AA2011-4

AIRCRAFT ACCIDENT
INVESTIGATION REPORT

ALL NIPPON AIRWAYS CO., LTD.

J A 5 6 A N

April 22, 2011

Japan Transport Safety Board

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

Norihiro Goto
Chairman,
Japan Transport Safety Board

Note:

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

AIRCRAFT ACCIDENT INVESTIGATION REPORT

ALL NIPPON AIRWAYS CO., LTD.
BOEING 737-800
JA56AN

AROUND 20:23 JST, AUGUST 10, 2009
RUNWAY 22, TOKYO INTERNATIONAL AIRPORT

March 29, 2011
Adopted by the Japan Transport Safety Board
Chairman Norihiro Goto
Member Shinsuke Endoh
Member Toshiyuki Ishikawa
Member Sadao Tamura
Member Yuki Shuto
Member Toshiaki Shinagawa

1. PROCESS AND PROGRESS OF THE INVESTIGATION

1. 1 Summary of the Accident

On August 10 (Monday), 2009, a Boeing 737-800, registered JA56AN, operated by Air Nippon Co., Ltd., as All Nippon Airway's flight 298 on a regularly scheduled service under the agreement of joint transportation, made a tail strike with the surface of runway 22, Tokyo International Airport upon landing around 20:23 Japan Standard Time (JST,UTC+9H)[1].

A total of 153 persons consisting of a pilot in command, five crew members and 147 passengers were on board the aircraft, but nobody sustained injuries.

The aircraft was substantially damaged but no fire broke out.

1.2 Outline of the Accident Investigation

1.2.1 Investigation Organization

Japan Transport Safety Board designated an investigator-in-charge and two investigators to investigate the accident on August 11, 2009.

1.2.2 Representatives from Foreign Authorities

An accredited representative from the United States of America, the State of Design and Manufacture of the aircraft involved in this accident, participated in the investigation.

1.2.3 Implementation of the Investigation

August 11, 2009	Site investigation, interviews and aircraft examination
August 12 – September 30, 2009	DFDR and CVR data analysis
May 20 and July 16, 2010	Interviews

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

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

1.2.5 Comments from the Participating State

Comments were invited from the United States of America.

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[1] Unless otherwise stated, all times are JST, based on a 24-hour clock.

2 FACTUAL INFORMATION

2.1 History of the Flight

On August 10 (Monday), 2009, a Boeing 737-800, registered JA56AN (hereinafter referred to as "the Aircraft"), operated by Air Nippon Co., Ltd. (hereinafter referred to as "the Company"), as All Nippon Airway's Flight 298 on a regularly scheduled service under the agreement of joint transportation, took off from Tottori Airport at 19:12 bound for Tokyo International Airport (hereinafter referred to as "the Airport").

The Aircraft's flight plan was outlined as follows.

Flight rules: Instrument flight rules (IFR)

Departure aerodrome: Tottori Airport

Estimated off-block time: 17:40

Cruising speed: 463 kt

Cruising altitude: FL350

Route: YME (Miyazu VOR/DME) – V59 (Airway) – LHE (Hamamatsu VOR/DME) – V17 (Airway) – XAC (Oshima VORTAC) – Y211 (RNAV route) – WESTN (Reporting point)

Total estimated elapsed time (EET): 56 min.

Fuel load expressed in endurance: 3 hr. 39 min.

A total of 153 persons consisting of a pilot in command (PIC), five crew members and 147 passengers were on board.

The PIC was in the left seat as pilot-not-flying (PNF) and the first officer (FO) was in the right seat as pilot-flying (PF).

Based on the Digital Flight Data Recorder (DFDR) records, Cockpit Voice Recorder (CVR) records, and statements of the PIC, FO and a cabin attendant, the situation from the reception of non-precision approach clearance to runway 22 of the Airport to the accident occurrence developed roughly as follows.

2.1.1 Flight History Based on the DFDR and CVR Records

(Position of flight controls are referenced from each control's datum point and shown in degree.)

Around 20:21:37	The PNF made a call-out saying "Landing checklist completed." The landing check was completed.
Around 20:21:41	Autopilot and Auto-throttle were deactivated.

	Airspeed (hereinafter speed refers to computed airspeed and is referred to as "speed") was approx. 140 kt.
Around 20:22:07	With aircraft heading 220 º and approx. 140 kt of speed, the Aircraft descended through 500 ft. Almost concurrently the FO said, "Please inhibit GPWS[2] glide slope warning when it is activated." The PNF said "Roger."
	(Irrelevant portions omitted)
Around 20:22:43	The pitch angle began to decrease from approx. 4 º followed by increased descent rate.
Around 20:22:44	The Aircraft flew over the Runway 22 threshold at a height of approx. 60 ft radar altitude (RA).
Around 20:22:45	The Automatic Callout "Fifty," speed 136 kt, pitch angle approx. +2 º, descent rate approx. 600 fpm.
Around 20:22:46	The Automatic Callout "Forty," speed 136 kt, pitch angle approx. +2 º, descent rate approx. 700 fpm.
Around 20:22:47	The Automatic Callout "Thirty," speed 136 kt, pitch angle approx. +3 º, descent rate approx. 700 fpm.
Around 20:22:48	The Automatic Callout "Twenty," speed 134 kt, pitch angle approx. +4 º, descent rate approx. 600 fpm.
Around 20:22:49	The Automatic Callout "Ten," speed 135 kt, pitch angle approx. +5 º, descent rate approx. 400 fpm.
Around 20:22:50 to 20:22:55	Around 20:22:50, the Aircraft's main gears touched down on the runway with pitch angel of approx. +6 º, descent rate of approx. 100 fpm, speed of approx. 135 kt, immediately followed by a bounce. Sometime between 20:22:50 and 20:22:51. increasing pitch angle turned to decrease. At the time of touchdown throttle levers were still in approach setting. They were retarded to idle during the bounce. Speed brake started to deploy

[2] Ground Proximity Warning System

around 20:22:52.

Just after the first touchdown the control column position (CCP) registered a movement of push followed by a pull around 20:22:51. The CCP fluctuated from approx. +7 º to approx. -4 º to approx. +11 º, while delayed pitch angle fluctuated from approx. +6 º to approx. +2 º to approx. +11 º. Sometime between 20:22:52 and 20:22:53, PIC's control column registered a push force. Around 20:22:53 the Aircraft substantially landed with its pitch angle of +6 º and vertical gravitational force of approx. 2.4G, however, the pitch angle continued to increase. The deployment of the speed brake completed between 20:22:52 and 20:22:54. Pitch angle around 20:22:55 exceeded +9 º.

Around 20:22:56 The pitch angle decreased below +9 º.

Around 20:22:58 The nose gear touched on the ground.

(See Figure 1 Scratch Marks on the Runway 22, Figure 3 DFDR Records (1) and Figure 4 DFDR Records (2))

2.1.2 Crew Statements

(1) PIC

I was in the left seat as PNF at the time of the accident. I set the flap to 30, at approx. 1,000 ft pressure altitude (PA), 5 nm on the final path. At 500 ft PA a stabilized 3 º approach was established, however, at 300 ft the Aircraft went down a little below 3 º glide path. At 200 ft the indication of the precision approach path indicator (PAPI[3]) was four reds. The FO added power a little to go back to the glide path and at 100 ft we were on the glide path. The head-up display indicated our touch-down aiming point to be approx. 1,200 ft from the runway 22 threshold. The touch-down was normal, however, the Aircraft bounced and touched down again with some amount of shock. I felt that a tail strike occurred.

After arriving at the passenger boarding bridge I asked a ground crew to

[3] PAPI is an instrument which provides proper glide slope angle for landing aircraft with four laterally arranged lights. Each light can be seen red or white depending on a glide path angle. White-white-red-red indication means the aircraft is on the proper glide slope, while four red indication means below proper glide slope.

check the rear of the Aircraft.

I decided to have the FO to land the Aircraft judging that the weather around the Airport was non-problematic for his landing. I heard that he had the experience of landing this aircraft type.

Type 737-800 has an extended fuselage so that if it becomes overly nose-up attitude it would have a tail strike. So I put my hands and feet near the controls in order to have a quick take-over of controls from him. The flight on final was within allowable stabilization limits until the initial touchdown. I need not to add my control input. When the Aircraft bounced I grabbed the control column and held it in place not to be pulled further and waited for the second touchdown. I didn't take the control from him.

(2) FO

I was in the right seat as PF and started a VOR approach to runway 22. The target speed at that time was 139 kt with 5 kt added to the reference speed of 134 kt.

I had a visual contact with the runway at 800 ft PA and deactivated the autopilot and auto-throttle system. The PNF made a 500 ft call-out when we descended through 500 ft. Around 400 ft the Aircraft went below 3º glide path. I added power to adjust the glide path. When the adjustment was completed I reduced power to the original setting. Because it was a night flight, I fixed my aiming point next to the PAPI. I felt duration between automatic call-outs of "Fifty" and "Forty" shorter than usual. So I gave an input of descent rate reduction. When I heard "Thirty," I flared the Aircraft to stay on the glide path. As the rate of descent was my concern, I decided to retard the throttle at the last moment. Upon hearing "Ten," I retarded the throttle. The Aircraft touched down and then bounced. I held the control column in position and waited for the second touch-down. I don't remember the shock at the time of the second touch-down or tail strike.

Wind was steadily blowing from 200º at approx. 12 kt during the landing.

(3) Cabin attendant in charge of right aft cabin

I was sitting in the right rearmost seat. I felt no jolts during the landing approach. The first touch-down was a usual one, but the Aircraft bounced and touched down again with a strong shock. I felt we bounced high but I didn't felt the Aircraft took a nose-up attitude. After the second touch-down, I heard grating sound coming from below the floor, which is quite different from the sound of the engines in reverse mode.

I informed the chief purser of the sound and other things when we were moving on the taxi way.

The accident occurred at the point approx. 618 m from the runway 22 threshold, Tokyo International Airport (35º33'12"N, 139º46'52"E) around 20:23.
(See Figure 1 Scratch Marks on the Runway 22)

2.2 Injuries

None

2.3 Damage to the Aircraft

2.3.1 Extent of Damage; Fire

The Aircraft was substantially damaged; no fire broke out.

2.3.2 Damage to the Aircraft Components

(1) Lower skin panel, aft fuselage: damaged
(2) Lower frames and stringers, aft fuselage: damaged
(3) Tail skid assembly: damaged
(See Photo 1 Damage on Tail Skid and Photo 2 Damage on Fuselage)

2.4 Other Damage

Scratch marks remained on the runway surface stretching approx. 67 m from the point approx. 618 m from the runway 22 threshold.

2.5 Personnel Information

(1) PIC (Male, Age 56)
a. Certificate

Airline transport pilot certificate (Airplane)	Oct. 29, 2004
Type rating for Boeing 737	Nov.13, 1995
Class 1 aviation medical certificate	
Validity	Aug. 13, 2009
Total flight time	12,683 hrs 37 min
Flight time in the last 30 days	13 hrs 07 min

Total flight time on the type of aircraft[4]	116 hrs 41 min
	(20 hrs 14 min)
Flight time in the last 30 days	13 hrs 07 min
	(6 hrs 23 min)

b. Corporate qualification

He was qualified as Landing Approved Captain (LAC) on Nov. 7, 2005, under which he can authorize an FO to fly an aircraft in the right seat.

(2) FO (Male, Age 31)

a. Certificate

Commercial pilot certificate	Mar. 25, 2005
Type rating for Boeing 737	Jul. 11, 2008
Instrument flight certificate	Aug. 22, 2005
Class 1 aviation medical certificate	
Validity	Aug. 25, 2009

Total flight time	834 hrs 53 min
Flight time in the last 30 days	61 hrs 47 min
Total flight time on the type of aircraft	487 hrs 23 min
	(144 hrs 48 min)
Flight time in the last 30 days	61 hrs 47 min
	(7 hrs 04 min)

b. Flight experience on Boeing 737-700 and 737-800 (hereinafter respectively referred to as "-700" and "-800")

The FO had 5 times of actual landing experience on -700 in the last 30 days before the accident, while his landing experience as PF was 275 times with day and night landings combined. Of 275, 2 daytime and 5 nighttime landings were logged on -800 after his first -800 landing as PF in April, 2009.

2.6 Aircraft Information

2.6.1 Aircraft

Type	Boeing 737-800
Serial number	33893

[4] Combined flight hours of -700 and -800. Figures in parenthesis show time logged on -800.

Date of manufacture	May 22, 2009
Certificate of airworthiness	2009-019
Validity	During a period in which the aircraft is maintained in accordance with the All Nippon Airways regulations
Category of airworthiness	Aircraft, Transport T category
Total time in service	341 hrs 02 min

(See Figure 2 Three Angle View of Boeing 737-800)

2.6.2 Weight and Balance

The weight of the Aircraft at the time of the accident was estimated to be approximately 131,400 lb with the center of gravity (CG) at 25.2 % MAC, being within the allowable limits. (cf. Maximum certified weight is 144,000 lb. Allowable CG range corresponding to this weight is between 6.1 and 36.0 % MAC in longitudinal axis)

2.7 Meteorological Information at the Airport

The weather condition observed around the time of the accident was as follows:

20:00 Wind 190 °, Wind velocity 10 kt,
Prevailing visibility 20 km,
Cloud amount FEW, Cloud type Cumulus, Cloud base at 1,300 ft,
Cloud amount BKN, Cloud type and Ceiling Unknown,
Temperature 28 ºC, Dew point 25 ºC,
Altimeter setting (QNH) 29.74 inHg.

20:30 Wind 190 °, Wind velocity 11 kt,
Prevailing visibility 20 km,
Cloud amount FEW, Cloud type Cumulus, Cloud base at 500 ft,
Cloud amount BKN, Cloud type and Ceiling Unknown,
Temperature 28 ºC, Dew point 25 ºC,
Altimeter setting (QNH) 29.74 inHg.

2.8 Accident Site and Aircraft Damage

2.8.1 Accident Site

The accident site was on the runway 22 (length 2,500 m, width 60 m) of the Airport. Scratch marks remained on the runway stretching approx. 67 m from the point approx. 618 m from the threshold. The scratch marks constituted of the tail skid contact (length approx. 20 m, width approx. 10 cm), drain mast contact (length approx. 47 m, width approx. 5 cm) and aft lower fuselage contact (length approx. 15 m, width approx. 25 cm).

2.8.2 Aircraft Damage

(1) Tail skid and other parts

Wear shoe at the end of the tail skid was worn and its fairing was damaged. Aft drain mast, APU drain mast and APU cowl door were scratched and deformed.

(2) Fuselage tail section

On the lower skin on and aft of Body Station[5] (BS) 867, the area approx. 2.5 m (length) by approx. 25 cm (width) had dents and scratch marks with damaged inner structures of stringers and frames in the area.

(See Photo 1 Damage on Tail Skid and Photo 2 Damage on Fuselage)

2.9 DFDR and CVR Information

The Aircraft was equipped with a DFDR and a CVR. The DFDR is a product of Honeywell (Part No. 980-4700-042) capable of 25 hours recording while the CVR is a product of L3 Communications (Part No. 2100-1020-00) capable of 2 hours recording. Both the DFDR and CVR records were intact and were retrieved.

The time correction of the DFDR and CVR data were made by synchronizing VHF transmission keying signal on DFDR to corresponding CVR radio communication which is synchronized with the JST time signals recorded on the ATC communication record.

(See Figure 3 DFDR Records (1) and Figure 4 DFDR Records (2))

2.10 Differences Training from -700 to -800

-700 and -800 belong to Boeing 737 series and the Civil Aviation Bureau, Ministry of Land, Infrastructure, Transport and Tourism, Japan authorizes that

[5] Distance from the forward datum point and the value indicates longitudinal position.

pilots qualified with -700 operations can obtain -800 qualification after learning difference between -700 and -800 by a classroom training.

The Company has established the differences training standard and provides 3-hour self-study training curriculum with audio-visual materials for captains and copilots who are type-rated with -700. In the curriculum, emphasis is placed on paying attention to tailstrike during takeoff and landing. The contents include:

a. Air system (such as air conditioning system, etc.)
b. Short Field Performance
c. Aircraft performance
d. Differences between -700 and -800.

Captains have to fly real -800 aircraft twice in the left seat under the supervision of a Route Training Captain (RTC) and other qualified captains.

A copilot's actual training flight is not included in the difference training standard because he/she always flies under the supervision of a qualified captain.

2.11 Take-over by Captains

The Company's operations manual stipulates take-over as follows (excerpt).

(1) A PIC, when he allows an FO to fly the aircraft, determines the proper extent of FO's flight operations considering weather conditions and other relevant factors. When a PIC evaluates the situation unfavorable, he should not let an FO fly.

(2) A PIC, in advance, makes thorough arrangement with his FO on the extent of aircraft maneuver.

(3) If a PIC judges that the FO's maneuver is unacceptable or the circumstance does not allow FO to continue flying, he takes over the flight controls without delay.

(The rest is omitted.)

The training material for LAC qualification training includes the following PIC's actions before taking over the aircraft control.

SUGGESTION: Verbal and mild expression such as "a little high" (on the premise of continued FO's control).

ASSIST: A PIC adds power or moves controls by touching them to assist FO's corrective action (on the premise of continued FO's control).

ORDER: An order of GO AROUND or other directions under the urgent

situation (on the premise of continued FO's control).

TAKEOVER: Transfer of controls under the extremely urgent situation.

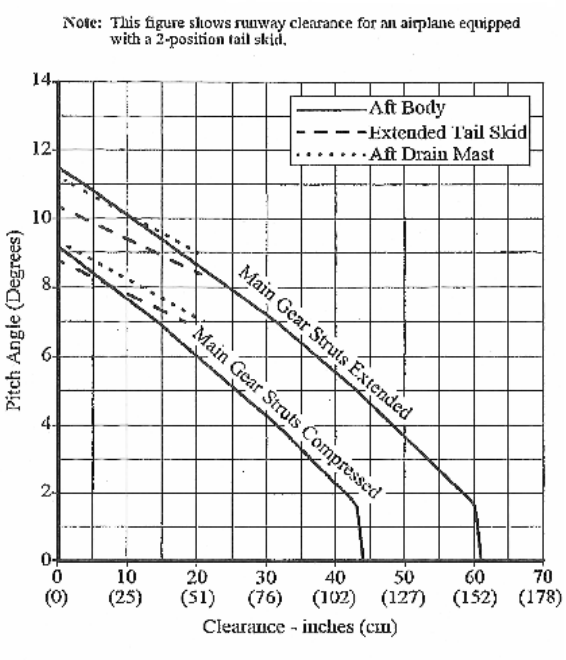
2.12 Parameter Settings for Landing

2.12.1 Pitch Angle and Runway Clearance during a Landing Flare

A -800's fuselage is extended by approx. 5.8 m from that of -700 and a tail strike occurs with smaller pitch angle as shown in this page.

A chart in B737 Maneuvers and Techniques Guide (MTG), which is used as the Company's reference guide for flight maneuvers, depicts -800 pitch angle for tail strike. With its main landing gears on the ground and gear struts compressed a tail strike occurs at approx. 9 º, whereas with extended struts, at approx. 11.5 º.

On the other hand, -700's corresponding value is approx. 12.5 º and approx. 14.7 º.



2.12.2 Post-flare Maneuvers in MTG (excerpt)

6-4 Flare and Touchdown

(Irrelevant parts omitted)

Initiate the flare when the main gears are approximately 20 ft above the runway by increasing pitch attitude approximately 2 º- 3 º. This slows the rate of descent.

After the flare is initiated, smoothly retard the thrust levers to idle, and make small pitch attitude adjustments to maintain the desired descent rate to the runway. Ideally, main gear touchdown should occur simultaneously with thrust levers reaching idle.

(Irrelevant parts omitted)

6-4-1 Landing Flare Profile

(Irrelevant parts omitted)

· *Typical landing flare times range from 4 to 8 seconds and are a function of*

approach speed.

(Irrelevant parts omitted)

· Do not increase the pitch attitude after touchdown; this could lead to a tail strike.

(Irrelevant parts omitted)

· Avoid rapid control column movements during the flare. If the flare is too abrupt and thrust is excessive near touchdown, the airplane tends to float in ground effect[6]. Do not allow the airplane to float.

(Irrelevant parts omitted)

6-4-2 Bounced Landing Recovery

If the airplane should bounce, hold or reestablish a normal landing attitude and add thrust as necessary to control the descent. Thrust need not be added for a shallow bounce or skip. When a high, hard bounce occurs, initiate a go-around. Apply go-around thrust and use normal go-around procedures. (Irrelevant parts omitted)

Bounced landings can occur because higher than idle thrust is maintained through initial touchdown, disabling the automatic speed brake deployment even when the speedbrakes are armed. During the resultant bounce, if the thrust levers are then retarded to idle, automatic speedbrake deployment can occur resulting in a loss of lift and nose up pitching moment which can result in a tail strike or hard landing on a subsequent touchdown.

2.12.3 Conditions for Auto-brake System Operation

A B737NG [7] AIRPLANE OPERATIONS MANUAL, which carries information for flight operations, maneuver techniques, limitations and performance data etc. for -700 and -800, stipulates the conditions for auto brake operation as follows.

· SPEED BRAKE lever is in the ARMED position.

· SPEED BRAKE ARMED light is illuminated.

· Radio altitude is less than 10 feet.

· Landing gear strut compresses on touchdown.

Note: Compression of any landing gear strut enables the flight spoilers to deploy. Compression of the right main landing gear strut enables the

[6] Aerodynamic influence exerted on an airplane near the ground.
[7] NG is the abbreviation of Next Generation.

ground spoilers to deploy.

Note: Once the landing gear struts are compressed and the system is in the ground mode, if the landing gears should become not- compressed, ground mode is held for 4 seconds for sure automatic speed brake operation.

· Both thrust levers are retarded to IDLE

·When the main landing gear wheels spin up (more than 60 kt), the SPEED BRAKE lever automatically moves to UP position and the spoilers deploy.

3. ANALYSIS

3.1 Airman Competence Certificate

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

3.2 Aircraft Airworthiness

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

3.3 Influence of the Weather

It is considered highly probable that the weather condition at the time of the accident had no bearings on the occurrence of the accident.

3.4 FO's flight Operations

(1) 200 ft to the Bounce

As depicted in Figure 3 and 4, DFDR records indicate that the CCP movement is followed by delayed pitch movement and there are points where a delay of approx. 1 sec is observed.

As depicted in Figure 3, the FO corrected the glide path near 150 ft, which the PIC mentioned that it was lower near 200 ft, by adding thrust and increasing pitch angle. Then he pushed the CCP after passing through 90 ft and it is considered highly probable that this input is linked to the decreasing pitch angle after flying over the runway 22 threshold with the altitude of approx. 60 ft RA and delayed increase in descent rate. He stated that he felt duration between automatic call-outs of "Fifty" and "Forty" shorter than usual, it is considered probable that his statement corresponds to then increasing descent rate of 600 to 700 fpm. Then the CCP value increases in the direction of pull when the Aircraft went through 30 ft. It is considered probable that this value increase corresponds to the action to reduce descent rate. He stated that when he heard "Thirty", he started to flare the Aircraft with added intention of maintaining then glide path, it is considered probable that this statement corresponds to the descent rate which started to decrease at around the time in the DFDR records. It is considered probable that the flare maneuver was started approx. 3 seconds before first touchdown, with the control column being pulled until the touchdown to reduce descent rate from 700 fpm, lead to a touchdown with approx. 100 fpm descent rate, while causing the pitch angle to

increase after the touchdown although it was a short period of time.

As for the thrust lever control, the FO stated he retarded the thrust lever to idle position upon hearing automatic call-out of "Ten," but the lever position remained in its approach setting. It is considered probable that he could not retard the lever to idle position because if he did, with then descent rate of approx. 400 fpm, not fully arrested descent rate for touchdown, it would be further increased.

It is considered provable that the Aircraft bounced due to:
approx. +6 º pitch attitude at touchdown with airspeed of approx. 135 kt and the remained power setting –thrust levers not being retarded to idle position;
and remained short-time nose-up attitude tendency of the Aircraft after the touchdown.

At this point, the conditions for auto brake operation mentioned in 2.12.3 were not met because thrust levers were not in idle position.

(2) During the Bounce

The FO stated that he held the control column for the second touchdown, however, CCP registered a big push and pull movement. It is considered probable that he pushed the control column (from approx. +7 º to approx. -4 º) to contain further bounce then pulled it (from approx. -4 º to approx. +11 º) to establish the landing attitude for the second touchdown.
The CCP movement reversed to decrease around 20:22:52 approx. one second before the subsequent touchdown, however, the pitch angle by contraries turned to increase.

Around 51 sec. with the thrust lever retarded to idle position, conditions for auto speed brake were met and around 20:22:52 spoilers began to deploy.

When the FO retard the thrust lever to idle, the situation mentioned in the latter half of the MTG's bounced landing recovery (During the resultant bounce, if the thrust levers are then retarded to idle, automatic speed brake deployment can occur resulting in a loss of lift and nose up pitching moment which can result in a tail strike or hard landing on a subsequent touchdown.) occurred. It is considered somewhat likely that he should have known the adverse outcome of retarded thrust lever to idle during a bounce, he did it as an impulsive action.

On the other hand, Figure 4 illustrates the PIC's control column force as a push around 20:22:52, it is considered probable that this push corresponds to the PIC's statement that when the Aircraft bounced he grabbed the control column and held it in place not to be pulled further, and he tried to restrain FO's big control

input.

(3) After the Subsequent Touchdown

The subsequent touchdown was made with pitch angle of approx. +6 º around 20:22:53. It is considered highly probable that the Aircraft landed with a vertical acceleration of 2.4 G after losing lift which was caused by deployed spoilers. It is considered probable that although CCP decreased from 11 º to 8 º between 20:22:52 and 53, pitch up attitude exceeded 9 º as a result of combined effects of bigger CCP value and pitch up moment generated by deployment of spoilers which took place around 20:22:52 and 53.

The Aircraft's average ground speed two seconds after the resultant touchdown was approx. 128.5 kt and the whole length of scratch marks on the runway surface was approx. 67 m. With this speed it requires approx. one second (67 / (128.5×1852 / 3,600) = 1.013) for the Aircraft to travel 67 m. On Figure 4, duration of 1 second which covers biggest pitch angle corresponds to the pitch angle of more than approx. 9.7 º.

Given the above mentioned facts it is considered highly probable that the effects of FO's large push-pull movement of the control column during the bounce lead to the delayed once-reduced pitch angle to regain its increase surpassing approx. 9.7 º, with added nose-up moment generated by the deployment of spoilers, consequently lead to a tail strike and fuselage damage.

The chart inserted in 2.12.1 indicates that with compressed main gear struts a tail strike occurs at approx. 9 º pitch angle whereas with extended struts it occurs at approx. 11.5 º. The Aircraft aft fuselage is estimated to have touched the runway with approx. 9.7 º pitch angle, it is considered highly probable that the struts were partially compressed, not fully extended.

3.5 PIC's Take-over

As the PIC stated that flight on final performed by the FO was within allowable stabilization limits until the initial touchdown he did not have to add his control input and there is no advice recorded in the CVR information, it is considered highly probable that he judged that a take-over is unnecessary until the first touchdown. However, as a PIC who supervises an FO, it is desirable that he positively involve himself in the operations to control the situation and, if necessary, he/she should take over the control of the Aircraft.

The Aircraft bounced just after the first touchdown and the resultant

touchdown occurred approx. 2 seconds later. During the bounce the FO gave push-pull input to the control column, the PIC pushed the control column to restraint excessive pull input, however, it did not prevent from occurring the tail strike.

3.6 Recurrence Prevention

A proper landing requires pilots to stabilize the last portion of an approach with proper control of speed, height, descent rate and other elements. In order to achieve this, it is important to establish a stabilized approach path in its early stage and precisely maintain it with small control input.

During the course of an approach, if a PIC judges FO's approach unstable, he should not hesitate to involve himself into the approach and to execute a take-over.

In case of a bounce and unstable aircraft situation, it is necessary to execute the counter measures stipulated in the MTG.

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4. PROBABLE CAUSES

In this accident, it is considered highly probable that the Aircraft, under the FO's piloting, was damaged in its aft fuselage as a result of the tail strike, after the initial touchdown followed by a quick bounce and a subsequent touchdown with bigger vertical G force and continued increment of nose-up attitude, in addition to the compression of main landing gear struts.

It is considered probable that the big amount of control column pull input during the bounce and the pitch-up moment generated by the deployment of auto speed brake activated by retarded thrust levers contributed to the continued pitch up after the subsequent touchdown.

5 ACTIONS TAKEN

The Company has taken the following corrective actions.

1. Reassessment of difference training contents

The training materials have been revised to deepen the knowledge of tail strike.

2. Revision of FO's flight training on -800

FOs who finished FO training fly -800 in the right seat under the supervision of inspector pilot, RTC, LAC (real aircraft training pilots only) and other qualified pilots until their flight times reach 10.

When a PIC judges it inappropriate to let an FO to continue to pilot the aircraft at or below 300 ft, the PIC immediately takes over the control instead of providing advice or direction.

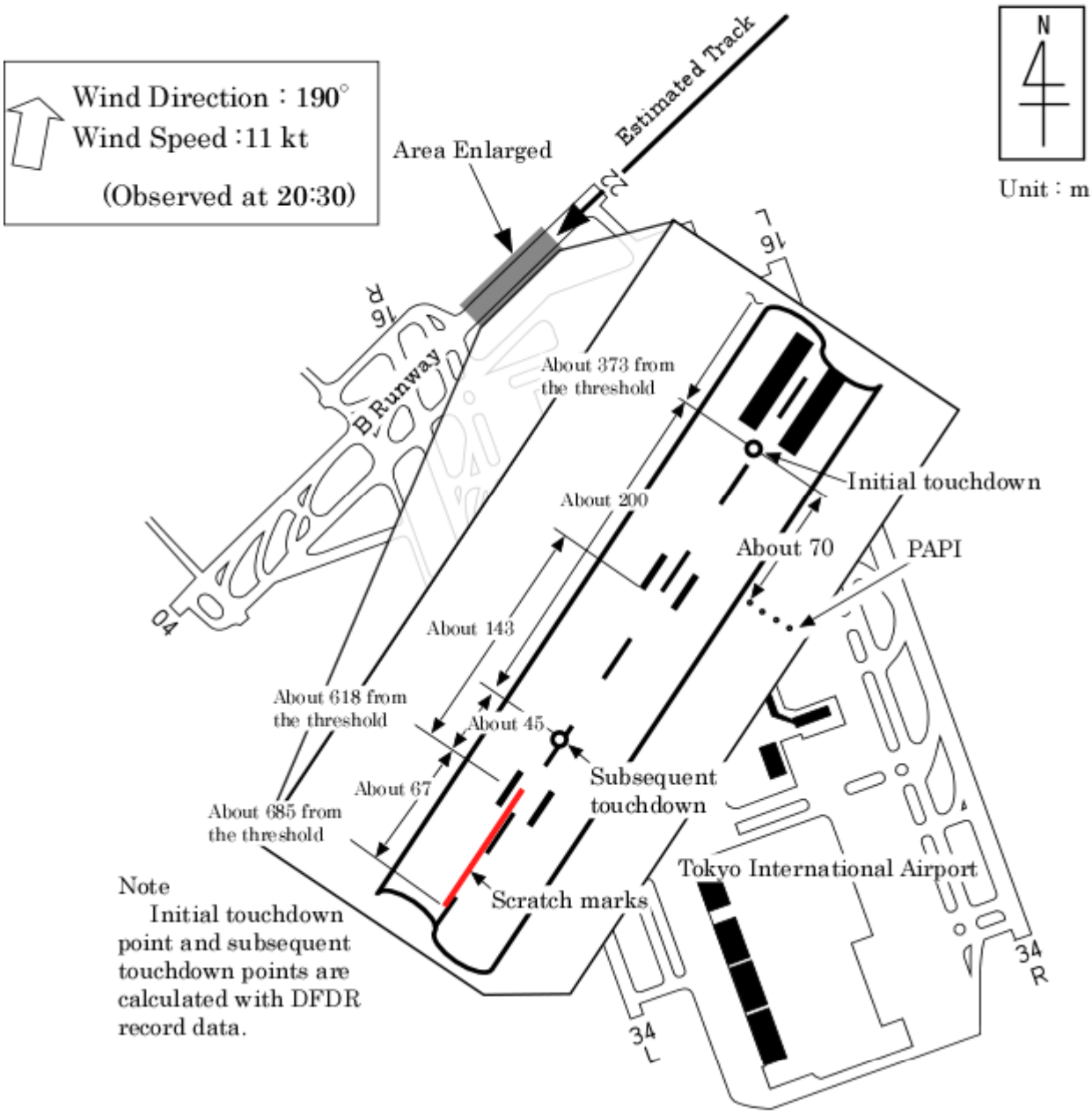
3. Study of landing technique

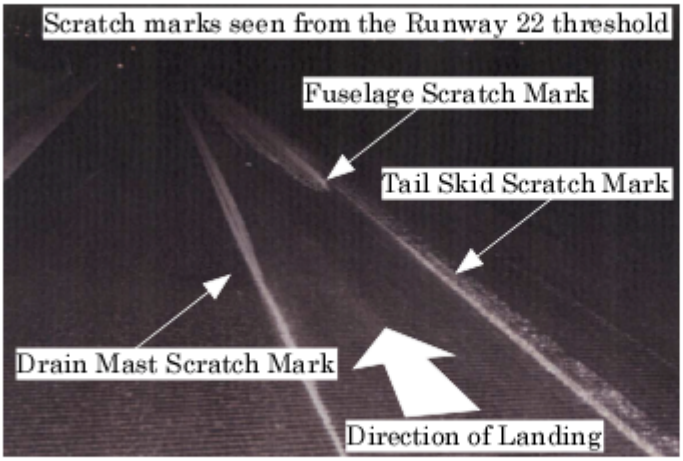
A study was made on -800 flight characteristic; effects of extended fuselage, speed brake effects, aircraft handling quality due to increased landing weight, elements affecting tail strike and other relevant matters. The results were disseminated to each pilot as points of attention during landing sequence.

4. Reassessment of LAC training

The Company not only revised the LAC training materials but expanded simulator training contents to better cope with the unstable approach situation on final approach path and bouncing after improper landing.

Figure 1 Scratch Marks on the Runway 22





Scratch marks starts at about 618m from the runway 22 threshold. Scratch marks (tail skid, drain mast and fuselage combined) extends to about 67m.

Figure 2 Three Angle View of Boeing 737-800

Unit: m

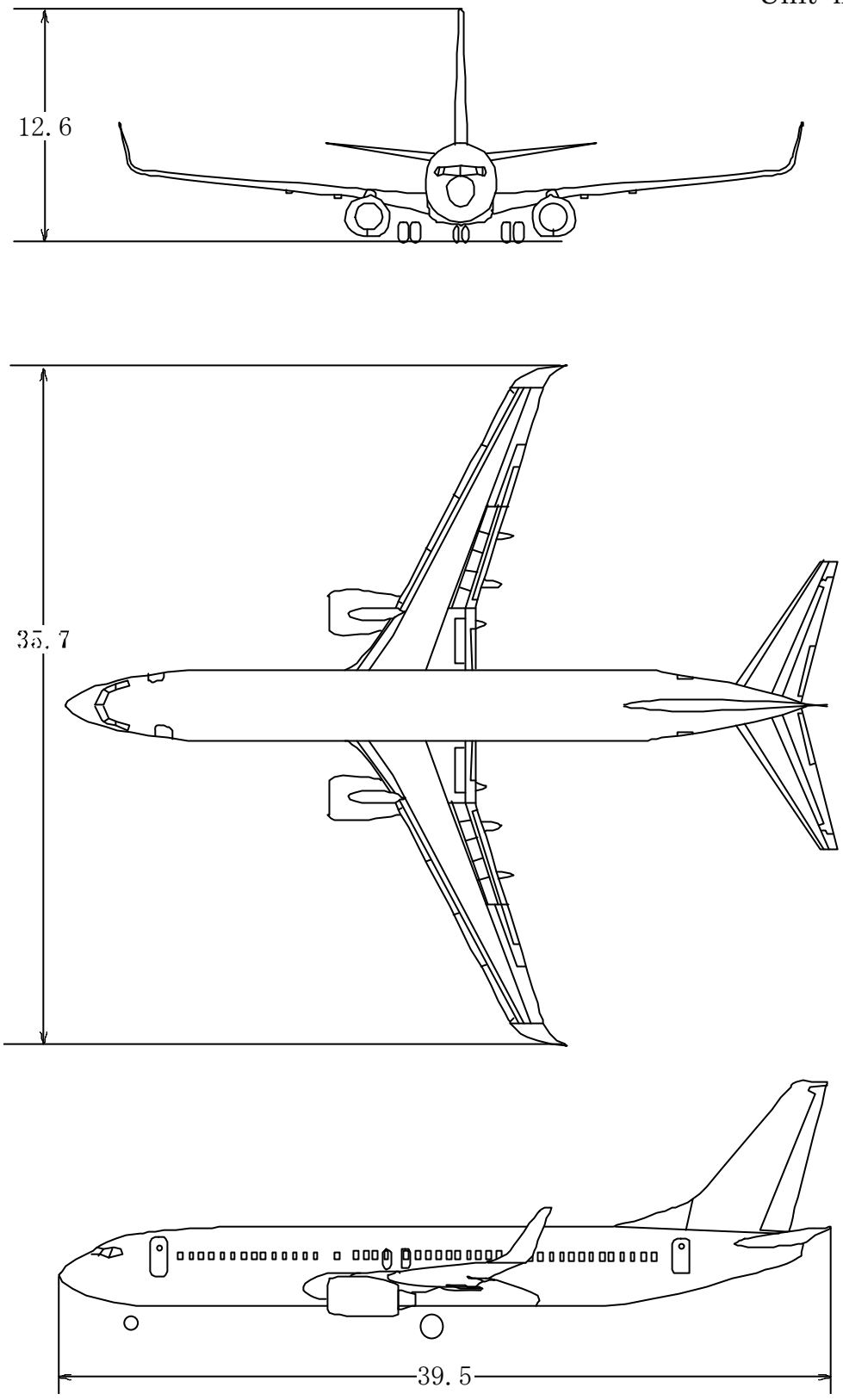


Figure 3　DFDR Records　(1)

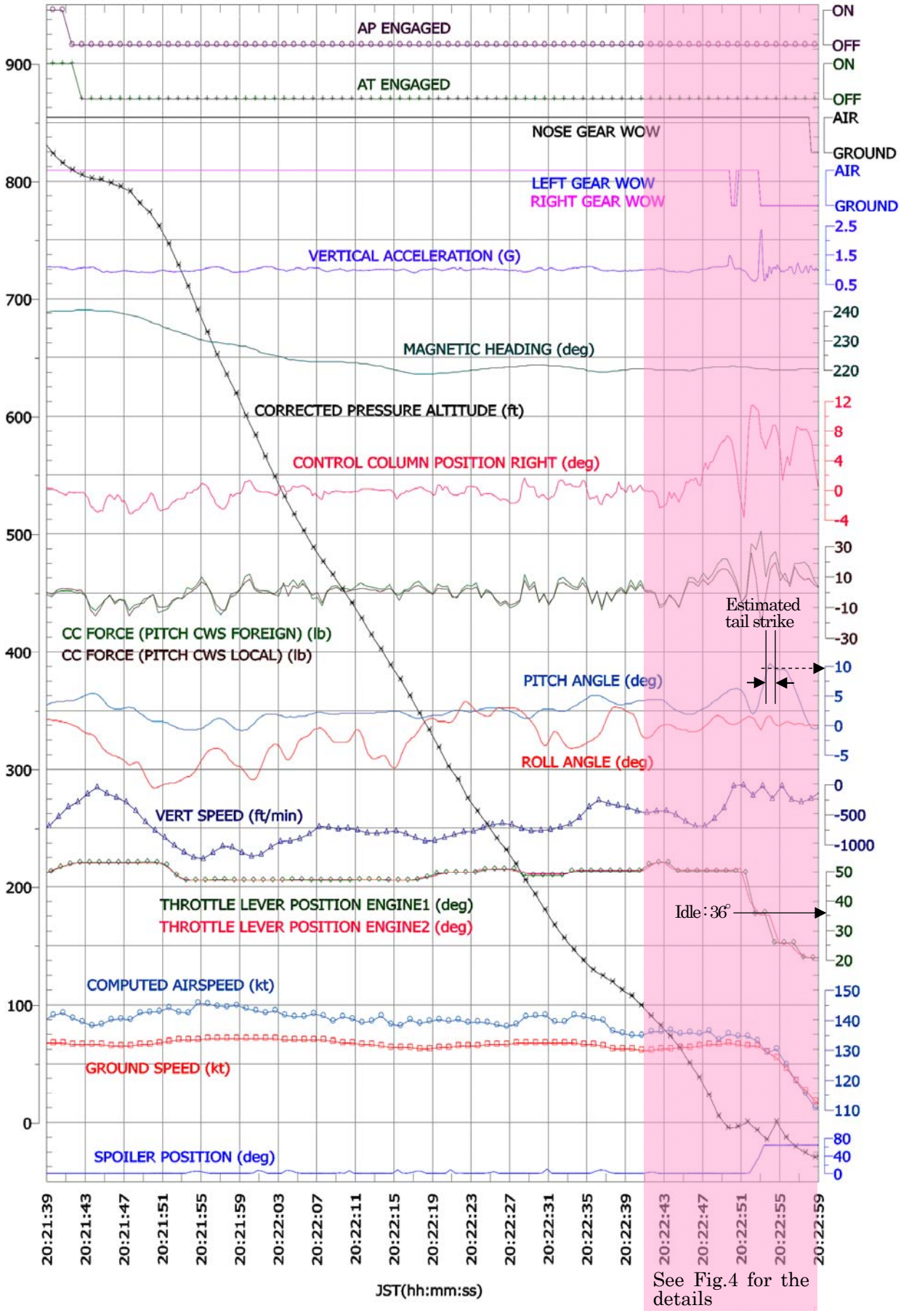
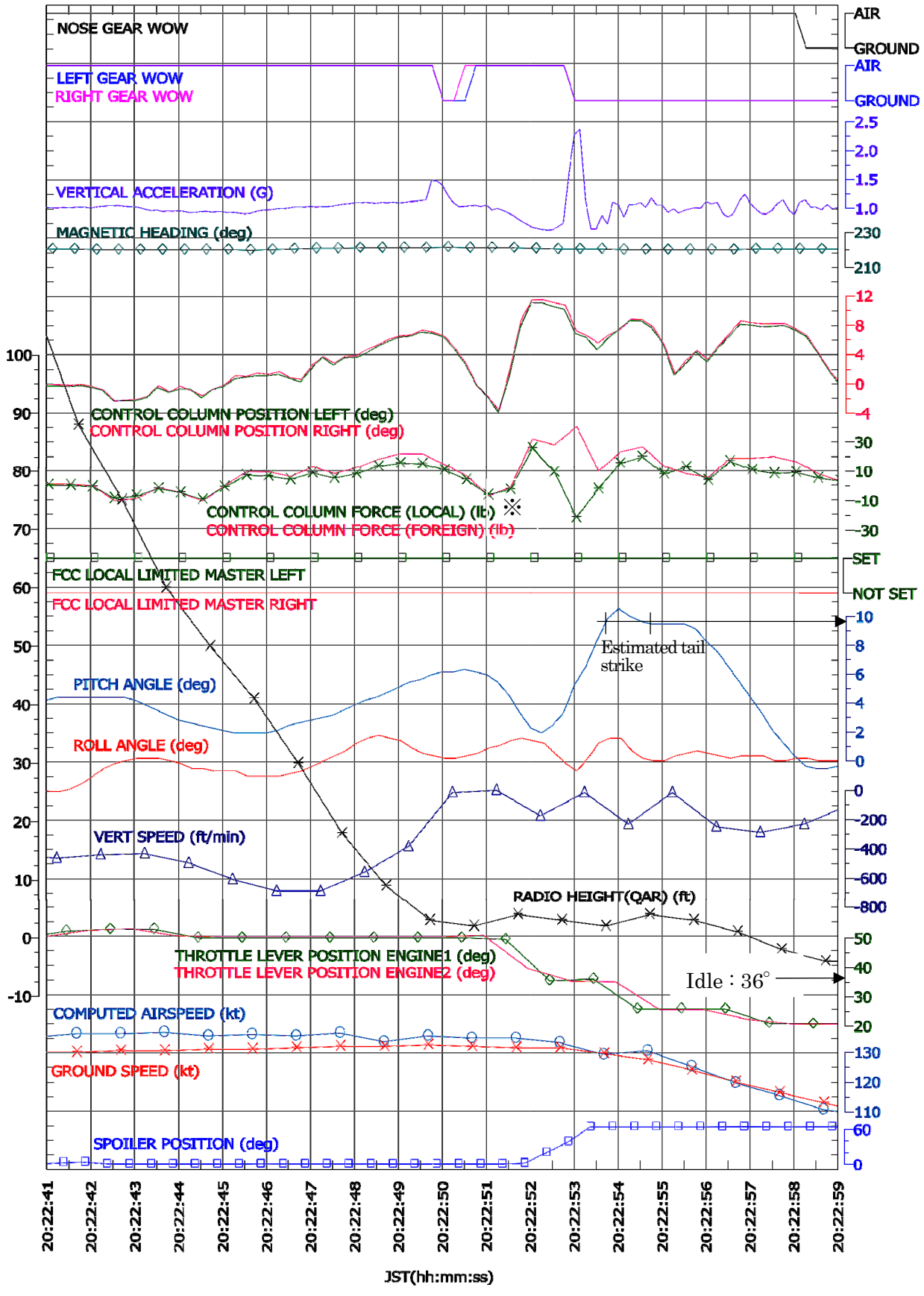
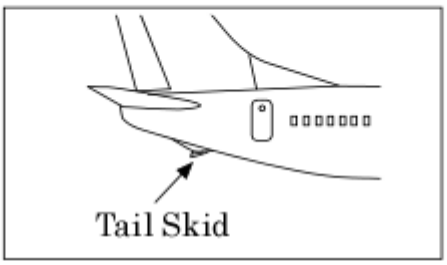


Figure 4　DFDR Records　(2)



Note　CONTROL COLUMN FORCE LOCAL applies to the left control column input while suffix FOREIGN to right control column input.

Photo 1　Damage on Tail Skid



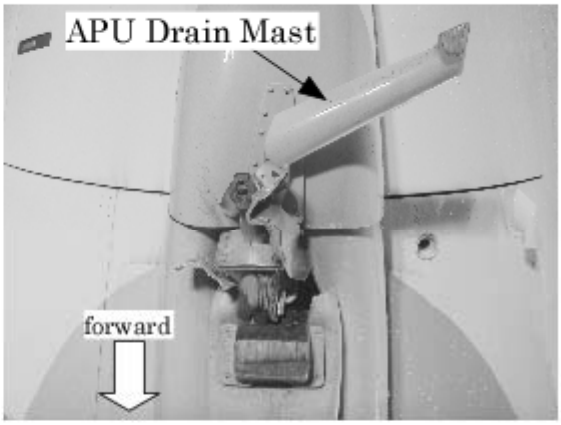


Photo 2　Damage on Fuselage