or power usage together with rudder operation is required.

NOTE: Taxi using differential braking and power.

In addition, at the time of the revision of the airplane operations manual, the manufacturer provided the following guidance material to operators.

Training Emphasis (BOMBARDIER)

- Adjust rudder pedals and pilot seat so that maximum braking can be achieved at maximum rudder deflection.
- Keep one hand on the control column and one hand on the power levers throughout landing.
- Land with heels of feet on bottom of rudder pedals and toes at the top of the pedals ready to apply brakes.
- Note that rudder application requirements increase with decreasing speed.
- Asymmetric braking may be required.
- Asymmetric thrust in strong crosswind conditions with Nosewheel Steering inoperative may be used but is not required.

- Use Tiller Steering only after aircraft has slowed to taxi speed.
- Conduct training exercises in simulator and on aircraft with Nosewheel Steering off to practice failure modes.

3. ANALYSIS

3.1 The PIC and the first officer possessed both proper airman competency certificates and valid aviation medical certificates.

3.2 The aircraft had valid airworthiness certificate and was maintained and checked properly.

3.3 Weather Conditions during Approach and Landing

According to the information in Section 2.7.1 of this report, surface wind near the touchdown zone just before touchdown of the right main wheels was about 028 degrees at 14 knots (i.e. wind from the front right of the aircraft). According to the company's airplane operations manual, the wind was within crosswind limit (DRY 32 knots).

3.4 Conditions of Landing of the Aircraft

The conditions of the landing of the aircraft from the moment of passing over the threshold to the occurrence of the serious incident are, based on the DFDR records, estimated as follows:

- (1) From the passing over the threshold to the touch down of both main gears

It is estimated that the aircraft made a visual approach, passed over the threshold at 14:24:16 with radio altitude of approximately 37 feet and CAS of approximately 122 knots. Since the PIC stated that PAPI showed three reds and one white, it is estimated that desired path was flown.

As mentioned in section 2.1.2 (1) of this report, the PIC stated to have set the V_{TG} at 118 knots by adding 10 knots to the V_{REF} of 108 knots, in consideration of a reported downdraught on short final. The CAS over the threshold was estimated approximately 122 knots. That was about 4 knots above the V_{TG} .

The PIC stated that he performed the approach using the 'wing low method' in consideration of the crosswind from the right. It is estimated that right main wheels touched down at around 14:24:25 at a point about 500 meters beyond the threshold, and left main wheels touched down one second later.

It is considered that the aircraft heading was approximately 320 degrees at the touchdown of both main gears, and the PIC corrected and aligned it using rudder to the runway centerline of 317 degrees (same as the localizer course) two seconds later. It is considered possible that the misalignment was the result of change of wind direction by approximately 20 degrees from 010 degrees to 028 degrees, which was measured instantaneously by an aero vane every three-second (as mentioned in Section 2.7.1 of this report).

- (2) From the touch down of both main gears to the running off the runway

Nose wheels touched down at 14:24:29, three seconds after both main wheels touched down, but immediately afterward the WOW sensors detected an “in-air” condition, and at 14:24:34 (five seconds later) they again detected an “on-ground” condition at a point approximately 910 meters beyond the threshold.

It is estimated that the relatively high touchdown speed (108 knots GS) contributed to insufficient load on the nose gear such that its WOW sensors detected an “in-air” condition again. Shortly before the first touchdown of the nose wheels, heading of the aircraft began to drift rightward from the runway centerline direction (approximately 317 degrees). It is estimated that this gradual rightward drift of the heading resulted from the fact that the PIC had been applying left rudder (leeward) to counter the weathercock effect*¹¹, but he reduced the left rudder, causing the rudder deflection to reduce from approximately 13 degrees left to approximately 2 degrees left, in anticipation of touch down of the nose wheels.

From the above-mentioned points, it is considered that the change of heading corresponded to rudder pedal position from touch down of main wheels to about the first “on-ground” condition of the nose gear WOW sensors.

After touch down of nose wheels, the PIC increased left rudder pedal movement in order to correct the heading drift to the right by means of nose wheel steering. Left rudder pedal reached maximum deflection at around 14:24:32, but the heading continued to drift to the right regardless of the rudder pedal position. It is estimated that because, as mentioned above, the nose wheels touched down once and then the WOW sensors detected an “in-air” condition, the nose wheel steering was hydraulically centered, bringing the nose wheels onto the runway in a condition not responsive to rudder pedal inputs. Due to the reduction of left rudder shortly before and the weathercock effect to the aircraft, the heading continued to drift to the right. It is considered that the PIC applied force on the left brake pedal as mentioned in his statement, but as the DFDR record indicates, the effect of the pedal movement was too small to prevent drift of the heading (although the left brake pressure increased slightly) and too small to make the brake pedal sensor detect the brake pedal movement. It is estimated that the PIC could not apply force on the brake pedal with sufficient force when he noticed the inoperative steering because it was his habit to control the pedals with his heels on the floor up to shortly after touch down. The movement of the brake pedals was not sufficient due to the positioning of his feet.

*¹¹ “Weathercock effect” is the phenomenon that makes a weathervane point in the direction of the wind. When it acts on an airplane, the nose of the airplane tends to point in the wind direction.

It is estimated that at around 14:24:34, the nose gear WOW sensors again detected an “on-ground” condition and that simultaneously both the master caution light and steering light illuminated, the aural warning was activated, and nose wheel steering reverted to caster mode.

It is considered that the aircraft started veering to the right significantly because: the aircraft was in crosswind from the right during landing as mentioned in Section 3.3 of this report and was thus influenced by the weathercock effect; the nose wheel steering had been centered; the rudder’s aerodynamic effect was reducing due to decreasing aircraft ground speed ; the nose wheels were in caster mode and the heading was then approximately 323 degrees (approximately 6 degrees to the right of the runway centerline).

It is estimated that if the PIC had been able to strongly apply force on the left brake pedal to counter the drift to the right, the veering could have been stopped and the serious incident would not have occurred.

The PIC started the reverse operation at 14:24:34 when the second “on-ground” condition was detected, and according to his statement in Section 2.1.2 (1) of this report, he carried out the reverse operation using his right hand while turning the handle to the left using his left hand, believing that the aircraft was in danger of running off the runway. The DFDR records show that the first officer started to apply left brake at 14:24:37. According to the first officer’s statement, he saw the PIC was operating the handle with his left hand. When the first officer saw the T-3 taxiway ahead on his right he started to apply left brake as the aircraft was passing the taxiway, in order to prevent the aircraft running off the runway. Consequently, it is estimated that the PIC released the control wheel and operated the handle at 14:24:34. The left reverse was used more than the right reverse, but it is estimated that differential reversing was almost useless because of its insufficient use and the delay before the reverse came into effect.

According to the CVR records, the first officer did not make a callout when the master caution light, in front of the right pilot’s seat, illuminated. The first officer is to make a callout whenever the master caution light illuminates, as it is located in front of the first officer and it is difficult from the PIC’s seat to notice. As mentioned in Section 2.11.4 of this report, the LANDING ROLL PROCEDURE shows that the PNF must call “Sixty” at 60 kt. However the CVR record shows that the first officer did not make this callout. It is considered that the first officer could not make these callouts because he had been preoccupied with the aircraft’s heading drift to the right and was engaged in applying force on the left rudder pedal and the left brake pedal to correct the heading drift.

The tire marks on the runway veers significantly to the right from a point

approximately 920 meters beyond the threshold. It is considered that the first officer started to apply only the left brake at 14:24:37 in an attempt to stop the aircraft's drift to the right, but it was too late to prevent the aircraft from running off the runway.

(3) From the running off the runway to the stop of aircraft

The aircraft touched a taxiway light with its right main wheels, and at 14:24:41 it experienced a vertical acceleration of approximately 1.3 - 0.7G as recorded. Consequently, it is estimated that the right main wheels ran off the pavement and entered the grass area at that time (at a point approximately 1,100 meters beyond the threshold). After the aircraft ran off the runway, use of the left brake pedal from the left seat was recorded at 14:24:57 when the aircraft was just about to stop. It is estimated that the reason the brake application by the PIC was rather slow was that the PIC was trying to operate the power levers differentially to cope with the inoperative steering.

(4) From the restoration of the steering function to the second stop of the aircraft

The aircraft came to a stop once at 14:24:59 on a heading of approximately 324 degrees. The first officer turned off the master caution light at 14:25:43.

Based on the first officer's advice and his own experience, the PIC recycled the steering switch at 14:26:29. This action restored the steering function and caused the steering light to go out. After the steering became operative, the first officer advised the captain to use only the right engine power in order to bring the right main wheels back onto the pavement. However, the PIC used both engines evenly for the purpose of preventing the wheels from damaging runway lights, thereby taxiing the aircraft almost in parallel with the runway from 14:27:12 to 14:27:22. However, it is estimated that the surface of the grass area was so soft and the right main wheels sunk by one third of the wheel diameter, making the aircraft unable to taxi any further.

(See Figures 2, 4-1, 4-2, 4-3 and 5.)

3.5 Path of the Aircraft on the Runway during Landing

The path of the aircraft during its landing roll as estimated from the DFDR record, in terms of the aircraft's deviations from the localizer course, shown in Figure 4-2, is such that both main wheels touched down when the aircraft was located nearly on the runway centerline. It is considered that the heading had been controlled in response to the rudder operation until the first touch down of the nose wheels, then the heading of the aircraft started to drift gradually to the right, though full left rudder was applied to counter the drift. This left rudder was not sufficiently effective to stop the drift because of a temporary return of the rudder to neutral and also because of a reduced aerodynamic effect resulting from the

decreased aircraft speed. The aircraft continued to deviate from the centerline to the right.

It is estimated that from about two seconds before the second touch down of the nose wheels (about 14:24:34), the aircraft rolled in such a way that the path of the right main wheels connect smoothly with the tire mark that formed a slightly right-biased straight line as mentioned in Section 2.9.

It is considered possible that the tire mark, left by the right main wheels, which began at the touchdown zone marking located approximately 850 meters beyond the threshold, indicates that it might be made due to a shift of aircraft weight onto the right main wheels, which started there.

(See Figure 2 and 4-2.)

3.6 Loss of Steering Function by PIC's Handle Operation

According to the outline of the steering system described in Section 2.10.1 of this report, during a landing roll with steering functioning normally, there are two cases in which the nose wheel steering function becomes inoperative and the steering light illuminates, and nose wheel steering reverts to caster mode. The first case is when the handle is operated in excess of ± 8 degrees with the nose gear WOW sensors detecting an "in-air" condition. The second case is when the handle is operated in excess of ± 8 degrees before a lapse of one second after the nose gear WOW sensors have detected an "on-ground" condition by compression of the nose gear strut. In this case, there was a time lag of eight (8) seconds between the touchdown of both main wheels and the detection of the second touch down by the nose gear WOW sensors. (In case of usual landings, there is a time lag of 2 - 6 seconds between touchdown of the main wheels and touchdown of the nose wheels.) Consequently, it is estimated that the PIC judged, based on his experience of usual landings that the nose wheels had already touched down. The PIC stated that he later recognized a danger of veering off the runway and operated the handle to the left using his left hand, while performing a reverse operation using his right hand. Consequently, it is estimated that at about the time of the detection of the second touch down by the nose gear WOW sensors, the PIC quickly operated the handle to prevent a large drift of the heading to the right. It is therefore estimated that the PIC operated the handle more than ± 8 degrees at this time, causing the temporary loss of steering function by SCU*¹², resulting in the illumination of the steering light and putting the nose wheel steering in caster mode.

Regarding the condition that led to the above-mentioned caster mode, it was not possible to determine which of the following two cases (among the cases described in Section 2.10.1 of this report) was applicable to this event: "(6) When handle is turned in excess of 8 degrees left and right with the nose gear shock strut not sufficiently compressed (i.e. nose

*¹² "SCU FAIL" is used in Japanese version with a special footnote explaining that "FAIL" means a phenomenon in which equipment or system temporarily loses its function.

gear's weight-on-wheel sensors detecting in-air state), or (7) When handle is turned in excess of 8 degrees left or right within one second of compression of the nose gear shock strut (i.e. WOW sensors detecting on-ground state)".

Figure 4-2 shows that the time the steering light illuminated (the time when the nose wheels touched down for the second time) coincided with the time the rudder deflection was reduced by approximately 10 degrees. Consequently, it is considered possible that a rudder return movement (decrease of rudder deflection) took place. At about the time of the nose wheels second touch down, the PIC's attention to rudder control became insufficient due to the concurrent reverse and handle operations.

If the PIC had not operated the handle in excess of ± 8 degrees, steering function by the SCU would not have been lost, even temporarily. The steering would have started functioning normally after the WOW sensors detected the second touch down [of nose wheels], and the serious incident would not have occurred.

3.7 Inoperative Steering Due to Design Characteristics

As mentioned in Section 2.10.4 of this report, no abnormalities were found during the investigation conducted at the repair company on the pilot hand control assembly or on the SCU. During this serious incident, from the DFDR records, it is estimated that the heading of the aircraft was controlled in response to the pilot's rudder operation from the touch down of both main wheels to the first touch down of the nose wheels, but thereafter the PIC could not adequately control the heading despite the PIC's application of full left rudder in an attempt to correct the heading drift to the right. Since it is understood that usually the heading can be controlled easily by rudder provided both main wheels are on the ground and nose wheels are in the air (not in contact with the runway), it is considered possible that the nose wheels were, at that time, actually on ground even though the WOW sensors detected an "in-air" condition. Between the first and second "on-ground" detections, it is considered that the nose gear WOW sensors were in a condition unable to detect an "on-ground" condition even though the nose wheels were actually in contact with the runway, because the nose gear shock strut was not compressed sufficiently due in part to the influence of the high CAS, which was about four knots higher than the V_{TG} (as mentioned in Section 3.4 (1) of this report) and the light aircraft weight. According to the description in Section 2.10.1 of this report, the nose wheels are hydraulically centered if the nose gear WOW sensors switch from an "on-ground" condition to an "in-air" condition. Consequently, it is estimated that the nose wheels were in the hydraulically centered condition immediately after the nose gear WOW sensors detected an "in-air" condition following the first touch down.

It is therefore estimated that despite the maximum movement of rudder pedals, increasing heading drift to the right could not be stopped because the nose wheels were in light contact with the runway and centered.

(See Figures 4-1 and 4-2.)

3.8 Response to “AOM No. 016 Issued by the Manufacturer” by the Company and Air Nippon

As mentioned in Section 2.11.2 of this report, the manufacturer of the aircraft provided information that required operators’ attention for ensuring operation of the steering system and preventing inoperative steering during landing. “AOM No. 016” was still in effect at the time of the occurrence of the serious incident, but the company and Air Nippon did not recognize that fact.

Also, the company and Air Nippon had experienced eight instances of inoperative nosewheel steering prior to the occurrence of this serious incident as mentioned in Section 2.11.1 of this report, but they had not taken comprehensive measures to resolve the problems, which included efforts to find the causes of steering light illumination.

Given that the manufacturer’s advisory information for the flight crew about control of aircraft, AOM No. 016, should still have been referred to at the time of the occurrence of the serious incident. It is considered possible that this serious incident could have been prevented if the company and Air Nippon had taken early actions to find the causes of the inoperative steering. Had they noted the manufacturer’s advisory information to ensure the steering function, consulted the manufacturer to confirm the procedure to cope with cases when aircraft speeds exceeding 60 knots (like the case of this serious incident), and had provided necessary training to their flight crew, the serious incident may have been avoided.

3.9 Actions Taken by PIC upon Occurrence of Inoperative Steering

As mentioned in Section 3.4 (2) of this report, the PIC started reverse operation when an “on-ground” condition of the nose gear was detected for the second time, but it is estimated that the effect of differential reverse was of little use because insufficient differential reverse was selected and there was a time lag before the differential reverse took effect. It is considered possible that the PIC could not adequately use differential braking or differential power in addition to rudder control because, as shown in Section 2.11.5 of this report, the company’s airplane operations manual that had been in use before the serious incident had not clearly described the procedure for landing with inoperative steering.

It is also estimated that the PIC applied the brake insufficiently as mentioned in Sections 3.4 (2) and (3) of this report.

As shown in Section 2.11.6 of this report, six months after the serious incident, the company’s airplane operations manual was revised to add a procedure to use differential braking or power together with rudder for crosswind landing roll with steering inoperative. It is estimated that this revision clarified the procedure for such a case. However, it is still necessary for the manufacturer to review the aircraft design issues mentioned below in order

to prevent PICs from experiencing unexpected inoperative steering.

3.10 Design Issues with the Type of Aircraft

WOW sensor characteristics relating to aircraft gross weight and other factors

It is estimated that the nose gear WOW sensors may detect an “in-air” condition even when the nose wheels are in contact with the ground, if the aircraft is at low gross weight or has an aft center of gravity or the aircraft speed is high. It is estimated that the following problems may occur.

(1) Centering of nose wheels

Due to detection of an “in-air” condition by the WOW sensors, the nose wheels start being centered during landing roll regardless of pilot’s operations, i.e. the steering becomes inoperative.

(2) Caster mode of nose wheels

Should condition (6) or (7) in Section 2.10.1 be satisfied as it was by the PIC’s handle operation described in Section 3.6 of this report, steering function by the SCU is lost temporarily, and the nose wheels are put in caster mode.

It is considered possible that these problems may disrupt control of aircraft unless immediate and adequate directional correction, using differential braking and reverse propeller selection is applied.

Provided pilot training is conducted according to the guidance materials provided by the manufacturer as mentioned in Section 2.11.6 of this report, it is considered possible that this kind of serious incident can be avoided in the future. However, it is necessary for the manufacturer to investigate and analyze the phenomenon in which nose wheel steering becomes inoperative after touch down and to take appropriate measures to deal with it.

4. PROBABLE CAUSE

The causal factors to this serious incident are estimated as follows:

When the aircraft landed during crosswind conditions at Kochi Airport, the nose wheels were centered and in caster mode; these conditions made it difficult to stop the aircraft heading drift to the right and the aircraft ran off the runway despite efforts made by the PIC and the first officer to correct the direction using rudder pedals, steering control handle, differential wheel brake and differential power.

With regard to the reason the nose-wheels were in caster mode, it is estimated that the steering function by SCU was lost temporarily due to the PIC's operation of the steering control handle in excess of ± 8 degrees when he was attempting to stop the heading drift while the WOW sensors were detecting an "in-air" condition or within one second after they had detected an "on-ground" condition. Contributing to the PIC's operation of the steering control handle in this manner is the company's failure to train relevant flight crew using the manufacturer's advisory information on control of the aircraft.

With regard to the failure to stop the aircraft heading drift to the right despite the PIC's corrective control measures using differential wheel brake and differential power, it is estimated that the PIC did not perform these operations appropriately. Contributing to this is the fact that the relevant descriptions in the company's manuals were unclear and that appropriate training was not given by the company to the PIC for operations such as braking during landing roll.

5. SAFETY RECOMMENDATION

In view of this serious incident, the Aircraft and Railway Accidents Investigation Commission recommends Transport Canada to take necessary measures in the following respects:

- (1) On an aircraft of type DHC-8-402, there happened a phenomenon in which the nose-wheel steering became inoperative in conjunction with the operation of the steering control handle during landing roll. The contributing factor of this was that a necessary amount of weight to detect an “on-ground” condition for the WOW sensors was not on the nose-gear shock strut even though the nose-wheels stayed in contact with the ground. In order to prevent the nose-wheel steering from becoming inoperative during high-speed landing roll, the manufacturer should investigate and analyze this phenomenon to adopt the possible improvement of the design of the WOW sensors and the mechanisms that set the steering to be centered or in caster mode.
- (2) In order for operators to acquire all of important information like the “All Operator Message”, the manufacturer should include them in manufacturer’s aeroplane-operating manual instead of notifying them only through internet website.

6. SAFETY OPINIONS

- (1) The company and Air Nippon had experienced several instances of inoperative steering, but they did not take measures to deal with these inoperative steering problems before occurrence of this serious incident. They should have investigated the causes of the steering light illumination and other abnormality indications in sufficient detail.
- (2) The company and Air Nippon were not aware of the “All Operator Message No. 016” dated February 7, 2001, issued by the manufacturer. Given that this advisory information on control of aircraft should still have been referred to at the time of occurrence of the serious incident, it is considered possible that the serious incident could have been prevented if the company had, in line with this manufacturer’s advisory information, consulted the manufacturer to confirm the procedure to cope with cases when aircraft speeds exceeding 60 knots (like the case of this serious incident) and, based on these information had required necessary training to their flight crew.

7. REFERENTIAL MATTERS

7.1 Issuance of Information Based on the All Operator Message No. 016 (Dated December 6, 2001) Issued by the Manufacturer of the Aircraft

On December 6, 2004, the company issued Airplane Operation Manual (AOM) Information No. 11, entitled “The Procedure to Ensure Operation for Nose Wheel Steering during Landing” to inform its flight crews of the causes of inoperative steering and of the methods to ensure operational steering during landing rollout.

7.2 Issuance of Airplane Operations Reference Textbook

On January 7, 2005, the company issued an [Airplane Operations Reference (AOR)] Textbook entitled “Response to Inoperative Nosewheel Steering at Landing of DHC8-400 ” to show its flight crews a general description of the nose wheel steering system (system overview, components and function) and notify them of the procedures to follow when nose wheel steering caution light illuminates or unexpected drift of heading occurs.

In addition, the company provided its flight crews with classroom training on the actions to take in the event of inoperative nose wheel steering and also added landing with nose wheel steering inoperative to the training for type rating, license conversion training for Japanese airline transport pilot certificate, and periodical training (simulator training).

7.3 Issuance of All Operator Message No. 016A

Dated December 23, 2004, the manufacturer issued a revision to its original All Operator Message No. 016, in which it introduced modification(by service bulletin) applicable to the aircraft type.

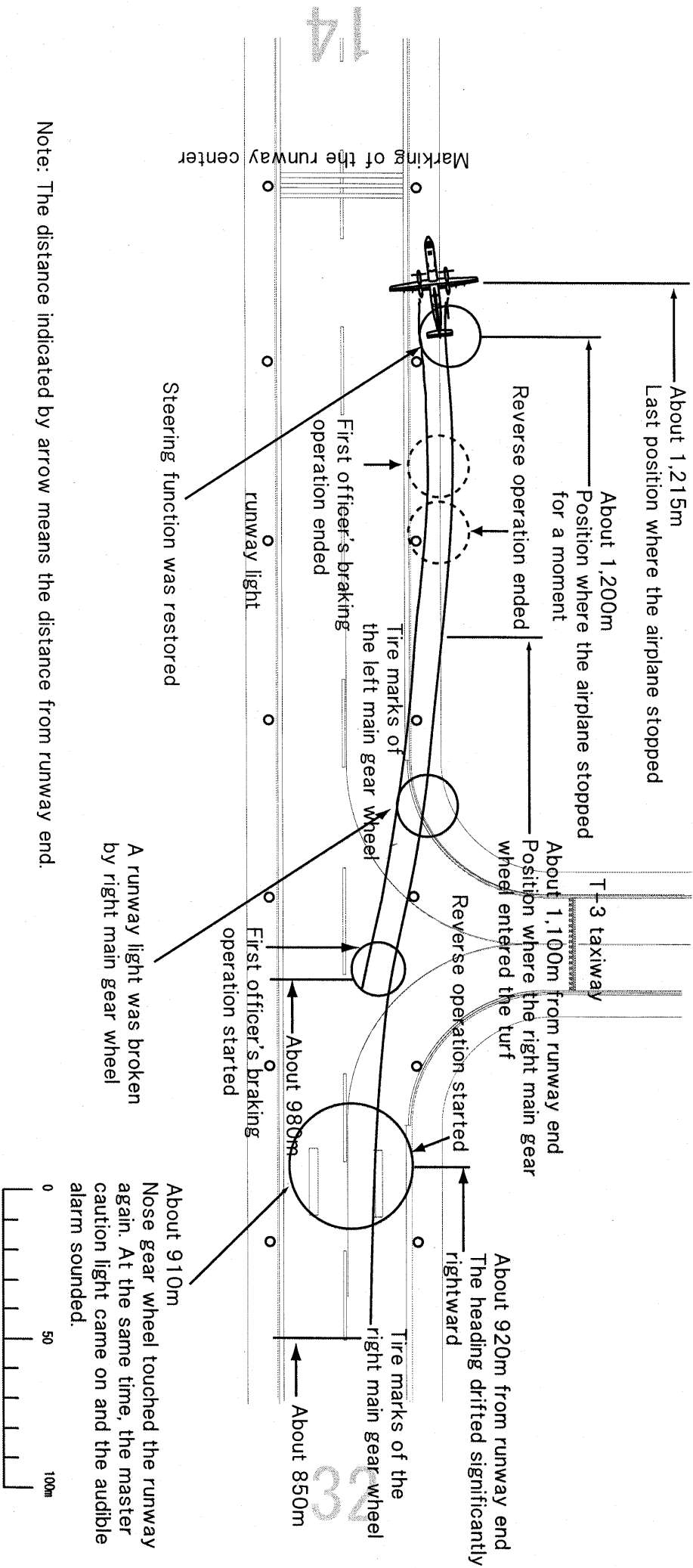
7.4 Revision to Aircraft Operations Manual

Dated July 25, 2005, the company revised its aircraft operations manual to add a note describing the operation to be performed when the nose wheel steering becomes inoperative, based on a revision of the aeroplane-operating manual of the manufacturer.

7.5 Issuance of Internal Instruction (No. 04-103) by the Company

Dated November 26, 2004, the company issued an internal instruction entitled “Application of Maximum Crosswind Limit” for DHC8-400, requiring operation within reduced interim limit of crosswind.

Figure 2 Sketch map where the incident happened (magnified)



Note: The distance indicated by arrow means the distance from runway end.

Figure 3 Three views of Bombardier DHC-8-402

Unit: m

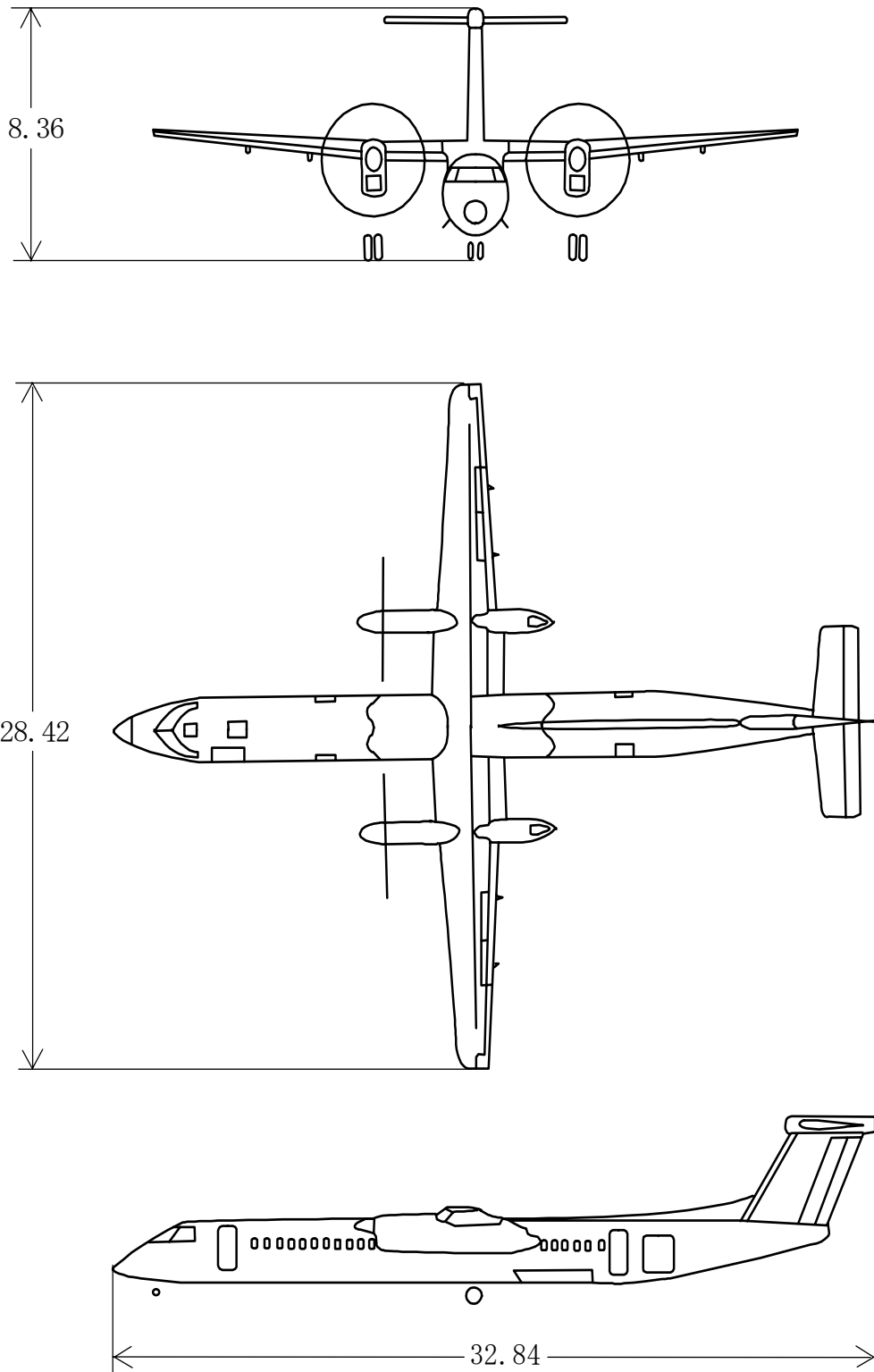


Figure 4-1 Records of DFDR (1)

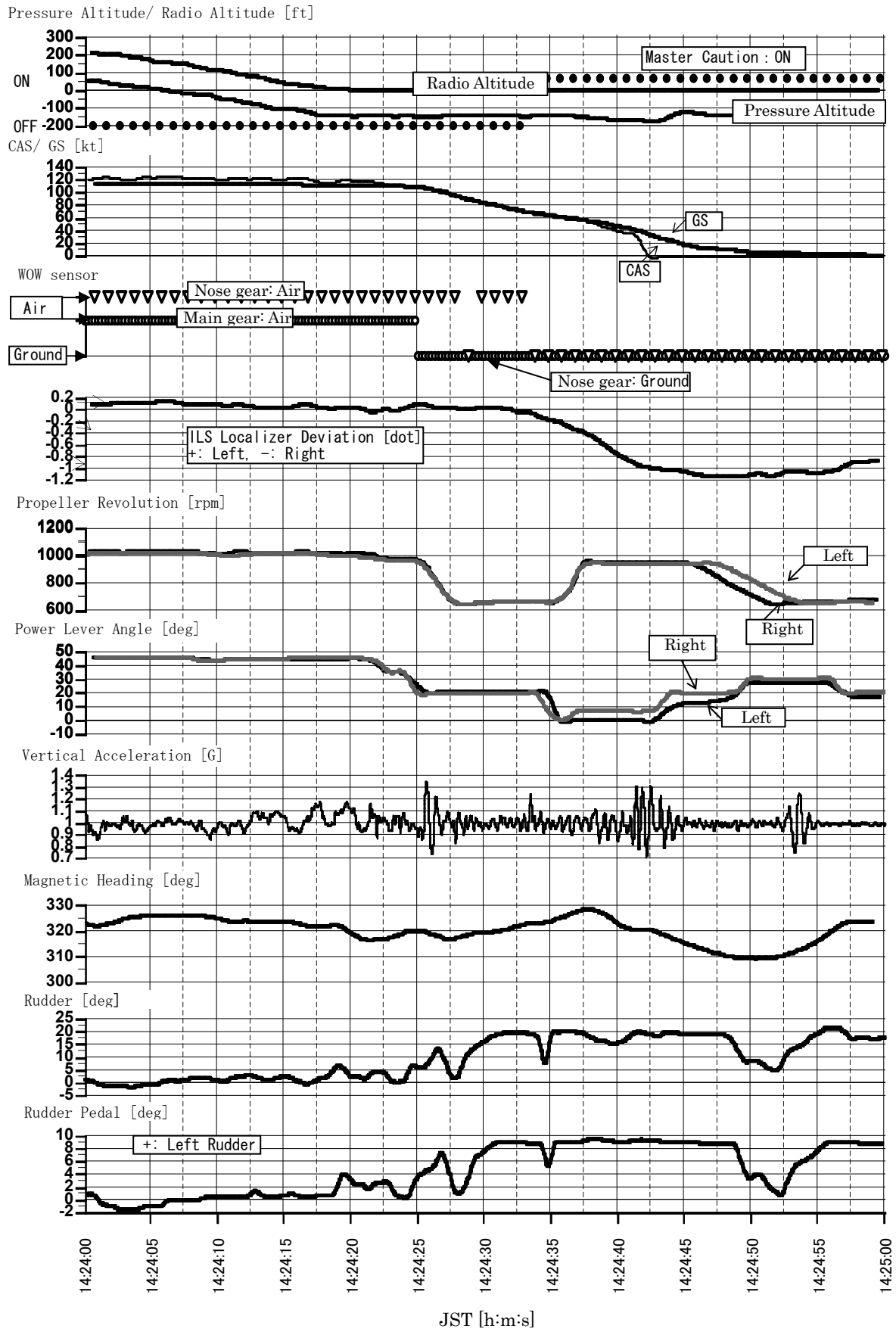


Figure 4-2 Records of DFDR (2)

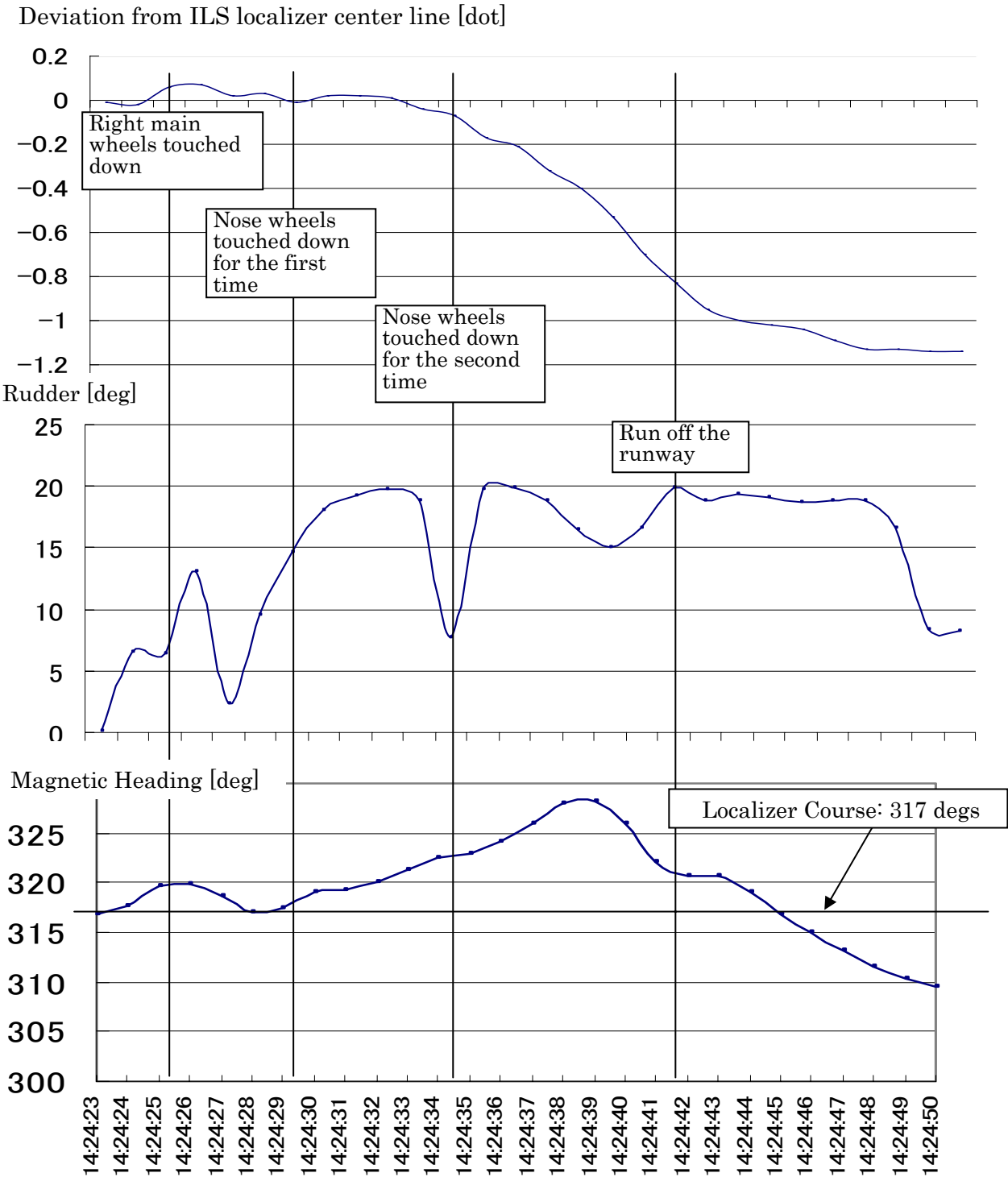


Figure 4-3 Records of DFDR (relating brake)

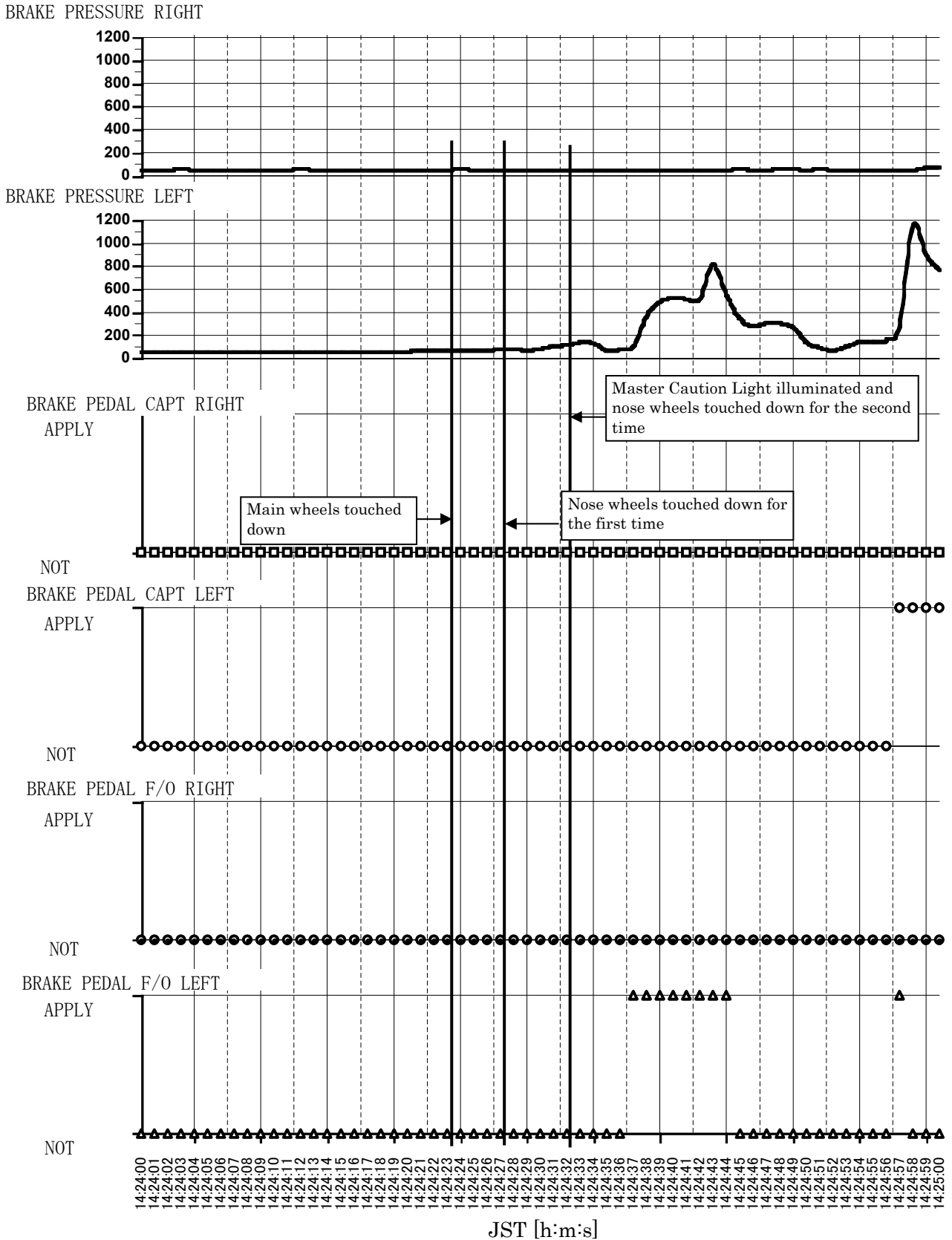


Figure 5 Estimated Approach and Landing Path

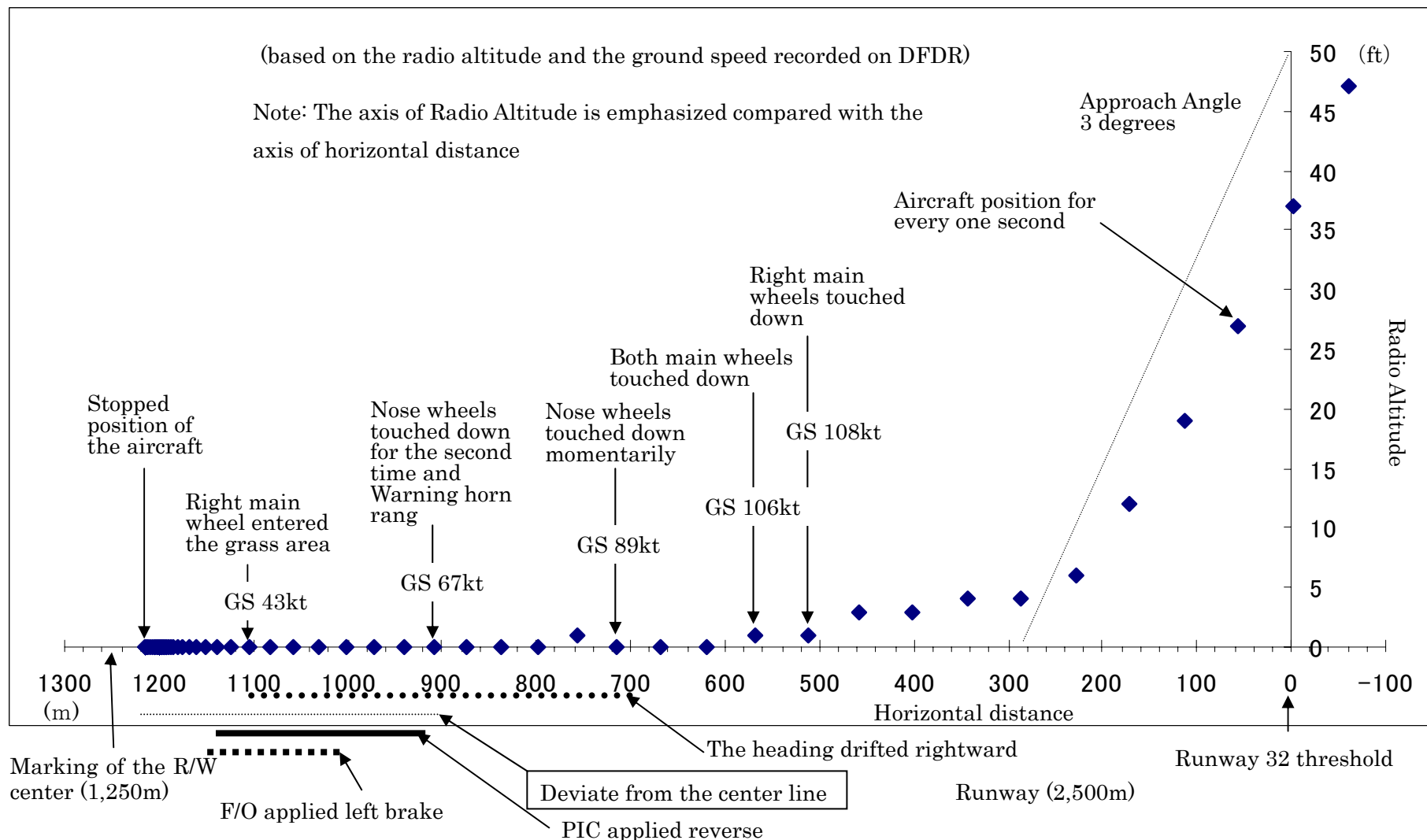


Photo 1 Aft View (Right Main Wheel Track)



Photo 2 Right Forward View



Photo 3 Right Main Wheel buried in the grass area



Photo 4 Cockpit of the Aircraft



Nose Wheel Steering Schematic

quoted from Airplane Operations Manual

