AA2013-4

AIRCRAFT ACCIDENT INVESTIGATION REPORT

FEDERAL EXPRESS CORPORATION

N526FE

April 26, 2013

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.

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

AIRCRAFT ACCIDENT INVESTIGATION REPORT

CRASH DURING LANDING
FEDERAL EXPRESS CORPORATION
MCDONNELL DOUGLAS MD-11F, N526FE
NARITA INTERNATIONAL AIRPORT
MARCH 23, 2009

April 5, 2013

Adopted by the Japan Transport Safety Board

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

SYNOPSIS

Summary of the Accident

On March 23 (Monday), 2009, about 06:49 local time*[1], a McDonnell Douglas MD-11F, registered N526FE, operated by Federal Express Corporation as the scheduled cargo flight FDX80, bounced repeatedly during landing on Runway 34L at Narita International Airport. During the course of bouncing, its left wing was broken and separated from the fuselage attaching point and the airplane caught fire. The airplane rolled over to the left being engulfed in flames, swerved off the runway to the left and came to rest inverted in a grass area.

The Pilot in Command (PIC) and the First Officer (FO) were on board the airplane, and both of them suffered fatal injuries.

The airplane was destroyed and the post-crash fire consumed most parts.

Probable Causes

In this accident, when the airplane landed on Runway 34L at Narita International Airport, it fell into porpoising. It is highly probable that the left wing fractured as the load transferred from the left MLG to the left wing structure on the third touchdown surpassed the design limit (ultimate load).

It is highly probable that a fire broke out as the fuel spillage from the left wing caught fire, and the airplane swerved left off the runway rolling to the left and came to rest inverted on the grass area.

The direct causes which the airplane fell into the porpoise phenomenon are as follows:

a. Large nose-down elevator input at the first touchdown resulted in a rapid nose –down motion during the first bounce, followed by the second touchdown on the NLG with negative pitch attitude. Then the pitch angle rapidly increased by the ground reaction force, causing the larger second bounce, and

b. The PF's large elevator input in an attempt to control the airplane without thrust during the second bounce.

In addition, the indirect causes are as follows:

a. Fluctuating airspeed, pitch attitude due to gusty wind resulted in an approach with a large sink rate,

b. Late flare with large nose-up elevator input resulted in the first bounce and

c. Large pitch attitude change during the bounce possibly made it difficult for the crewmembers to judge airplane pitch attitude and airplane height relative to the ground (MLG height above the runway).

d. The PM's advice, override and takeover were not conducted adequately.

It is somewhat likely that, if the fuse pin in the MLG support structure had failed and the MLG had been separated in the overload condition in which the vertical load is the primary component, the damage to the fuel tanks would have been reduced to prevent the fire from developing rapidly.

It is probable that the fuse pin did not fail because the failure mode was not assumed under an overload condition in which the vertical load is the primary component due to the

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*[1] Japan Standard Time (JST): UTC + 9hr, unless otherwise stated all times are indicated in JST on a 24-hour clock.

interpretation of the requirement at the time of type certification for the MD-11 series airplanes.

Safety Recommendations

On March 23 (Monday), 2009, about 06:49 JST (Japan Standard Time), a McDonnell Douglas MD-11F, registered N526FE, operated by Federal Express Corporation as the scheduled cargo flight FDX80, bounced repeatedly during landing on Runway 34L at Narita International Airport. During the course of bouncing, its left wing was broken and the airplane caught fire. The airplane rolled over to the left being engulfed in flames, swerved off the runway to the left and came to rest inverted in a grass area on the west side of the runway.

The airplane approached with a high sink rate, with its autothrottle "on" amid strong gusty winds and with unstable airspeed and attitudes. The late flare caused hard landing and the airplane bounced. Large nose-down elevator input just before and during the touchdown caused the second touchdown on the NLG with negative pitch attitude developing into porpoising. Upon the third touchdown, the left wing structure fractured because it surrendered to an overload transferred from the left MLG.

As a result of the investigation of this accident, the JTSB makes the following recommendations to the Federal Aviation Administration of the United States of America to take the following measures to prevent the recurrence of similar accidents.

Actions to Be Taken by the Federal Aviation Administration

a. Although the MD-11 airplane was certified to the requirement 14 CFR 25.721(a) under the interpretation at the time of certification, its design would not meet the present interpretation of the requirement since the design allows the possibilities of causing severe damage to the airplane structure in the failure mode under an overload condition where the vertical load is the primary component, resulting in the fire due to fuel spillage. As this kind of design should not be certified from now on, the airworthiness regulation rather than the guidance material should be revised to mandate the assumption of the overload condition in which the vertical load is the primary component.
b. Heat and smoke from the fire reached the cockpit at an early stage after the accident, making it difficult to initiate quick rescue activities from outside. In order to increase the crew survivability, studies about ways to separate the flight crew compartment from heat, smoke and toxic gas should be made, and if there are any effective solutions, the FAA should consider their application to in-service airplanes.

Measures to Be Taken to Supervise the Boeing Company as the airplane Manufacturer

Past MD-11 accident investigation reports pointed out that in case of the primarily vertical overload transferred from MLG to wing structures, the gear design allows the fire hazard as a result of the destruction of wing structure followed by fuel spillage. The Boeing Company has so far focused its efforts on improving flight control programs which are effective in lessening overloads and these efforts are positively appraised to some extent;

however, it’s not a fundamental solution. As the occurrences of vertical overload have been reported after this accident, the measures taken so far are not considered to be satisfactory.

The JTSB recommends that the Federal Aviation Administration require the Boeing Company to study the possibility of design change for the MLG support structure and matters mentioned below in order to prevent the recurrence of similar accidents and minimize damage to be caused by such accidents.

a. In order to reduce the occurrence of MD-11 series airplanes’ severe hard landing and bounce in which an overload is transferred to the MLGs and their supporting structure, the Boeing Company should improve the controllability and maneuver characteristics by improving the LSAS functions, reducing the AGS deployment delay time and other possible means.

   Possible improvement on LSAS functions may include: a function to limit large nose-down elevator input during touchdown phase, which is a common phenomenon in severe hard landing cases accompanied by structural destruction for MD-11; and a function to assist bounce recovery and go-around in case of bounce.

b. In order to help pilots to conduct recovery operation from large bounces and judge the necessity of go-around, studies should be made to install a visual display and an aural warning system which show gear touchdown status on MD-11 series airplanes.

Abbreviations used in this report are as follows:

AC : Advisory Circular
AFS : Auto Flight System
AGS : Auto Ground Spoilers
ALPA : Airline Pilot's Association
AMC : Acceptable Means of Compliance
AMM : Aircraft maintenance Manual
ATS : Auto Throttle System
CAS : Calibrated Airspeed
CAWS : Central Aural Warning System
CCP : Control Column Position
CFM : Company Flight Manual
CFR : Code of Federal Regulations
CST : Central Standard Time
CVR : Cockpit Voice Recorder
CWP : Control Wheel Position
DFDR : Digital Flight Data Recorder
EASA : European Aviation Safety Agency
ELF : Elevator Load Feel
EPR : Engine Pressure Ratio
FAA : Federal Aviation Administration
FCC : Flight Control Computer
FCOM : Flight Crew Operation Manual
FO : First Officer
FOM : Flight Operation Manual
FOQA : Flight Operations Quality Assurance
GACA : General Authority of Civil Aviation
GS : Glide Slope
HUD : Head-Up Display
ILS : Instrument Landing System
IRU : Inertial Reference Unit
JAXA : Japan Aerospace Exploration Agency
JST : Japan Standard Time
LASE : Low Altitude Stability Enhancement
LOC : Localizer
LOSA : Line Operations Safety Audit
LSAS : Longitudinal Stability Augmentation System
MAC : Mean Aerodynamic Chord
METAR : Aerodrome routine meteorological reports
MLG : Main Landing Gear
NLG : Nose Landing Gear
NTSB : National Transportation Safety Board
PAP : Pitch Attitude Protection
PAPI : Precision Approach Path Indicator

PF ：Pilot Flying
PFD ：Primary Flight Display
PIC ：Pilot in Command
PIREP ：Pilot Report
PM ：Pilot Monitoring
PMI ：Principal Maintenance Inspector
PNL ：Positive Nose Lowering
POI ：Principal Operations Inspector
PRD ：Pitch Rate Damper
RA ：Radio Altitude
RAAS ：Runway Awareness Advisory System
RNAV ：Area Navigation
RSPA ：Research and Special Programs Administration
S/O ：Second Office
SPECI ：Aerodrome special meteorological reports
TRA ：Thrust Resolver Angle
UTC ：Universal Time Coordinated
VASI ：Visual Approach Slope Indicator

Unit Conversion Table

1 nm ：1,852 m
1 ft ：0.3048 m
1 kt ：1.852 km/h (0.5144 m/s)
1 fps ：0.3048 m/s
1 G ：9.8 m/s^2
1 lb ：0.4536 kg
1 in ：2.54 cm
1 inHg ：3,386 Pa：345.3 kgf/m^2
1 psi ：0.07031 kgf/cm^2 (1ksi = 1,000 psi)

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1. PROCESS AND PROGRESS OF THE INVESTIGATION

1.1 Summary of the Accident

On March 23 (Monday), 2009, about 06:49 local time, a McDonnell Douglas MD-11F, registered N526FE, operated by Federal Express Corporation as the scheduled cargo flight FDX80, bounced repeatedly during landing on Runway 34L at Narita International Airport. During the course of bouncing, its left wing was broken and separated from the fuselage attaching point and the airplane caught fire. The airplane rolled over to the left being engulfed in flames, swerved off the runway to the left and came to rest inverted in a grass area.

The Pilot in Command (PIC) and the First Officer (FO) were on board the airplane, and both of them suffered fatal injuries.

The airplane was destroyed and the post-crash fire consumed most parts.

1.2 Outline of the Accident Investigation

1.2.1 Investigation Organization

a. On March 23, 2009, the Japan Transport Safety Board (JTSB) designated an Investigator-in-charge (IIC) and five investigators to investigate this accident.

b. The JTSB also designated two expert advisers to look into the following technical matters:

(1) For investigation into aircraft maneuver
Mr. Naoki Matayoshi
DREAMS Project Team,
Institute of Aeronautical Technology,
Japan Aerospace Exploration Agency (JAXA)
(He had been assigned for the other case. His assignment was extended for this case.)

(2) For investigation into airframe structure
Dr. Takeshi Takatoya
Structures Research Group,
Institute of Aeronautical Technology,
Japan Aerospace Exploration Agency (JAXA)
(He was designated on May 14, 2009.)

1.2.2 Representatives from Relevant States

An accredited representative and advisers of the United States of America, as the State of Design, Manufacture and the Operator participated in the investigation.

1.2.3 Implementation of the Investigation

March 23 to 29, 2009	On-site investigation
April 2, 2009	Interviews
October 19 to 26, 2009	Progress meeting (meeting with the relevant state about the fact-finding investigation) Verification using a flight simulator

March 22 to 26, 2010	Teardown investigation of the nose landing gear (NLG) and the left main landing gear (MLG)
October 26, 2009 to April 30, 2011	Flight maneuver analysis
October 26, 2009 to November 2, 2011	Structural analysis
November 8 to 9, 2011	Progress meeting
September 17 to 18, 2012	Exchange of opinions with the relevant States on the touchdown operation of the MD-11 airplane

1.2.4 Interim Report

On April 16, 2010, an interim report based on the fact-finding investigation up to that date was submitted to the Minister of Land, Infrastructure, Transport and Tourism (MLIT), and made public.

1.2.5 Comments from Parties Relevant to the Cause of the Accident

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

As the PIC and the FO had been deceased, their comments were not available.

1.2.6 Comments from the Relevant States

Comments were invited from the relevant State.

2. FACTUAL INFORMATION

2.1 History of the Flight

On March 23 (Monday), 2009, a McDonnell Douglas MD-11F, registered N526FE, operated by Federal Express Corporation (hereinafter referred to as "the Company"), took off from Guangzhou Baiyun International Airport (hereinafter referred to as "Guangzhou Airport") as the scheduled Flight FDX80 (a cargo flight) to Narita International Airport (hereinafter referred to as "Narita Airport").

The flight plan of the airplane was summarized as below:

Flight rules: Instrument Flight Rules (IFR)
Departure aerodrome: Guangzhou Airport
Estimated off-block time: 03:15
Cruising speed: 493 kt (913 km/h)
Cruising altitude: S1010[*2]
Route: Omitted – A593 (airway) – LAMEN (reporting point)
Cruising speed 498 kt
Cruising altitude FL290
Route – A593 (airway) – FU (Fukue NDB) – Y23 (RNAV route) – PERRY (reporting point) – Y231 (RNAV route) – VENUS (reporting point)
Destination aerodrome: Narita Airport
Estimated elapsed time: 3 hr 26 min
Alternate aerodrome Kansai International Airport
Fuel load expressed in endurance: 6 hr 03 min

The PIC and the FO were on board the airplane, and the PIC was seating in the left seat as the PM (the pilot monitoring: pilot mainly in charge of duties other than flying) and the FO in the right seat as the PF (the pilot flying: pilot mainly in charge of flying).

The history of the flight after the initiation of landing procedures on the final approach toward Runway 34L at Narita Airport was as follows, according to the records of digital flight data recorder (DFDR) and cockpit voice recorder (CVR), the records of images taken by a surveillance camera at the airport (hereinafter referred to as “Camera Images” recorded of 15 frames in every four seconds), and broadcasted video images (hereinafter referred to as “Broadcast Images”) as well as the air traffic control (ATC) communications records and the statements of air traffic controllers involved:

2.1.1 History of Flight According to DFDR CVR Records, Camera Images, Broadcast Images and ATC Communications Records

a. From the first communication established with the Narita Airport Traffic Control Tower aerodrome control station to the descent to 1,000 ft

06:41:35 The airplane called Narita Airport Traffic Control Tower aerodrome control station (hereinafter referred to as “Narita Tower”) and reported that it was 13 nm to Runway 34L.

[*2] Cruising level expressed by Standard Metric in tens of meters, expressed as “S” followed by 4 figures.

The airplane was flying with autopilot and auto throttle engaged.

06:41:39 Narita Tower informed the airplane that the runway in use was 34L and its landing sequence was second. It also informed the airplane that the wind was 320° at 28 kt (the maximum 40 kt and the minimum 20 kt) and instructed the airplane to continue its approach.

06:41:40 The FO instructed the PIC to perform a before-landing checklist.

06:41:51 The airplane read back the approach instructions to Narita Tower.

06:42:14 The FO asked the PIC about a speed additive to Vref (reference landing speed) to get Vapp (approach speed). The PIC gave a value of 10 kt as the additive. Vapp was set at 164 kt (Vref plus 10 kt).

06:42:32 The auto ground spoiler (AGS) was armed.

06:42:40 The flight crews confirmed AUTO BRAKE at MEDIUM and GEARDOWN FOUR GREEN.

06:43:57 Narita Tower provided the pilot report (PIREP) to the airplane that there was a windshear of plus or minus 15 kt on the final approach toward Runway 34L below 2,000 ft and added that the surface wind was 320° at 23 kt with the maximum 34 kt and the minimum 15 kt.

06:44:11 Responding to the wind information, the crews exchanged a conversation to the effect that the situation was not so bad due to near head wind.

06:44:50 The PIC advised the FO to check the windshear guidance and the FO checked it out.

06:45:16 Narita Tower informed the airplane that the surface wind was 320° at 26kt with the maximum 38 kt and the minimum 16 kt.

06:45:32 The FO instructed the PIC to set flap 35, and the PIC did the setting.

06:45:45 The PIC completed the before-landing checklist and called this out.

06:46:16 Narita Tower asked Flight NCA037, the preceding flight of the airplane, about the final approach conditions. It replied that it encountered fairly strong turbulence with wind fluctuations of plus or minus 15 kt below 1,000 ft.

06:46:29 Narita Tower issued a landing clearance for Runway 34L to the airplane and added that the wind was 320° at 29 kt with the maximum 36 kt and the minimum 17 kt and the QNH (altimeter setting) 29.56.

06:46:39 The airplane read back the landing clearance and the QNH.

b. From 1,000 ft radio altitude (RA) to AUTOPILOT OFF

The control column position (CCP) was fluctuating plus or minus 2° from -2°, generating the pitch angle change from -2° to 4°.

The engine pressure ratios (EPR) of the three engines were changing in ranges of 1.0 to 1.25, while the calibrated airspeed (CAS) in a range of 152 kt to 180 kt.

The control wheel position (CWP) was fluctuating more than 20°, generating the roll angle change of plus or minus 5°.

The rudder pedal input did not largely change while the heading changed within plus or minus 5° from 330°

The vertical acceleration was 1.4 G at about 800 ft and 700 ft, and 0.4 G at about 450 ft. But these vertical acceleration was not abrupt in nature.

The longitudinal acceleration was between +0.2 G and -0.1G, while its lateral acceleration was ±0.1 G.

06:46:53 Central aural warning system (CAWS) called 1,000 ft.

06:47:10 The PIC said, "Yee haw ride' em cowboy."

06:47:17 The runway awareness advisory system (RAAS) called an approach to Runway 34L.

06:47:40 CAWS called 500 ft.

It was flying with CAS 179 kt, heading 331°, pitch angle 1.8°. Its Glide Slope (GS) deviation was 0.09 dot and Localizer (LOC) deviation was -0.03 dot from the instrument landing system (ILS) course.

06:47:42 The PIC reconfirmed the runway 34L and called "stabilized" (followed by the recording of the PIC's laughter and the FO's response.)

It was flying with CAS 166.5 kt, heading 331°. The pitch angle was decreasing from 0.7° to -1.1°. ILS deviation was GS 0.16 dot and LOC -0.03 dot.

c. From AUTO PILOT OFF to 50 ft RA (Neutral column position was -2° during landing phase.)

06:48:03 CAWS announced "autopilot off." The indication of the radio altimeter (RA) was 198 ft.

CAS was 178.5 kt and its heading was 332°. The pitch angle was decreasing from 1.4° to 0.7°. ILS deviation was GS 0.19 dot and LOC -0.02 dot.

At 06:48:04 just after the autopilot was disconnected, the pitch angle temporarily decreased to 0.4°, but it soon began to increase and at 06:48:05, the angle returned to 1.8°. Around that time, the CAS decreased to 165 kt. The pitch angle continued to increase and at 06:48:09 it reached 3.5°. The CAS decreased to 157.5 kt.

The EPR was near 1.0, which indicated the idle power until 130 ft.

06:48:08 Narita Tower informed the airplane that the wind was 320° at 27 kt, with the maximum 34 kt and the minimum 18 kt.

06:48:11 CAWS called out 100 ft. The RA indicated 92 ft.

The airplane was flying with the CAS 154.0 kt, heading 331°, CCP -3°, pitch angle 3.5°, roll angle 0.7° to 1.1° and ILS deviation GS -0.54dot, LOC -0.10 dot.

Three EPR began to increase as the airplane descended through 130 ft. When CAWS called out 50 ft, each EPR value increased to 1.3.

As the airplane descended to 50 ft, the pitch angle decreased as low as 1.1°, while the CAS was increasing.

d. From 50 ft RA to the first touchdown on MLGs

At 06:48:15, CAWS called out 50 ft with RA 48 ft, CAS 161 kt, heading 333°, pitch angle 1.1°, roll angle -1.4° to -1.1°, and ILS deviation GS -1.11 dot, LOC -0.04 dot. From just before this moment until touchdown, the EPR was decreasing from 1.3 and reached 1.0 at the time when the altitude was less than 20 ft.


1 Passing through 50ftRA
6:48:15.6

(Note) The figure at the upper left corner of the indicates the number given to the 61 pieces of pictures "From about 50 ft Radio Altitude to Stoppage of aircraft" as shown in Attachment 3

At 06:48:17, the altitude dropped below 30 ft. The control column was slightly pushed forward (and the corresponding CCP changed from -2.5° to -0.7°, and to -3.0°), but this column input was not a distinctive one. The control wheel was also steered to the left. When the CCP was -3.0°, the CWP was -14.4°. At 06:48:18, when the altitude dropped below 20 ft, the pitch angle, which had been stable at 1.1° until then, decreased temporarily to 0.7°.


6 Passing through 30ftRA
6:48:17.0

At 06:48:18, the control column was pulled (CCP from 0.8° to 1.5°, to 1.2° and then to 1.1°) at 20 ft RA, and within the next one second the pitch angle started to increase (from 0.7° to 1.1° to 1.8° to 2.5° to 2.8° and to 3.5°) until around the touchdown. For about two seconds from 06:48:19 (just before the touchdown), the control column was pushed forward largely (CCP from 1.1° to -4.9°), while the pitch angle continued to increase from 4.2° to 4.6°. The airplane touched down on the right MLG at 06:48:20. A Camera Image showed white smoke spewing out from the right MLG tire. The CAS at the time of the touchdown was 166.0 kt (just after this, the CAS increased to 169.0 kt). The heading was 333° with the roll angle of 0.4°. The vertical acceleration recorded was 1.63 G (the G sensor was installed near the CG point). The Camera Images showed that airplane was relatively stable with no sign of being tossed abound by the winds. The Broadcast Image showed that the first touchdown was made near the runway threshold where a 60-meter-long runway aiming point marking is located.


10 Passing through 20ftRA
6:48:18.0


17 1st touchdown 6:48:19.9

The CAWS called out at every 10 ft from 50 ft to 10 ft RA. The interval between 20 ft and 10 ft was one second, while that of other calls were less than one second.

e. From the first touchdown to the second touchdown

After the first touchdown, the airplane bounced. The control column was pushed forward (CCP from -4.9° to -6.3°, and to -6.7° and -5.7°) for a very short period just before and after the touchdown, while the pitch angle continued to decrease from 4.6° to -1.8° during the corresponding period. When the airplane reached the highest point during the bounce, the pitch angle was 1.1°. According to a Camera Image, at around 06:48:21 when the MLGs left the ground during the bounce, the auto ground spoilers (AGS) started to deploy.

At 06:48:22, the airplane made the second touchdown in a nose-low attitude. The maximum value of the vertical acceleration recorded was 2.21G. The pitch angle when the NLG touched down was -1.8°. A sound of loud bang was recorded in CVR. The CAS at the time of the touchdown was 161.0 kt with the heading 331.9° and roll angle -0.4°. The EPR remained unchanged at 1.0.

f. From the second touchdown to the third touchdown

Another bounce followed the second touchdown. When the airplane bounced, the DFDR recorded a big 3Hz vibration with a damping tendency.

After the second touchdown


21 AGS deployed 6:48:21.0


22 1st bounce 6:48:21.2


24 2nd touchdown on NLG 6:48:21.8


25 2nd touchdown on MLGs 6:48:22.0


27 2nd bounce 6:48:22.6

on the MLGs, the ground spoilers were retracted, and the pitch angle increased to 6.7° in about one second (from 2.5° to 3.5° to 4.6° to 5.6° to 6.3° and to 6.7°). The control column forward input, which temporarily decreased (to -2.6°), increased again (from -2.6° to -4.3° to -7.5°).

During the second bounce, from 06:48:24 to 06:48:25, the control column forward input continued (-7.7° to -7.4° to -7.6°), and the pitch angle gradually decreased (6.7° to 6.3° to 5.6° to 4.9° to 3.5° to 2.5° to 0.7°).

At 06:48:25, the EPRs of the No. 2 and No. 3 engines increased to 1.1 from 1.0. When the pitch angle decreased to 2.5°, the airplane reached the highest bouncing point (16 ft). From 06:48:26 to 06:48:27 after reaching the highest bouncing point, the control column input became backward (from -1.1° to 1.6° and to 0.9°), but the pitch angle continued to decrease (from -1.1° to -2.8° to -3.9° to -4.6° to -4.9°).

g. From the third touchdown on

The airplane touched down again at 06:48:27 on the NLG, followed by the Left MLG, the Center MLG and the Right MLG. A recorded sound of loud bang was larger than that of the second touchdown. The EPRs of the No. 2 and No. 3 engines became 1.0. The CAS then was 157 kt-147 kt, with the pitch angle of -4.6° and the roll angle of -3.9°. The recorded vertical acceleration reached the maximum value of 3.06 G. The value was reduced to 1.97 G,


31 Pitch angle: at about6.7° 6:48:23.6


37 Highest bouncing point 6:48:25.2


39 Start of nose down 6:48:25.8


43 3rd touch down on NLG 6:48:26.8


44 Just after 3rd touch down (MLGs) 6:48:27.1


45 Fuselage twists to the right 6:48:27.4

increased again to 2.98 G. The maximum longitudinal acceleration which was recorded was 0.39 G backward, while the maximum lateral acceleration was 0.5 G to the left.

According to a Camera Image, when the NLG and the Left MLG touched down and the airplane sank, the left main wing greatly bent downward. When the Right MLG touched down, the fuselage was steered to the right. The left wing had been located to unusual position to the fuselage.

After the MLGs touched down, the pitch angle increased again (from 3.9° to 6.0° to 8.1° to 10.2° to 11.2°), while the roll angle to the left also increased (from -3.5° to -4.2° to -12.7° to -26.7°). The pitch angle decreased after reaching a peak of 11.2°, but the roll angle was recorded to increase as large as -140.3°.


48 Roll to the left 6:48:28.2

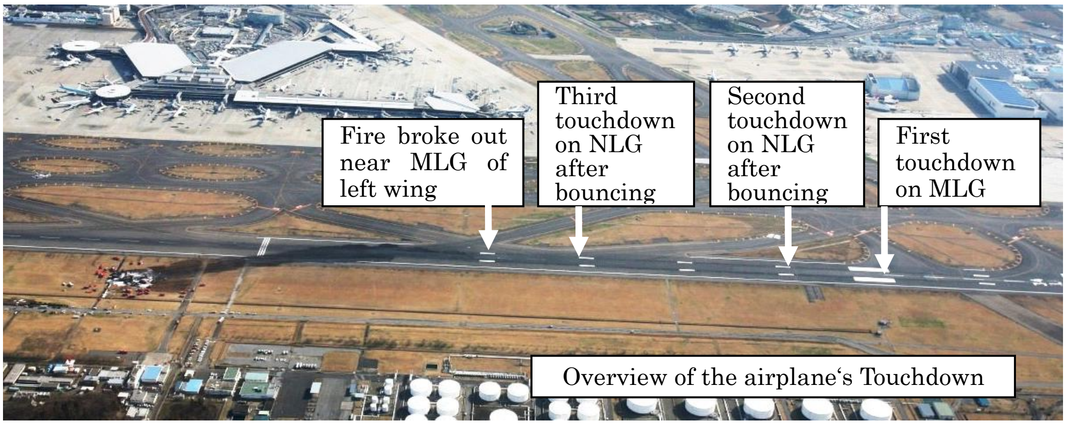

51 Fire break out 6:48:29.0


59 The airplane completely inverted 6:48:31.1

According to a Camera Image, a fire broke out near the rear of the left engine at 06:48:29. The pitch angle then was about 10°, while the roll angle was about -15°. The airplane was engulfed in flames. After further rolling over to the left, the airplane got inverted and swerved off to the left from Runway 34L to stop in the grass area.

The fire became stronger due to strong winds. The fire consumed the most part of the fuselage except the cockpit.

The vertical acceleration recorded in FDR was measured around the center of gravity.



Overview of the airplane‘s Touchdown

2.1.2 Statements of Air Traffic Controllers

a. Narita Tower Air Traffic Controller

The controller assumed his duties at the station at about 06:30. He started his jobs with communications with flight JAL710, two flights before the flight FDX80, and he provided the windshear information then obtained to the following flight NCA037. Because FDX80 had already switched to his frequency, the controller thought that its flight crew had heard the information, but to be on the safe side, he broadcast the information. When FDX38, which was the follow-on flight after FDX80, called the controller, he provided the same windshear information to FDX38. After the NCA037 landed, he asked its flight crew about the windshear conditions and he read back the information so that it may be heard by the crew of FDX80. Later, he issued a landing clearance to FDX80 with new QNH.

There was nothing unusual in communications with the airplane, but because he felt the airplane was in a level flight near the D taxiway before touchdown, he thought it may go around, but it landed. The situation after that was the same as shown in broadcasted TV images.

No windshear warning had been issued.

b. Deputy Chief Air Traffic Controller

FDX80 was approaching on the final approach toward Runway 34L and it didn’t appear unstable, compared to the airplanes approaching on the final toward Runway 34R. He tried to actively obtain the PIREP data and provide them to the airplanes.

Because he was watching the airplane landing, he immediately used the crash horn and took actions to have the following airplanes diverted.

He didn’t think the landing position of the airplane had been greatly different from the normal position.

(See Appendix 1: Estimated Flight Route, Appendix 2: Overview of Runways for Narita International Airport, Appendix 3-1 to 3-3: DFDR Records, Attachment 1: CVR Records, Attachment 2: ATC Communications Records, and Attachments 3-1 to 3-6: Camera Images From about 50 ft RA to Stoppage of Airplane)

2.2 Injuries to Persons

The PIC and the FO suffered fatal injuries.

2.3 Damage to the Airplane

2.3.1 Extent of Damage

Destroyed

2.3.2 Damage to Aircraft Components

The left main wing separated from the fuselage just inboard of the left MLG attaching point. The airplane came to rest inverted with the fuselage pointed to the landing direction. The fire consumed the most part of the airplane except the cockpit, right main wing, fuselage midsection, tail fuselage and part of the left main wing.

2.4 Other Property Damage

a. Seven runway lights (including Secondary Cable broken at four points) were broken.

b. Two runway centerline lights were broken.

c. Three centerline lights on the highspeed taxiway were broken.

d. There were traces of scratches and scoops on the runway surface and the landing area.

e. Spilled fuel and oil as well as the fire damaged the runway surface and the landing area.

f. The holding pond and the soil above buried pipeline etc were contaminated with spilled fuel and oil.

2.5 Personnel Information

2.5.1 Certificates and Flight Hours

a. PIC (Male, Age 54)

Airline transport pilot certificate (airplane)	April 4, 1989
Type rating for McDonnell Douglas MD-11	June 4, 2000
Class 1 aviation medical certificate	
Validity	September 30, 2009
Total flight time	8,132 hr 00 min
Flight time in the last 30 days	52 hr 26 min
Total flight time on the type of aircraft	3,648 hr 11 min
Flight time in the last 30 days	52 hr 26 min

b. FO (Male, Age 49)

Airline transport pilot certificate (airplane)	June 21, 1995
Type rating for McDonnell Douglas MD-11	October 10, 2006
Class 1 aviation medical certificate	
Validity	August 31, 2009
Total flight time	5,248 hr 00 min
Flight time in the last 30 days	28 hr 47 min
Total flight time on the type of aircraft	879 hr 13 min
Flight time in the last 30 days	28 hr 47 min

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2.5.2 Working Conditions of PIC and FO up to the Accident

2.5.2.1 Commuting from Residences to Anchorage

PIC's residence in the State of Oregon and the FO's in Texas made them commute to the Company's base in Anchorage, Alaska. Each of them had rented a commuter apartment in Anchorage, sharing it with another pilot of the Company.

It could not be determined how the PIC commuted to Anchorage. The FO commuted via FedEx jumpseat to Anchorage and details of his movement there to board the flight FDX80 was as follows:

He departed an airport in Texas on March 13 at 21:24 local time, (March 14, 03:24 UTC) and arrived at Memphis International Airport at 23:13 local time (March 14, 05:13 UTC). He departed Memphis International Airport on March 14 at 03:46 local time, (March 14, 09:46 UTC) and arrived at Anchorage International Airport on March 14 at

08:28 local time (March 14, 16:28 UTC).

2.5.2.2 Flights from Anchorage to the Occurrence of the Accident and Previous 72-Hour Activities for the PIC and FO

The PIC and the FO were paired for sequence of flights from Anchorage consequently ended up in the accident.

a. The show-up time at Anchorage International Airport was at 09:55, March 15 local time (March 15, 17:55 UTC).

b. They departed Anchorage at 10:48 local time (18:48 UTC) the same day and arrived at Narita Airport at 11:16 local time (02:16 UTC), March 16.

The flight duty hour was 8 hr 51 min and the flight time was 7 hr 28 min. The rest layover time was 34 hr 44 min.

c. On March 17, they departed Narita Airport at 21:59 local time (12:59 UTC) and arrived at Guangzhou Airport at 01:45 local time, March 18 (17:45 UTC, March 17).

The flight duty hour was 6 hr 15 min and the flight time was 4 hr 46 min. The rest layover time was 26 hr 00 min.

d. On March 19, they departed Guangzhou Airport at 03:58 local time (March 18, 19:58 UTC) and arrived at Penang International Airport via Kuala Lumpur at 09:41 local time (01:41 UTC).

The flight duty hour was 7 hr 26 min and the flight time was 4 hr 40 min. The rest layover time was 28 hr 19 min.

e. On March 20, they departed Penang at 13:56 local time (05:56 UTC) and arrived at Clark International Airport, Philippines via Taipei at 22:20 local time (14:20 UTC).

The flight duty hour was 9 hr 50 min and the flight time was 6 hr 04 min. The rest layover time was 48 hr 10 min.

The PIC and the FO both telephoned their families. An FO's family member stated that he sounded good.

f. The PIC and FO had several periods of no documented activity from checking in on March 20 until checking out on March 22. The longest period of no documented activity for the PIC was 10 hours 34 minutes, between 19:15, March 21, and 05:49, March 22 local time. The longest period of no documented activity for the FO was 11 hours 23 minutes, between 18:55, March 21, and 06:18, March 22 local time.

g. On March 22, the period of no documented activity for the PIC was 4 hours and 38 minutes, between 14:40 and 19:18 local time. The periods of no documented activity for the FO were 2 hours and 28 minutes between 08:15 and 10:43, 2 hours and 49 minutes between 11:05 and 13:54, and around 3 hours between 16:40 and 19:57 when the FO was sighted at the reception desk.

After that, the PIC and FO departed Clark International Airport at 21:44 local time (13:44 UTC) and arrived at Guangzhou Airport at 23:48 local time (15:48 UTC). The flight time was 2 hr 04 min. They departed Guangzhou Airport 2 hr and 18 min later on March 23, at 02:06 local time (March 22, 18:06 UTC). The estimated arrival time at Narita Airport was 06:53 local time (March 22, 21:53

UTC). According to a family member of the PIC who received his telephone call from Guangzhou Airport, he sounded normal.

(See Attachment 5-1 and 5-2: Working Conditions of the PIC and the FO)

2.5.3 Medical History

a. PIC

He started to feel pain in the sacrum in August 2008 and took extended sick leave for treatment from October 2008 to February 2, 2009. He submitted a medical certificate on January 29, 2009 stating that he had made a full recovery.

He was on medication for cholesterol and hyperlipidemia and both drugs are authorized in the aviation medical examination.

b. FO

He had an ankle bone fracture in 1995 and received a knee surgery in 2002. He had passed the aviation medical examination.

He was on medication for hyperlipidemia and the drug is authorized in the aviation medical examination.

2.5.4 Physical Conditions of PIC and FO

The physical conditions of the PIC and the FO during the flight from Clark International Airport to Guangzhou Airport as the flight leg just before the occurrence of the accident was as follows, according to the two captains who boarded the airplane on the cockpit jumpseats:

During the flight, the PIC performed duties as the PF and the FO as the PM. The PIC made the best possible landing. Both of them were very proficient and they interacted well together during the flight.

There were no remarks or behaviors related to fatigue. One captain heard about the PIC's back pain, but the PIC appeared healthy and the PIC's back didn't appear bothering him. Summarized statements of other persons on the physical conditions of the PIC and the FO, are as follows:

a. PIC

According to a line check airman who flew along with the PIC on February 22, the PIC did not complain of back pain during the flight at that time, but he left his seat twice to stretch himself out during their six or seven hour flight.

According to another line check airman who flew along with the PIC on February 27 and 28, the PIC regularly stood up to stretch out during the long flight.

According to the PIC's spouse, he usually slept for eight hours when he was off duty for an extended period of time, and he had no sleep disorder like insomnia and apnea. Although, sometimes, he apparently got tired while he was on flight duties accompanied with an overnight stay, she thought he got enough rest. His physical condition was fine and he did not complain of symptoms of illness.

On the day before the accident, the PIC spoke with the PIC's spouse that he had planned to go to bed by 15:00 to rest for his upcoming flight.

b. FO

According to his spouse, he did not complain of the old injury in the knee and his physical condition was fine.

The FO usually slept for eight hours when he was off duty for an extended period of time. He had no sleep disorder like insomnia, but when he returned home from the trip to Asia, he apparently had difficulty in sleeping for one or two days, perhaps because of changes in the sleep pattern during his job.

About 45 minutes before the occurrence of the accident, the FO told the PIC that they knew they were both tired, and the PIC replied yes. Then the FO told the PIC that, if it was real quiet, make some noise, and the PIC replied yes.

2.5.5 Possession of Medicines

The following medications were found from the PIC's personal effects, but no medicines were found from those of the FO:

Zolpidem	A non-benzodiazepine sleeping medicine (a sleep inducing medicine with very short-term effect; effects carried over to the next morning are limited)
Sonata	A non-benzodiazepine sleeping medicine
Watson 825	Acetaminophen/oxycodone (Pain-killer belongs to combined medicine of medicine-class narcotic analgesic)
Mylan 345	A benzodiazepine anti-anxiety medicine (long-term type) A benzodiazepine general anesthetic medicine (very short-term type)
Excedrin Back and Body	A non-steroidal anti-inflammatory drug, an antipyretic analgesic medicine
Motrin IB	An antipyretic analgesic medicine

There were other substances which were not identified

2.5.6 Autopsy Results and Criteria of Medicine Use

a. PIC

(1) Blood

The blood tested positive for Lidocaine, possibly originating from a medical treatment applied when he was rescued.

(2) Urine

Substances detected in the PIC's urine

- Benzodiazepine
- Ibuprofen
- Temazepam (a benzodiazepine derivative)

(3) Cause of death: Thoracic organ damage

b. FO

(1) His blood and urine tested negative for therapeutic medicines.

(2) Cause of death

Systemic burns with burns of the respiratory tract. (Primary shock due to the exposure to high temperature and acute respiratory failure due to burns of the respiratory tract)

c. Criteria of Medicine Use

(1) The Federal Aviation Administration (FAA) allows a pilot to fly after taking acetaminophen, aspirin and/or ibuprofen provided there are no side-effects and the underlying medical condition doesn't interfere with the safe performance of flying duties.

(2) The FAA doesn't allow a pilot to take oxycodone, diazepam (Valium), or temazepam on a regular basis; however, the FAA allows a pilot to use these medications on an occasional basis (defined as less than twice a month).

This guidance presumes that there are no prolonged side-effects from the medication and the underlying condition for which the medication was taken does not interfere with the safe performance of flying duties.

Once taken, a pilot has to wait at least five dosing intervals of the medication before operating an aircraft.

2.5.7 Periodic Training and Others

a. PIC

He missed an opportunity of scheduled training during his extended sick leave. But he received requalification training when his sick leave ended. In the proficiency check on February 15 and 16, 2009, he performed landings, go-arounds and other subjects in cross winds of 25 kt, and he successfully passed the check.

He received Bounce Recovery Training on August 20, 2006.

b. FO

He had received scheduled training as prescribed in the Company's rules.

In the proficiency check on October 17, 2008, just like the PIC, he performed landing, go-arounds and other subjects in cross winds of 25 kt, and he successfully passed the check.

He received Bounce Recovery Training on September 13, 2006.

2.6 Airplane Information

2.6.1 Airplane

Type	McDonnell Douglas MD-11F
Serial number	48600
Date of manufacture	November, 1993
Certificate of airworthiness	October 21, 2004
Validity	(As long as the Company maintenance policy applies)
Category of airworthiness	Airplane Transport T
Total flight time	40,767 hr 00 min
Total cycles	7,131 cycles
Flight time since last periodical check	
(A check (every 250 flight hours) on March 21, 2009)	7 hr 00 min

The airplane was initially manufactured as a passenger airplane, but it was modified into a cargo plane on July 25, 2006.

(See Appendix 4: Three Angle Views of McDonnell Douglas MD-11)

2.6.2 Engines

Type : Pratt and Whitney PW4462 turbofan engines

Engine position	No.1	No.2	No.3
Serial number	P723953	P723836	P723955
Date of manufacture	December 1992	November 1990	December 1992
Total time	51,219 hr	53,828 hr	35,165 hr
Total cycles	7,046	8,073	5,696

The total time since the last periodical check (A check (every 250 flight hours) on March 21, 2009) was 7 hr 00 min.

2.6.3 History of Airplane Maintenance and Repair Work

The airplane was one of the Company's McDonnell Douglas MD-11F fleet. The airplane had been maintained under a maintenance program authorized by the FAA. The maintenance records show that the airplane underwent a C check (every 6,000 flight hours or every 18 months) on November 9, 2007 with its total flight time of 40,262 hours. The next C check was scheduled on May 7, 2009. The airplane received an A check (every 250 flight hours) on March 21, 2009 with its total flight time of 40,760 hours. The maintenance records covering the last 30 days before the accident included a carried-over repair item. A temporary repair work was done with aluminum alloy tape to cover a hole with a diameter of 1/4 inch created in the left inside fillet of the No. 1 slat. The permanent repair was planned to be made on the occasion of the next B check (every 650 flight hours: scheduled on April 10, 2009).

On May 19, 1999, the airplane, belonging to a different airline, flew a ferry mission and landed at Cambridge Airport (the United Kingdom) at 00:53 UTC. When the airplane began to lower its nose after touchdown, it encountered uncommanded nose-up. As the captain was unsure whether the airplane was still on the runway as he considered the runway was too short and stopping within the remaining distance, he executed a go-around. During the course of the maneuver it had a tail strike. The repair records on this incident had no remarks on major repair works other than that for the lower aft fuselage (Fuselage Station 1862 to Fuselage Station 2047).

2.6.4 Weight and Balance

When the accident occurred, the airplane's weight was estimated to have been 405,120 lb and the center of gravity (CG) was estimated to have been 30.9 % mean aerodynamic chord (MAC), both of which were estimated to have been within the allowable ranges (the maximum landing weight of 481,500 lb, and the CG range of 12.6 to 34.0 % MAC corresponding to the weight at the time of the accident).

2.6.5 Remaining Fuel at the Time of Landing

The estimated remaining fuel for the airplane at the time of the accident was about 28,000 liters.

2.6.6 Flammable Liquids on Board

The airplane had about 400 kg of onboard flammable liquids. Major liquids are as follows:

Polysilazane	75 units of 5.0-liter container
Ethanol	2 units of 7.5-liter container

2.6.7 Natural Frequency of Fuselage Structure

The airplane manufacturer stated that the first bending frequency in the longitudinal axis of the fuselage structure for the McDonnell Douglas MD-11 Series is approximately 3 Hz.

2.7 Meteorological Information

2.7.1 General Weather Outlook

The Asia-Pacific surface analysis chart for 21:00 on March 22 depicted that a low pressure system at 990 hPa in Hokkaido was moving to the northeast at 35 kt, while a cold front from this low pressure system was extending to the middle of Honshu. Another low pressure system at 996 hPa was moving to the east-northeast in the Tokai region with the cold front extending to the sea south of Japan. The areas around Japan were covered by a pressure trough. Meanwhile, a high pressure system near Lake Baikal at 1,034 hPa was moving to the southeast at 15 kt. Its influence spread toward the south, from the Yellow Sea to the East China Sea.

The Asia-Pacific surface analysis chart for 09:00 on March 23 depicts that the low pressure system located over Hokkaido in the surface analysis chart for 21:00 on March 22 had moved near Sakhalin and deepened to 988 hPa with an occluded front and a cold front extending from the east of Hokkaido to the sea east of the Tohoku region. The low pressure system which had been over in the Tokai region had also moved to the sea east of Japan and had deepened to 992 hPa. A cold front extending from this low pressure system also reached the sea east of Japan. Meanwhile, the high pressure system located near Lake Baikal in the surface analysis chart for 21:00 on March 22 had also increased to 1,040 hPa. The pressure trough which had previously covered the areas around Japan moved away to the east, resulting in the winter-type pressure pattern with an increased pressure gradient over Japan with northwesterly winds over Japan.
(See Appendix 5: Asia-Pacific Surface Analysis Chart)

2.7.2 METAR & SPECI for Narita Airport Relevant to the Time of the Accident

06:00 Wind direction 300°, Wind velocity 13 kt, Gust 28 kt / 03 kt,
Wind direction variable 260°-330 °,
Visibility 10 km or more
Clouds Amount FEW, Type Cumulus, Cloud base 2,000 ft,
Temperature 13 °C, Dew point -1 °C,
Altimeter setting (QNH) 29.48 inHg,

06:08 Wind direction 310°, Wind velocity 25 kt, Gust 35 kt / 16 kt,
Visibility 10 km or more,
Clouds Amount FEW, Type Cumulus, Cloud base 2,000 ft
Temperature 12 °C, Dew point -1 °C,

Altimeter setting (QNH) 29.49 inHg

06:30 Wind direction 320º, Wind velocity 26 kt, Gust 40 kt / 13 kt,
Visibility 10 km or more,
Clouds Amount FEW, Type Cumulus, Cloud base 2,000 ft,
Temperature 12 ºC, Dew point -2 ºC,
Altimeter setting (QNH) 29.52 inHg,
Windshear Runway 34L,
P/RR (pressure / rising rapidly)

06:50 Wind direction 310º, Wind velocity 27 kt, Gust 39 kt / 16 kt,
Visibility 10 km or more,
Clouds Amount FEW, Type Cumulus, Cloud base 2,000 ft,
Temperature 12 ºC, Dew point -2 ºC,
Altimeter setting (QNH) 29.56 inHg,
P/RR (pressure / rising rapidly)

On the day of the accident, strong northwesterly winds were blowing. It died down late at night.

2.7.3 Wind Observed by Doppler LIDAR (Light Detection and Ranging)

A Doppler LIDAR is a system which observes the wind velocity, wind velocity variation and other parameters by monitoring floating aerosol (dust particles in the atmosphere, etc.). It rotates its head scanning laser beams at prescribed elevation angle and bearing (Elevation angles of 1°, 2°, 3° and 45° in all directions, and elevation angles from 0° to 90° to the bearing of 336° comprise one pattern, and this pattern is repeated in 2 minutes and 30 seconds).

The Doppler velocity is a wind component associated with the location of the Doppler LIDAR as the observation point. The cold colors represent the wind components toward the LIDER site, while the warm colors represent away from the site. An area where the wind direction and the laser beam cross almost perpendicular is indicated in white due to the absence of wind components to and away from the observation point.

A shear line represents a boundary where the wind velocity difference of both sides of the shear line exceeds 5 m/s.

Airspaces which require to particularly cautious about windshear are established to cover a runway and neighboring area as detection area; 3 nm from the approach runway end and 2 nm from the departing runway end, laterally 1 nm on either end of the runway, at a height of less than 1,600 ft. In case of a windshear of 20 kt or more, a low level windshear information is issued for air traffic control and other related organizations.

The wind velocity variation indicates the degree of wind disturbance in a given space by observing the direction and the speed of aerosol. The variation becomes zero when the movement of the whole aerosol in the space is uniform, but when a strong wind (a gust) blows instantaneously, the variation grows larger. Therefore, the areas where the variation exceeds 7 m/s (red ellipses in Appendices 7-1 and 7-2) is detected are shown as TURB (turbulence).

The Doppler velocity, the wind velocity variation and TURB at Narita Airport around the time of the accident were as follows:

a. Doppler velocity (Elevation angle 2°) and shear line

Doppler velocity observation data between 06:40:45 and 06:48:08 depicted that a cold color area, representing a wind component toward the LIDAR site, prevailed on the northwestern side of the LIDAR and a warm color area, representing a wind component away from the site, prevailed on the southeastern side.

According to the analytical chart for 06:40:45, northwestern winds exceeding 15 m/s were observed at the center, and as time passed the winds at the center weakened to 10-15 m/s. Around the final approach course of Runway 34L, 15-20 m/s of winds were observed, and the velocity remained unchanged.

No shear line was observed around the final approach course of Runway 34L. No low level windshear information was issued, either.

b. Wind velocity variation and TURB

The wind velocity variation data for 06:40:45 and 06:48:08 depicted that the number of red dots with the variation of 7 m/s or more, most of which prevailed over the runway around the LIDAR site, became smaller as time passed. Yellowish green dots with the variation of 4 to 5 m/s occupied most of the Runway 34L final. Yellow and orange dots with the variation of greater than 5 m/s occupied small portion of the area at 06:40:45, while red dots partially emerged at 06:45:40.

A red ellipse shows an area of TURB. Numbers of red ellipses were observed over Runway 34L throughout the relevant time. On Runway 34L final, TURBs (t07: maximum variation 9 kt) was detected near TH (threshold) at 06:45:40, while it became smaller in size at 06:48:08.

(See Appendices 6-1, 6-2: Doppler Velocity and Shear Line (Elevation Angle 2°), Appendices 7-1, 7-2: TURB (Turbulence) (Elevation Angle 2°), Appendix 9: Glide Path of the Airplane and the Shooting Angle of the Doppler LIDAR Laser)

2.7.4 Instantaneous Wind Direction and Wind Velocity

The wind direction remained stable— generally from the northwest, while the velocity fluctuated widely and tended to gradually increase, with the gusts of about 40 kt between 06:30 and 07:00.

Wind profile from 06:48:00 to 06:48:21, just before the landing of the airplane, depicted the wind direction varying from west-northwest to northwest, and the varying wind velocity from 25 kt to 36 kt, with instantaneous wind velocity of 33 kt at 06:48:18, 2 seconds before the landing.

(See Appendix 8: Instantaneous Wind Direction and Wind Velocity over Runway 34L area)

2.7.5 Wind Information Collected by Narita Tower

Narita Tower had foreseen turbulence from the wind condition in the morning of the accident, and collected the following information separately from each arriving airplane concerning winds and windshear on Runway 34L final approach course, and disseminated it to other arriving airplanes and sent it as PIREP at 06:16 to meteorological and other organizations:

06:02	QFA21	Wind fairly gradual decrease, 50 kt indicated at 2,000 ft and mostly 30 kt on the approach. No windshear on final.

06:12	THA640	Fluctuating.
06:16	JAZ718	Below 10,000 ft plus minus 15 kt. Rough air at 500 ft and below, till touchdown
06:19	JAL6524	Plus minus 10 kt below 1,000 ft.
06:22	JAZ472	At 2,000, 320° 50 kt.
06:25	JAZ472	Below 1,000 ft plus minus 10 kt.
06:27	NCA007	Just a lot of rolling. Plus minus 15 kt.
06:32	NCA228	Plus 15, maybe sometimes 20, minus 10. Below 1,000.
06:41	JAL710	Below 2,000 ft plus minus 15 kt.
06:46	NCA037	Really rough, plus minus 15 kt, below 1,000.

The predictive type and reactive type windshear warning devices were onboard flights NCA007, NCA228 and NCA037; no warning was issued.

2.7.6 Relations between Information Mentioned in 2.7.5 and the Airplane in View of ATC Communications Records

At 06:42, the airplane called Narita Tower at 13 nm on the final to Runway 34L. The airplane received the information that the wind then was 320° 28 kt, with the maximum 40 kt and the minimum 20 kt.

Later, Narita Tower informed other airplane that the wind was 320° 29 kt, with the maximum 40 kt and the minimum 20 kt, and provided the PIREP from a Boeing 747 (Below 2,000 ft, wind velocity variations plus or minus 15 kt) at 06:41.

At 06:44, Narita Tower broadcasted the PIREP information from the Boeing 747 at 06:41 saying that it encountered a windshear on Runway 34L below 2,000 ft and wind velocity variations were plus or minus 15 kt, adding that the wind condition then was 320 ° 23 kt, with the maximum velocity of 34 kt and the minimum 15 kt.

At 06:46, Narita Tower received a report about the condition of the final approach course from NCA037. Then Narita Tower cleared FDX80 to land on Runway 34L, adding that the wind was 320° 29 kt with the maximum 36 kt and the minimum 17 kt. The airplane read back the landing clearance and acknowledged the wind information by replying "Copy that."

At 06:48, Narita Tower informed FDX80 that the wind was 320° 27 kt with the maximum 34 kt and the minimum 18 kt.

(See Attachment 1: CVR Records, Attachment 2: ATC Communications Records)

2.8 Air Navigation Facilities

At the time of the accident occurrence, the instrument landing system (ILS) and the precision approach path indicator (PAPI) for Runway 34L at Narita Airport were functioning normally.

2.9 DFDR and CVR

The airplane had been equipped with a DFDR (part number: 980-4700-001) made by Honeywell of the United States of America and a CVR (part number: 175497-01-01) (To be precise, it was CVFDR (Combined Voice and Flight Data Recorder). This is an integrated flight recorder with both functions of DFDR and CVR. Because it had been used only as a

CVR aboard the airplane, the device is described as “CVR” in this report.) made by GE Aviation of the United States of America.

The DFDR retained data from the time when the airplane took off from Guangzhou Airport to the accident at Narita Airport.

The time was determined by correlating the VHF transmission keying signals in the DFDR with the NTT speaking clock recorded on the ATC communications records.

The CVR was a 2-hour type and it retained voices at the time when this accident occurred.

The past flight records left in the airplane’s data server were also used for this report.

Photo 1 DFDR and CVR

2.10 Information about Aircraft Wreckage and Traces

2.10.1 Distribution of Wreckage and Traces

The airplane wreckage and debris widely scattered covering the runway and the grass areas on left and right (west and east) either side of the runway. The fuselage came to rest inverted about 60 m to the west of the runway centerline, about 1,430 m from the runway 34L threshold, with the nose directing to the northwest. The left wing was located next to the east of the fuselage. The left wing separated from the fuselage and its winglet separated, with its lower surface on the ground. Other components and structural parts separated from the airplane were scattered along the fuselage skid marks from the runway. Northwesterly strong winds blowing on the accident day pushed some part of the wreckage (flat light weight debris) leeward.

The wreckage of the airplane had been scored by the fire that occurred at the time of the accident. The fuselage had been connected from nose to tail; however, the fuselage and right wing for the most part had been destroyed by fire.

Details are as follows: (Figure 1)

a. In the vicinity of the first touchdown point

At 300 m from the threshold, there were touchdown marks of the MLG tires astride the runway centerline.

b. In the vicinity of the second touchdown point

(1) At 475 m from the threshold near the runway centerline, there were traces of grease from the NLG.
(2) At 513 m to 596 m from the threshold near the runway centerline, there were a hub cap, grommet, gasket and strap from the NLG.
(3) At 565 m from the threshold near the runway centerline, there were four pieces of NLG components (a band, wiring, etc.).
(4) At 596 m from the threshold on the left side of the runway, there was a NLG wheel cap.
(5) At 700 m from the threshold on the left side of the runway, there was a fragment of the left inboard flap.

c. At 795 m from the threshold on the right side near the runway centerline, there were two nose tire rubber marks (9.6 m on the right and 8.85 m on the left) followed by two tire wheel scratch marks (10 m on the right and 27.8 m on the left).

d. At 814 m from the threshold near the runway centerline, there were scrape mark (8.9 m by 0.9 m) by the left engine cowl.

e. At 875 m from the threshold on the right side of the runway centerline, there were three pieces of NLG components (grommet, etc.).

f. At 877 m from the threshold near the runway centerline, there was a 79 m-long scrape mark. Parallel with this mark on the right side of the runway centerline, there was a 14.5 m-long scrape mark. On the left side of the runway centerline, there were grooves and fragments of engine fan blades.

g. On A5 and A6 taxiways and near their crossings to the taxiways, there were fragments of the nose wheel and flap, and one NLG tire.

h. At 1,115 m from the threshold on the right side of the runway, there were parts of the fuselage structure.

i. At 1,130 m from the threshold in the grass area to the right of the runway, there was the other NLG tire.

j. At 1,250 m from the threshold on the left side of the runway, there were fragments of the horizontal stabilizer.

k. At 1,350 m from the threshold in the grass area to the left of the runway, there were fragments of the left wing scattered around, and there were a fragment of the vertical stabilizer on the left side of the runway.

l. At 1,400 m from the threshold in the grass area to the left of the runway, there were the rear parts of the fuselage including the No. 2 engine.

m. At 1,450 m from the threshold in the grass area to the left of the runway, there was the nose section.

n. Fuel and oil discharged from the airplane spread over the runway with a length of 210 m and a width of about 50 m, and in the grass area with a length of 230 m and a width of 30-60 m.

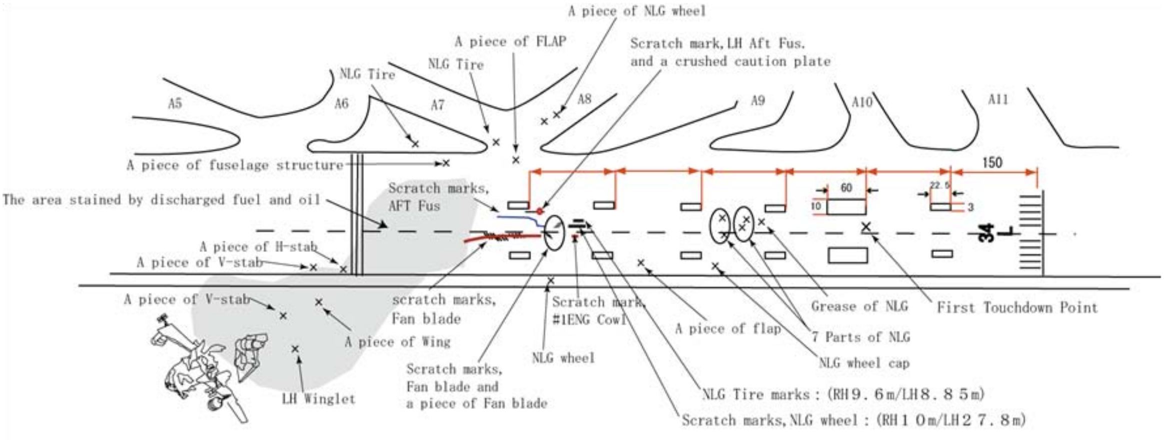

Figure 1　Overview of the Airplane's Wreckage

2.10.2　Details of Damage

a.　Fuselage

The ceiling remained tied together from the nose to the tail section, but the fire consumed most of the interior, from the cockpit to the tail. The fire also consumed the lower outer skin of the fuselage around the main wings (the parts facing upward due to the inversion) and most parts of the cabin including the floor, leaving cargo fixture brackets scattered around.

The fire consumed the chemical fiber net and the synthetic rubber curtain, located between the flight crew compartment and the cargo bay.

Plastics in the cockpit melted and deformed, and the interior was sooted. The inside of the acrylic side windows was burned.

Photo 2　　Accident Airplane

b.　Left Wing

The left wing, with left MLG and the No. 1 engine, was separated from the fuselage near the attachment point and the detached major wing structure lay near the fuselage.

The fire consumed the wing root section, leading edge along with the inboard slats near the wing attachment point to the fuselage, leaving leading edge and slats. The trailing edge surface was sooted, but the fractured area of the rear spar had retained its original shape. The double-plated rear spar, which consisted of the same thickness plate, was fractured almost at the same place. The fracture formed a diagonal line linking the lower end near WS*[3]230.6 and the upper end near WS197.2. Bends and cracks perpendicular to the fracture line were observed at the mid section and the stringer at the base of the spar had span-wise cracks. The outer skin in the area involved exhibited no vertical bending. (See Photo 3 and Figure 2)

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*[3] WS stands for wing station meaning a distance in inch measured on the outer wing rear spar from the fuselage centerline.

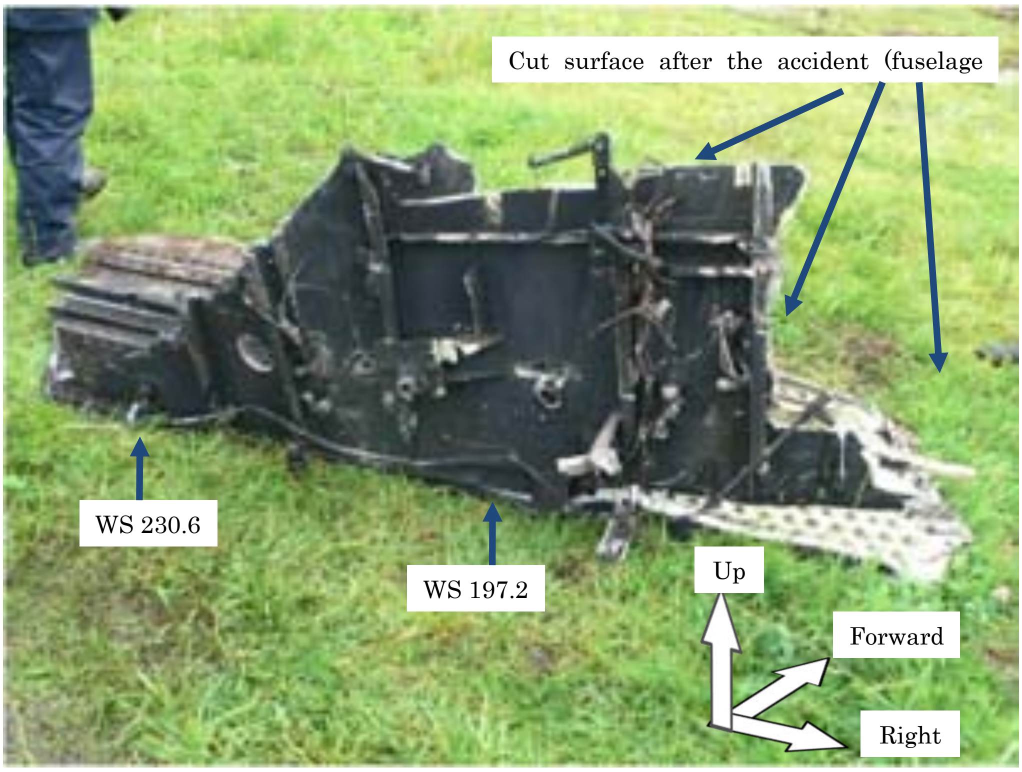
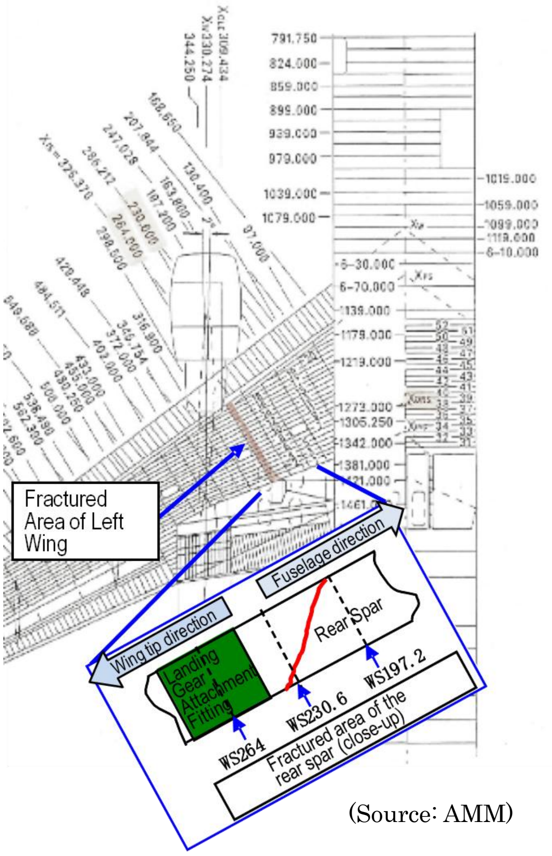


Photo 3 Fractured Area of Left Wing (Fuselage Side)



(Source: AMM)

Figure 2 Fracture Surface of Left Wing

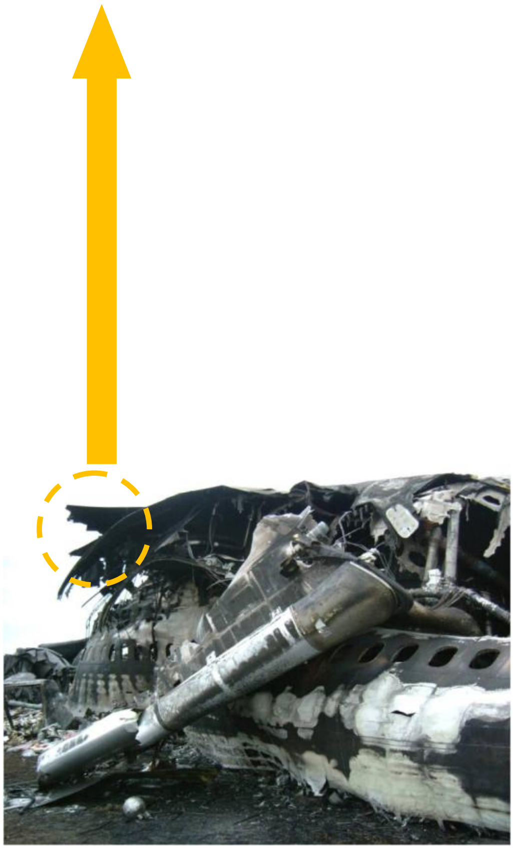


Photo 4 The inverted Airplane (Fractured Area of Left Wing)

Photo 5　Fractured Left Wing

The No. 1 engine and the left MLG remained attached to the left wing structure lay on its lower surface on the grass area to the east of the fuselage.

The shape of the broken face of the rear spar matched that of the fuselage side.

The fire consumed the slats outboard side of the engine pylon leaving the skeletal parts. The main wing structure of the slat of inboard leading edge was damaged by fire; accordingly, it was hanging on the lower side of the fuselage which was upside down. The inboard flap was separated and found on the runway near the A7 taxiway.

The rear spar fractured around WS230.6, just inboard of WS264 where the rib of the bulkhead for separation of the No. 1 and No. 2 fuel tanks, which were located in the forward area of the left MLG warehouse. The fracture surface was partially sooted. The wing tip portion with winglet separated from the wing.

On the fracture face of upper skin, most of the stringers were fractured with the upper wing skin. Some of them were bent upward being burned out. One stringer was remained 1 m away from the fracture surface of upper wing sin and rivets were missing.

The fractured lower wing skin was applied with tension stress, forming openings between the skin and the stringer, with rivet heads broken. The skin near the rear spar was bent downward. (Photo 6)

Photo 6 Fractured Area of Left Wing (Wing Side)

The front spars were vertically fractured at about 50 cm inboard (close to the wing root) of WS264.

Fractured rear spar (except for the areas exposed to fire) was examined by JAXA. The fracture surface showed no indications of repetitive loads such as scratching. The examination showed that the spar fractured quickly under the excessive stress. (Photo 7)

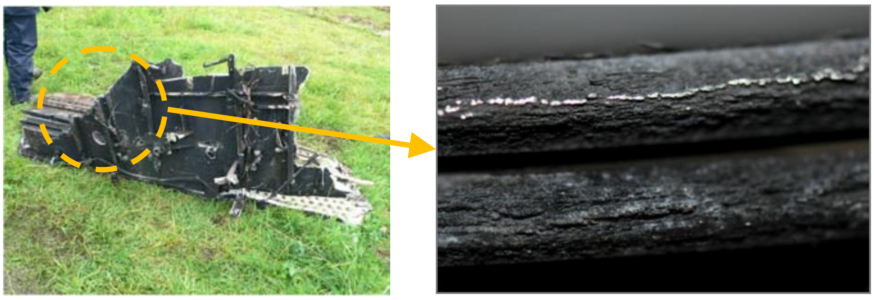


Photo 7 The fracture face of the left wing rear spar (fuselage side)

c. Right Wing

The right wing lay inverted attached to the fuselage. The fire consumed the most part of the wing. The remaining parts from the fire were melted or sooted.

Photo 8 Right Wing

d. Landing Gears

The NLG remained attached to the fuselage. The wheel rims were broken, and the broken rims, tires and the wheel caps were detached. The right wheel was able to rotate by hand; on the contrary, the left wheel was unable. Part of the left wheel hub outer surface was grinded and some tie bolts were lost or loosened. The strut torque link was fully extended. The NLG support in the NLG wheel well exhibited no sign of structural damage, except cracks in the web near the NLG support.

Photo 9 Nose Landing Gear

The left MLG remained attached to the left wing, and the retractable side brace and the fixed side brace were found attached to the MLG. The forward trunnion bolt (fuse pin) was slightly deformed, however, it did not fail. About the two bolts which were attached to the side brace fitting (pillow block) and the trapezoid panel, the inboard bolt was broken leaving part of it in the panel, while the outboard bolt was removed from the pillow block out of the broken bolt hole, remained in the pillow block with the landing gear. A lug, which is connected to the lower end of the landing gear, was torn apart. The sooted left MLG strut was fully extended with no apparent damage. The surface of the four wheels and tires were all burned and sooted. There were slight traces of scratch on the two outer wheels. No. 5 and No. 6 tires were deflated without any indications of burst. The torque link was undamaged. The MLG attachment fitting had no damage, but in the lower part of fitting, there was dent caused by the strut. (See Photos 9, 10 and 11, Figure 3)

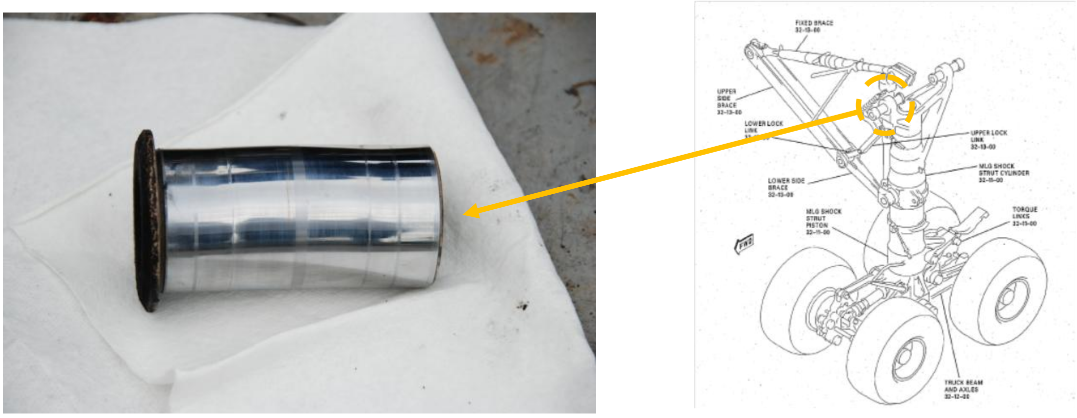


Photo 10 Forward Trunnion Bolt (Fuse Pin)

(Source: AMM)


Crushed mark of the attachment fitting

Photo 11　Left MLG

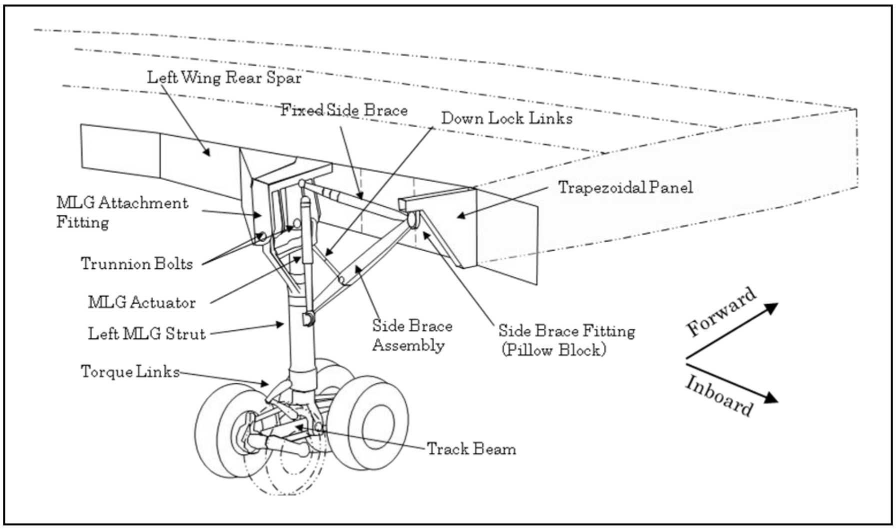


Figure 3　Left MLG-to-Wing Attachment

The center MLG remained attached to the inverted fuselage, but as the fire consumed the fuselage interior, it somewhat drooped into the body. Borescope image (See Photo 12) through the strut blow-out hole shows the smashed crush tube[*4], indicative of a strut bottoming. (See Figure 4)

The sooted right MLG also remained and attached to the inverted fuselage. The four tires were all sooted with traces of heat damage on the surface. The tires remained inflated with no severe damages.

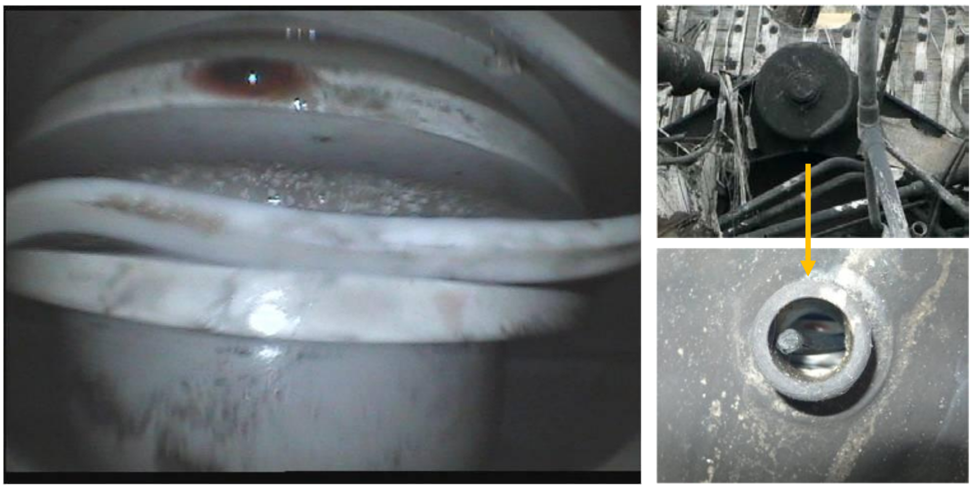


Photo 12 The Inside of the Blow-out Hole of Center MLG

e. Engines

The three engines remained attached to the wings and the vertical stabilizer.

Photo 13 No.1 Engine

The lower side of the No.1 engine inlet cowl was grinded to inside of the fan cowl. The tip of the fan blades suffered gradual bending damages, while the left upper section of the fan cowl was crushed, smeared with the paint of the fuselage. The thrust reverser actuator was in the retracted position. There was no indication of in-flight engine fire.

The No. 2 engine (installed in the tail section) remained fixed to the vertical stabilizer pylon. The engine intake duct had fire damage, while all the fan blades were found intact. The thrust reverser actuator was in the retracted position. There was no indication of in-flight engine fire.

The No. 3 engine were damaged to the cowling and other parts by fire, but remained attached to the wing. The thrust reverser actuator was in the retracted

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[*4] The crush tube, a built-in device inside of the center landing gear strut, collapses when the strut receives a bottoming, and the inner pressure of the strut may be released through the blow-out hole.

position. There was no indication of in-flight engine fire.


No.2 Engine

No.3 Engine

Photo 14 No.2 and No.3 Engine

f. Control System, etc.

In the avionics compartment, several units (including two FCC-908) were escaped the fire but most of the sections were burned or sooted. (See Photo 15)

The fire consumed cockpit interior. The circuit breaker panel was partially burned, and some circuit breakers were open. Because the fuselage was inverted, the overhead panel and other components exhibited foot prints of rescuers.


Photo 15 Removed Avionics Rack

The flap/slat handle was in 28° G/A (go-around) gate. The No. 1 thrust lever was in the mid-forward position, the No. 2 lever in the backward (pulled) position and the No. 3 lever in the forward (pushed) position. All reverse levers were in the retracted (not for use) position, while the ground spoiler/speed brake handle was in the retracted position. The engine fire handle on the overhead panel was in the UP position.

NAV select switch, Flap Limit Feel switch and the Elev. Feel Switch were in AUTO position.

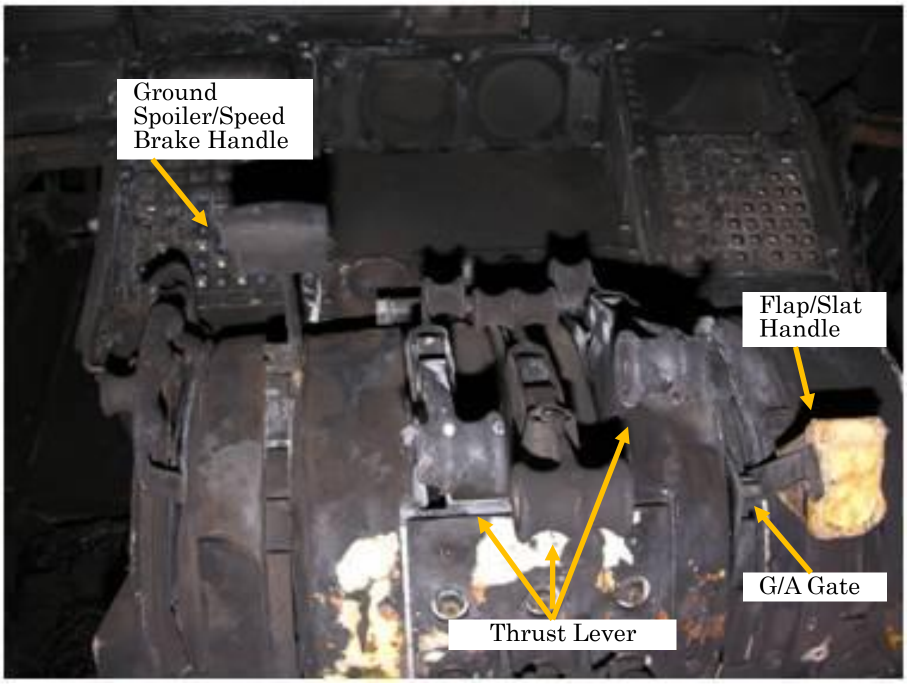


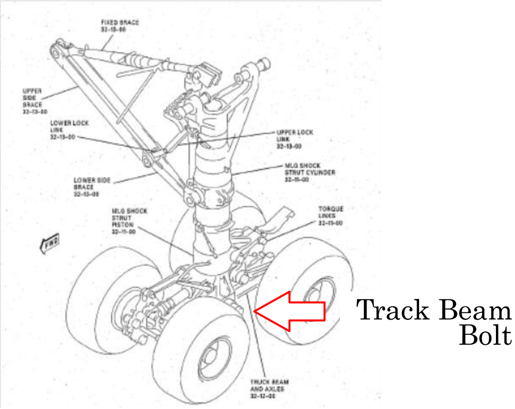
Photo 16 Center Pedestal

2.11 Detailed Examination of Landing Gears

2.11.1 Examination of Left MLG

The left MLG had no exterior damage except for the fire damage or that caused by the movement from the accident site to the storage site. The longitudinal straightness of the outer diameter of the track beam bolt (parts number: ARG7373-1), which transfers the loads on the landing wheels to the struts, was measured with a thickness gauge at JAXA, and a gap of 0.03-0.04 mm was observed. The residual deformation generated the gap, and the gap was made as a result of the plastic deformation occurred to the bolt when it was exposed to a load.

Photo 17 Track Beam Bolt



(Source: AMM)

2.11.2 Teardown Examination of NLG and Left MLG Struts

The Landing Gear strut is completely compressed as shown in Figure 4, when they are shipped from a maintenance facility. Before installation, the strut is inflated with nitrogen gas up to the regulated pressure. At landing, nitrogen gas is compressed from the extended position and the fluid is forced to pass through the orifice that generates the resistance of fluid flow so that the landing gear absorbs the landing force.

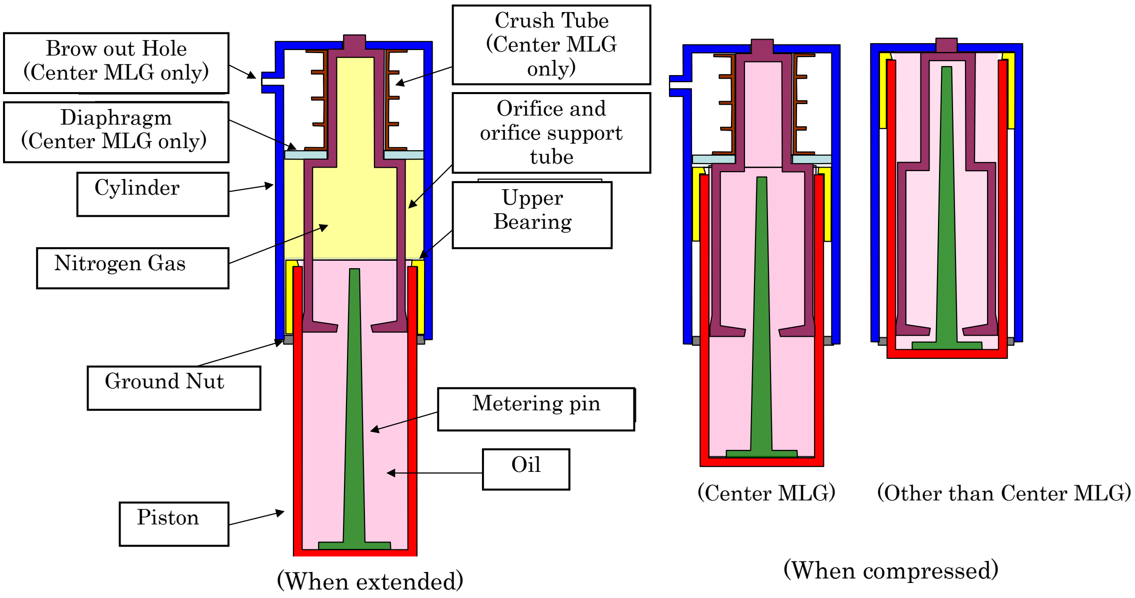


Figure 4 Mechanism of NLG/MLG Strut

A teardown examination was carried out at the maintenance facility in the United States of America for the NLG and the left MLG struts which had been installed in the body sections which sank hard when the airplane made the third touchdown. Later the JAXA conducted detailed examinations for wheel-related components and interior components of the struts. The examinations revealed the following:

a. NLG (part number: NCG6201-5519, serial number: AP134)

Visual examination of the gear found no major damage except for damage caused by the movement from the accident site. The examination of the NLG components found that the orifice support tube was fractured through holes due to axial compression load.

Photo 18 NLG Orifice Support Tube

After the wheel tie bolts on both sides of the NLG were found to have been loosened, the JAXA conducted a detailed examination on the wheels. It confirmed that the tie bolts had become loose because the threads of the tie bolts and the nuts had been damaged, then the nuts moved to loosen direction.

The NLG wheel rims were crushed from one direction to be deformed into an elliptic shape. It was estimated that a large load applied only once. Because the shape of the deformation of the left and right rims was similar to each other, the NLG tires on both sides had touched down almost at the same time. The condition of the fracture surface of the rims showed that the fracture went from the bottom to upward in Photo 19. This fact also showed that the NLG was exposed to a large upward load (in the direction of being pushed up).

The findings are as follows:

(1) The rims were fractured with a upward load,
(2) The wheel halves, which form the wheel hub, were extended outward and deformed to opening direction, and
(3) The threads of the tie bolts and the nuts were fractured.

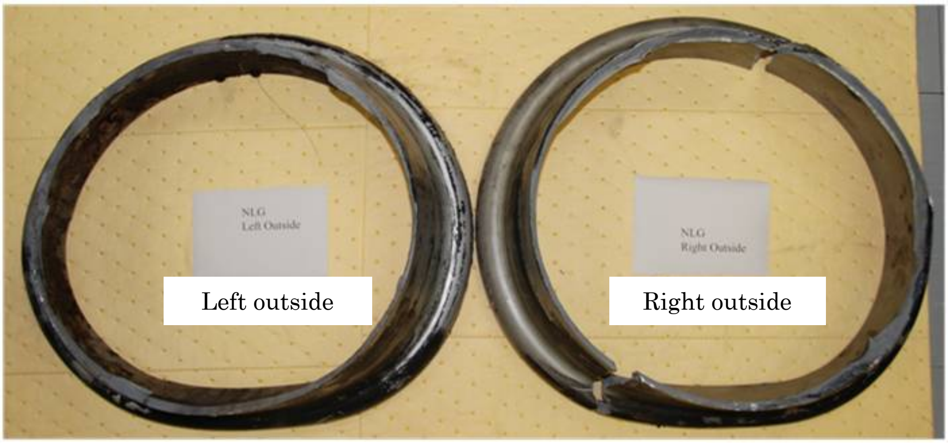
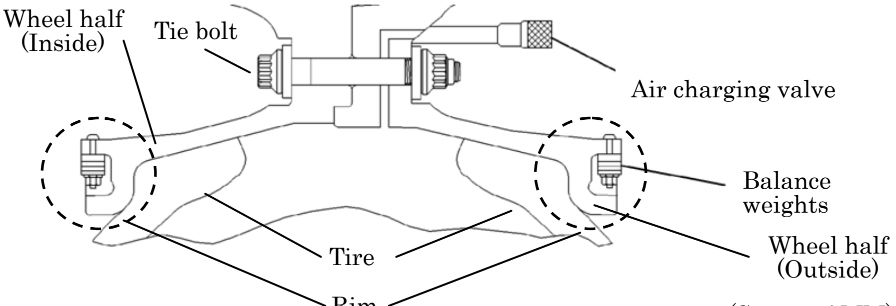


Photo 19 Fractured Pieces of NLG Wheels (Rim)

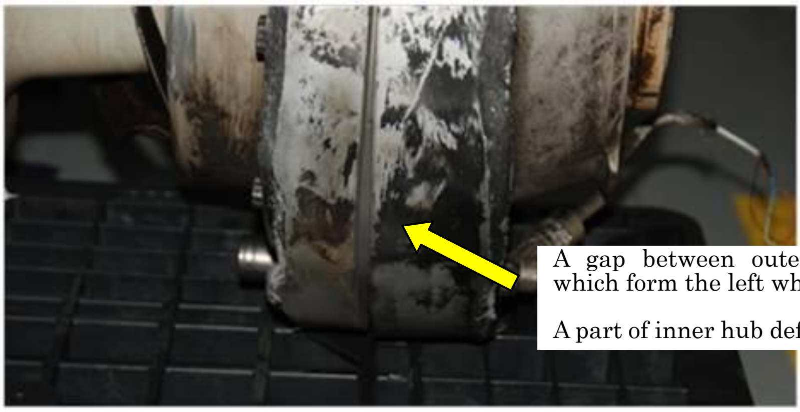
These findings showed the sequence of to the loosened bolts and nuts as follows: (see Figure 5)

(1) Large upward load applied upon touchdown of NLG caused the tire to expand sideways,
(2) The rims were fractured with the bending load, while the wheel halves were forced to expand sideways stretching the tie bolts, and
(3) The fracture of bolts' and nuts' threads made the nuts loose.



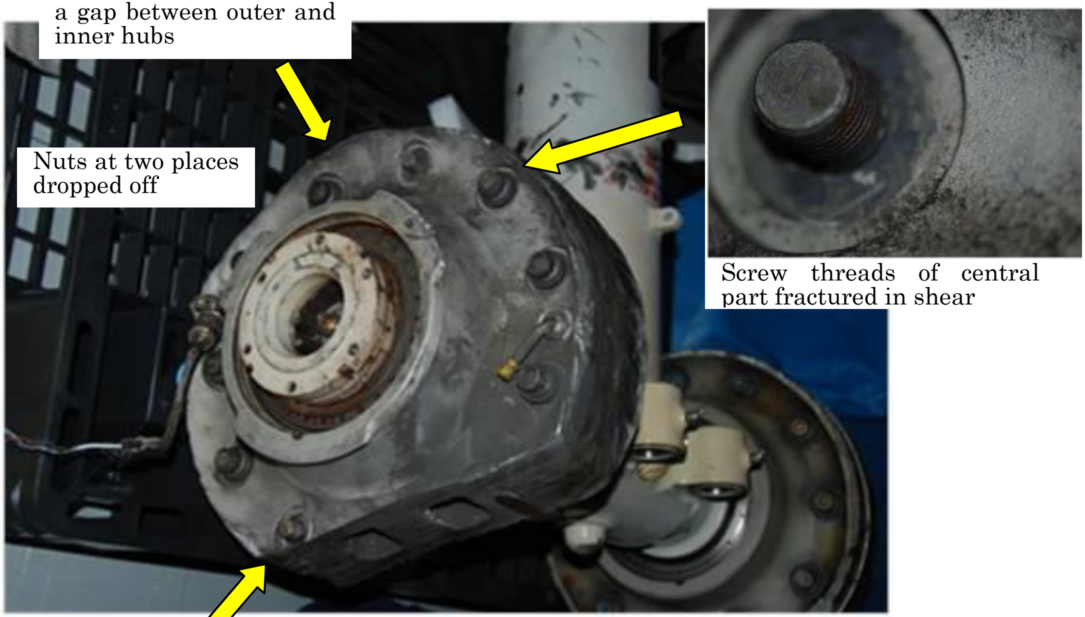
(Source: AMM)

Figure 5 Cross-sectional schematic of NLG Wheel Hub



A gap between outer and inner hubs which form the left wheel

A part of inner hub deformed to the inside

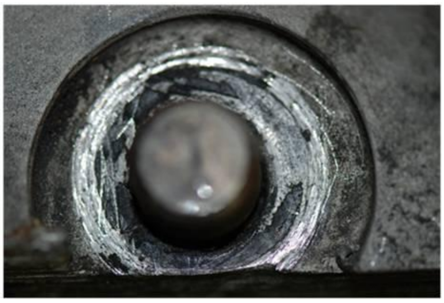


The place where there is a gap between outer and inner hubs

Nuts at two places dropped off

Screw threads of central part fractured in shear

Scratch mark with washer (Nuts displaced by scraping with the ground.)



The inside of loosened nut (screw threads shaved, about to come off with tensile load)

Photo 20 NLG Left Wheel Hub

b. Left MLG (part number: NRG6719-501 (D10-32-001-07, serial number: BFGS00985)

Visual examination of the left MLG strut found no visible damage. The examination of the MLG components found no major damage with exception that the lower lip of the upper bearing (the inner part that supports the upper end of the piston) completely separated from the bearing halves at the place where it is connected to the other components.

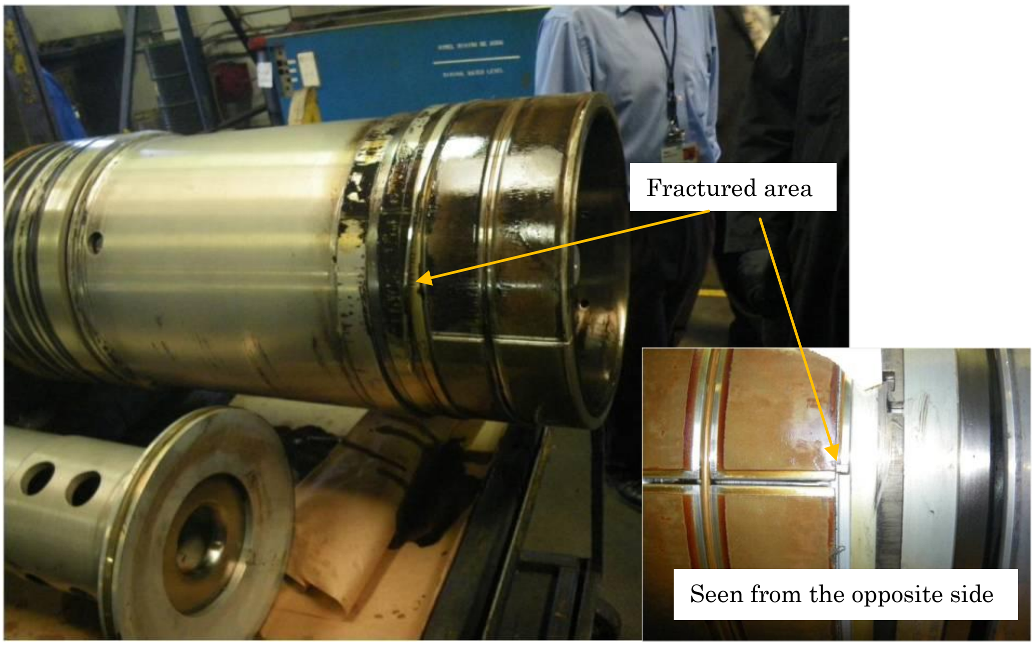


Photo 21 Left MLG Upper Bearing

2.12 Firefighting and Rescue Activities

a. According to the firefighting operations room of NAA Fire and Security Inc., the records from the occurrence of the accident to the end of firefighting and rescue operations were as follows:

06:49	The Narita Tower notified the company's operations room by crash horn that the airplane swerved from Runway 34L and caught fire. The operations room immediately ordered the level 3 mobilization (to the accident site) to dispatch fire engines and disseminate the information to relevant organizations such as the Narita City Fire Department.
06:50	The NAA fire engines arrived at the accident site and started firefighting.
06:57	The Narita City fire engines arrived at the accident site and started firefighting.
07:03	Rescuers tried to enter the cockpit, but the heat and smoke hindered their entry. A demolition fire engine started cutting open the rear part of the cockpit from the eastern side of the airplane by the rescuers using the engine cutter.

07:18 The demolition fire engine started cutting open the rear part of the cockpit from the western side of the airplane by the rescuers using the engine cutter..

07:25 A Narita City firefighting rescue team started to enter the cockpit.

07:30 The team secured an access route to the occupants, confirmed them and continued to clear interior obstacles.

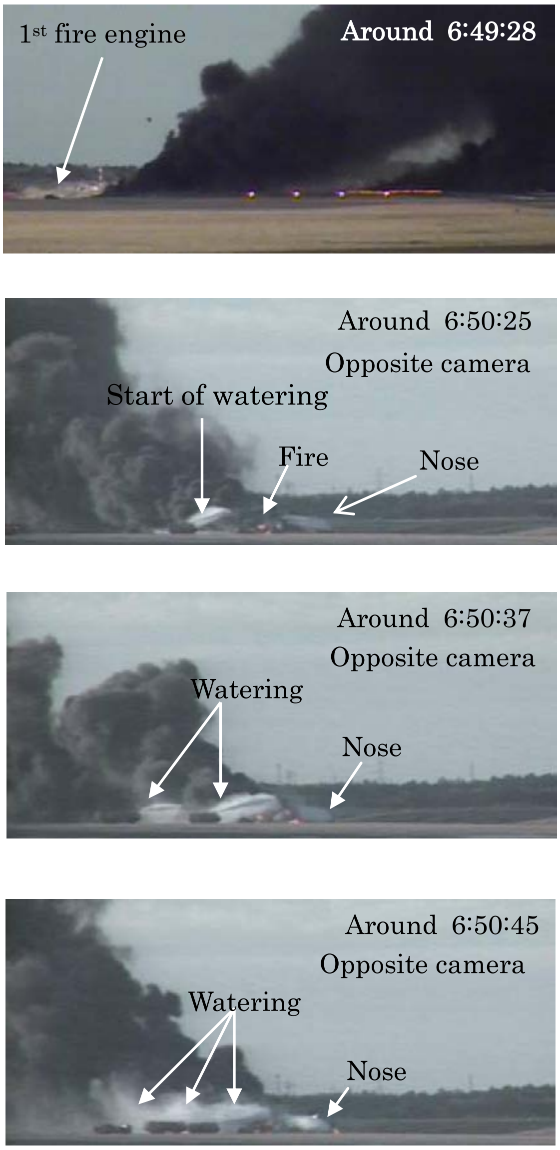
08:00 The PIC was rescued and transported to the hospital by ambulance.

08:16 FO was rescued and transported to the hospital by ambulance.

08:36 The fire was brought under control. The efforts were shifted to the ember disposal and vigilance.

12:00 The ember disposal was completed. The fire was completely extinguished.

Picture 2 Fire Fighting Activities



b. The fire-extinguishing activities captured by Camera Images

At 06:49:28, the first fire engine arrived at the accident site.

Three other fire engines arrived there, each at 06:49:51, 06:49:59 and 06:50:06.

At 06:50:25, the first water discharge started. At this time, a flame was coming out of the rear part of the cockpit.

By 06:50:45, several fire engines had started fire-extinguishing operations.

c. Mobilized vehicles and personnel

Total number of vehicles:	47
Number of personnel:	137

Fire-extinguishing agent used:
Aqueous film foam concentrates[*5] (Mega Foam F-623T[*6]) 5,540 liters
(See Attachment 4: Fire fighting)

[*5] The aqueous film foam concentrates is an agent which is suitable for extinguishing a fire caused by liquid fuel like gasoline. The fire can be put out with: the “suffocation effect” by separating the flame from the air by covering the liquid surface of the burning fuel with the agent; and the “cooling effect” of water present in the foams.

[*6] Used with 3 % concentration.

2.13 The Airplane's Landing and Related Control Operations

2.13.1 Procedure Included in the Chapter 7-1-5 Landing, the Company's Flight Manual

Following descriptions explain the landing and related control operations:

a. *NORMAL LANDING*

Plan to touch down 1500 ft from the runway threshold. The runway threshold should disappear under the nose at about the same time CAWS announces "100." Maintain a stabilized flight path through the 50 and 40 foot CAWS callouts (unless sink rate is high). At 30' a smooth 2.5 degree flare should be initiated so as to arrive below 10' in the landing attitude. Do not trim in the flare. Elevator back pressure should be relaxed, and a constant pitch attitude should be maintained from 10' radio altitude to touchdown.

The autothrottles switch to the retard mode at 50' RA. In the retard mode, the throttles move to idle at a preprogrammed rate without regard to airspeed, vertical velocity, or RA. The PF must maintain the appropriate glide path to touchdown. If a deviation occurs from that glide path, the PF must override the autothrottles to prevent retard.

At main wheel touchdown the autospoilers partially deploy, if throttle #2 is at idle. If throttle #2 is above idle at touchdown, AutoSpoilers and AutoBrakes may not activate. Counter any pitch-up tendency associated with spoiler extension. Fly the nose wheel smoothly to the runway. Avoid full elevator down input. If selected, autobraking will begin shortly after spoiler deployment. When the nose wheel is lowered to the runway, the spoilers will fully deploy.

(The rest is omitted)

The PM monitors spoiler deployment and manually deploys the spoilers if necessary. During landing and reversing the PM monitors the engine instruments and call out "80/60 knots." When applicable, the captain normally initiates transfer of control from the F/O after the "60 knots" callout.

(The rest is omitted)

b. *HIGH SINK RATE/BOUNCE RECOVERY*

If a high sink rate or low bounce occurs, the PF should establish a 7 1/2° pitch attitude and increase thrust until the sink rate has been arrested and/or a normal landing is accomplished. Avoid rapid pitch rates in establishing a normal landing attitude. If a high bounce occurs, a low-level go-around should be initiated. Low-level go-arounds are dramatically different than normal go-arounds. During low-level go-arounds, main wheel touchdown may be unavoidable. The PF must not exceed 10° of pitch or retract the landing gear until the aircraft is safely airborne with a positive rate of climb.

2.13.2 Summary of Pilots' Statements about Controllability at Landing for the Same Type of Aircraft

When several pilots with licenses for the same type of aircraft were interviewed, they made comments summarized as below about the control characteristics of these aircraft at the time of landing:

Their controllability is similar to that of Boeing 727 airplane which have the No. 2 engine in the tail, just like the same type of aircraft. Compared to other aircraft with no engine in the tail, this type of aircraft is sensitive in the pitch correction and therefore, steering must be made rather finely. No significant difference has been felt in the control characteristics when the aircraft weight on landing is heavier and when the weight is lighter. When strong winds are blowing, a sinking tendency may be felt from around when the ground effects emerge. When a gust is blowing, the speed changes so greatly that the auto throttle cannot follow the situation. The pilots concerned have not felt that this type of aircraft easily bounces.

Because these aircraft are equipped with LSAS (to be described later in 2.14.5), the pilots have not felt any particular difficulties in controlling or any situation which requires particular caution.

2.13.3 Landing Operations

When a line checker (hereinafter referred to as “Captain A”) of the Company was interviewed about desirable landing operations with the cooperation of the investigation organization (hereinafter referred to as “NTSB”) of the State of manufacture, comments as summarized below were obtained.

The pilot would maintain the same attitude that had been used when following the glide slope and would not change pitch attitude when they heard the Central Aural Warning System (CAWS) call out 100 feet. A pilot could begin the flare as early as 50 feet.

Light airplanes, heavy airplanes, and MD-10s all land differently. In a heavy MD-11, it was best to begin the flare at 50 feet, but a light MD-10 was going to float if a pilot flared that early. The pilot had to think about how heavy the airplane was and what the CG was. By 30 feet at the latest, the pilot should start flare and holding attitude until he heard the CAWS call ten feet. At ten, he would relax the back pressure and hopefully the airplane would roll out smoothly on the runway.

The CAWS 50-40-30-20-10 callouts should come progressively farther apart. If a pilot heard them all come by quickly, he had better get ready for a bounce recovery.

The autothrottles would generally start to retard about 50 feet. As they retarded, the pilot would start pitching up and the throttles would come back at a pretty steady rate. If the airplane was flared too quickly, it might run out of airspeed and drop in. If the airplane was not flared quickly enough, it might touch down with a bit of power and then the throttles would come back. If the pilot is flying with the autothrottles off and he forgets to retard them, then the airplane is going to float.

2.13.4 Bounce Recovery

Comments about bounce recovery obtained from the Company’s several pilots in charge of flight training and Captain A, with the cooperation of NTSB, are summarized as below:

a. Several pilots in charge of flight control training

Bounce Recovery training was implemented in 1996 as a result of two tailstrikes. After the 1997 FedEx MD-11/Newark accident, it was given to all MD-11 pilots and subsequently required only in initial and transition training. Since it was a simple maneuver, there was no indication that bounce recovery had to be trained more frequently.

Some pilots said they received tailstrike awareness and/or bounce recovery training after their initial training and most indicated that they had at least received some sort of tail-strike awareness or bounce recovery briefings since their initial training. However, most pilots interviewed indicated that they only received tail strike awareness or bounce recovery simulator training during their initial or transition training on the MD-11. As a result of the Narita accident, the Operator is reevaluating the frequency of the tailstrike awareness and bounce recovery training.

Captain A stated that in addition to providing the training in initial and transition training, the Operator is immediately going to make tailstrike awareness and bounce recovery simulator training either an annual or bi-annual event.

b. Captain A

When asked to describe what she would do with the control column after the initial bounce, the Captain said the procedure was to hold the nose at 7.5 degrees and use the thrust as necessary to adjust the sink rate on landing or execute a go-around if necessary. She did not know how high the accident airplane bounced but looking at the video it looked like a high bounce, and she thought she would have been bringing the throttle forward and executing a go-around at that time. Bounce recovery raised a risk of a tailstrike, so she would not want to increase the pitch too much.

Asked whether the flight crews would need to hold the control column a bit aft to recover during a bounce, the Captain said yes, she would hold it a bit aft. If coming down the glide slope at between 2.5 and 5 degrees and as you start flare you bring it up a couple degrees. At 20 to 10 feet you're relaxing the back pressure slightly, so it would definitely be an increase in back pressure required to hold it up to 7.5 degrees.

2.14 Tests and Researches

With the cooperation of the NTSB, the airplane manufacturer, the Company and JAXA, the airplane flight status at the accident were analyzed. As the DFDR and other devices aboard the airplane had no recording parameters for descent rates (sink rate) and thrust resolver angles (TRA), those values were estimated by the following method in this analysis.

Sink rate: An estimate was obtained by integrating the acceleration values recorded in the DFDR considering the effects of the airplane attitude and the bias errors of the accelerometer.

TRA: An estimate was obtained from the engine pressure ratio (EPR) by using the manufacturer's conversion program.

The flight simulation program of the manufacturer was used in this analysis and the simulation was conducted under the following conditions:

a. Flights are simulated based on the nonlinear six-degree-of-freedom equations of motion.

b. The airplane structure is assumed to be a rigid body, while the aerodynamic effect of the aeroelastic deformation during the flight was considered.

c. The flight characteristics of the airplane is reproduced based on the flight characteristics data for the MD-11 series airplane provided by the airplane manufacturer.

d. The flight environment (winds, atmospheric pressure, ambient temperature, etc.) at the time of the accident is reproduced based on the DFDR data and the flight characteristics data for the MD-11 series airplane provided by the airplane manufacturer. But vertical winds shall not be considered (the relevant value to be set at zero).

e. The control inputs are produced based on the DFDR records. But the control input data are corrected to simulate the airplane maneuver in the air (particularly its attitude).

2.14.1 Windshear Warning

According to the DFDR records, a head wind component of the horizontal winds which the airplane encountered below 1,500 ft RA were about 60 kt at 1,000 ft or above, about 50 kt from 1,000 ft to 500 ft, and about 25 kt near the ground, meaning that there were the wind velocity difference of about 25 kt between the ground and 500 ft or more. (Figure 6) The onboard windshear warning device was functional and didn't activate the windshear warning.

According to FAA TSO-C117a, which prescribes the minimum performance standards for the windshear warning systems, the system generate an alert when the F Factor[*7] exceeds the threshold value (-0.21 on a 5 second average and -0.105 on a 10 second average). The F Factor (Figure 6), estimated with the DFDR records, was below the thresholds both on a 5 second average (red broken line in Figure 6) and a 10 second average (blue broken line in Figure 6).

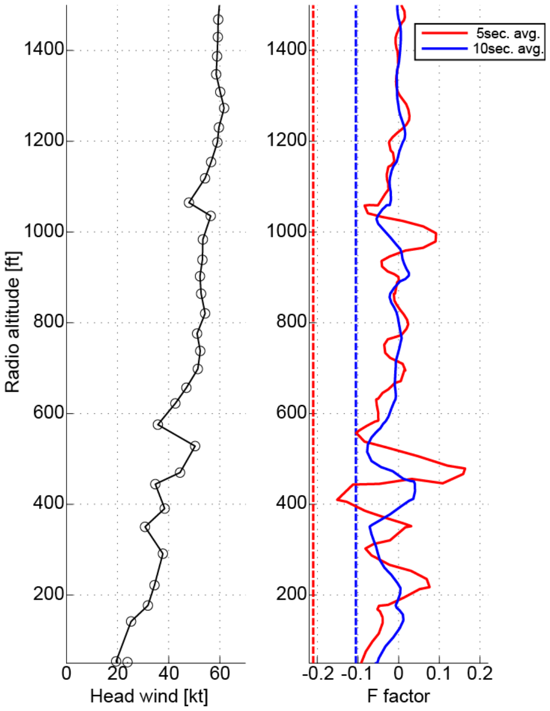


Figure 6 Evaluation of Operation of Windshear Warning Device

2.14.2 Comparison of the Accident Landing with Previous 60 Landings

To get a clearer landing profile of the accident landing, the accident landing was compared with previous 60 landings recorded in the quick access recorder (QAR), synchronizing the first touchdown timing. The study revealed following distinctive aspects. (See Figure 7)

[*7] The F Factor is defined as in the following equation based on TSO-C117a appendix 3 (technical standard for windshear warning devices), in which "W_h" is downward wind; "V" is true airspeed; "$\dot{W}_x$" is the rate of change in the head wind component; and "g" is vertical acceleration

$$f(t) = \dot{W}_x / g - W_h / V$$

In the TSO standard, the threshold of the F Factor is indicated as a positive number, but the definition of the f(x) requires it to be negative value, it must be evaluated by multiplying it with -1.

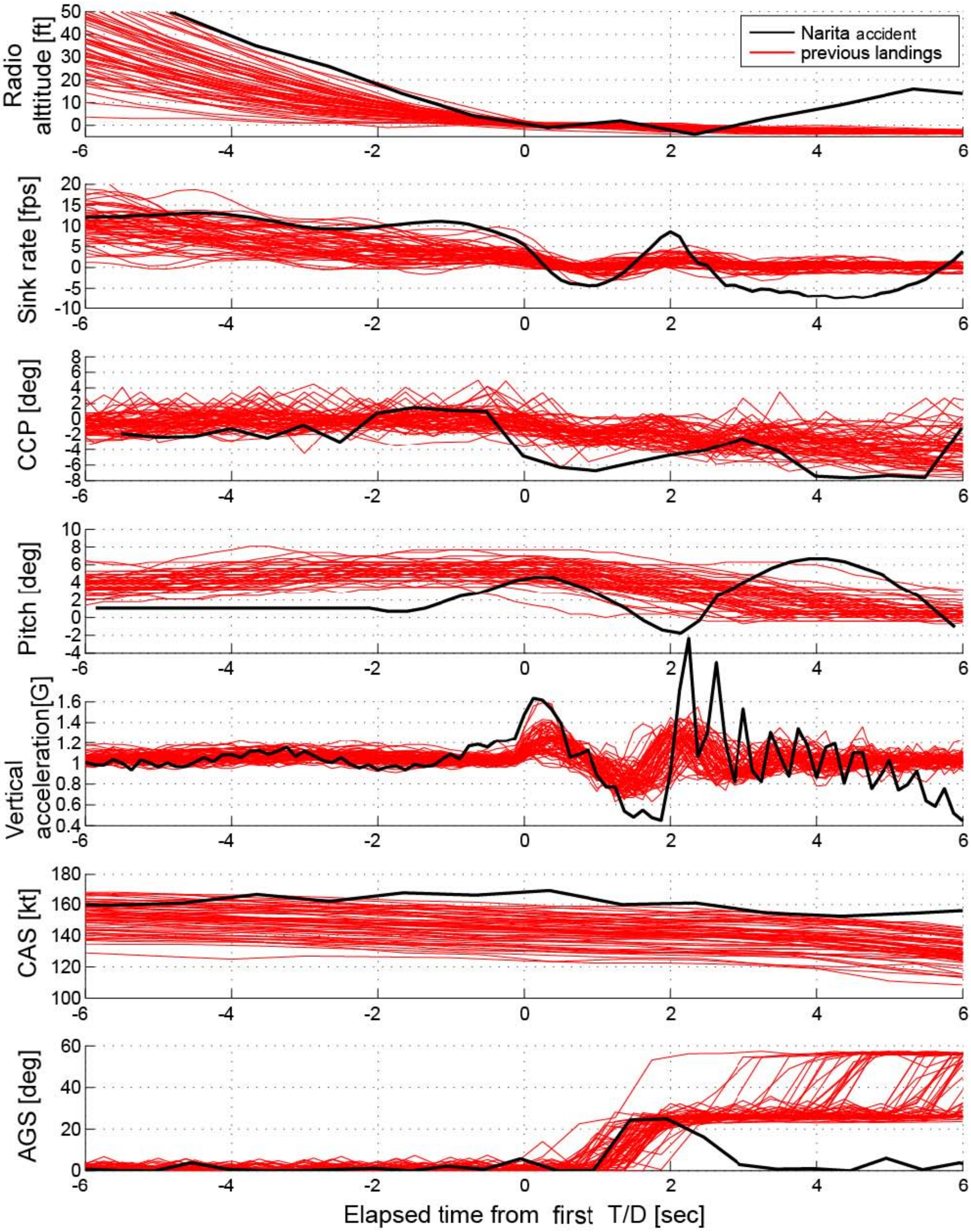


Figure 7 Comparison of the Accident Landing with Previous 60 landings

a. The descent angle and the sink rate are large until touchdown. The sink rate at 50 ft RA was about 13 fps and the sink rate at touchdown was about 7 fps.

b. The control column input just before and during the touchdown is large. The control column was pulled backward about 2 seconds before touchdown, held there and pushed forward with large stroke just before the touchdown.

c. Pitch attitude variation just before and during the touchdown are large. The airplane approached with the smallest pitch angle until flare and the pitch angle increased rapidly just before the touchdown. Then, the pitch angle decreased rapidly to negative when it made the second touchdown.

d. The vertical acceleration just before and during touchdown was large, about 1.2 G and 1.6 G, respectively.

e. The airspeed just before and during the touchdown is fast (166 to 169 kt CAS).

f. The time required for AGS deployment after touchdown was within the range of variations observed in the past landings. The AGS did not deploy to 60° the maximum and they began to retract in 2 seconds after touchdown.

g. Other landings also had two positive vertical acceleration peaks upon landing, just like those observed in this accident. These data suggest the airplane bounces on those occasions. But in the accident landing, the height of bounce and the change of vertical acceleration are larger than any other cases.

h. Forward control column movements just before and during touchdown were found in some previous landings. However, these are different from this accident in that the airplane attitude in these previous landings did not become negative pitch angle after the first touchdown in spite of the forward control column input.

2.14.3 CAWS Call-out Interval

The CAWS call-out is used as a timing reference to start flare or retard the thrust lever.

The recorded call-out interval of CAWS in the CVR, with an interval of 10 ft from 50 ft to 10 ft RA, and the average sink rate for every 10 ft are shown in Table 1. Suppose a pilot starts flare at 30 ft, the follow-on sink rate decreases while the call-out interval becomes longer. According to the FOM of the airplane manufacturer, the ideal sink rate should finally be 2 to 4 fps (120 to 240 fpm) upon touchdown. In the accident, the call-out interval remained almost unchanged below 40 ft.

Table 1: CAWS Call-out Interval and Average Sink Rate for Every 10 ft

Radio altimeter (ft)	Interval (sec)	Sink rate (fps)
50 ~40	0.64	15.63
40 ~30	0.91	10.99
30 ~20	0.85	11.76
20 ~10	1.01	9.90

2.14.4 Factors Linked to Pitch Attitude Variation

The observed pitch attitude variations were large in this accident. Therefore, contributing factors to the pitching moment were examined by using a flight simulation program made by the airplane manufacturer. The examination revealed the following: (Figure 8)

a. The elevators have the largest influence on the pitch attitude variations just before and during the first touchdown and the nose-down motions during the two bounces. The pitch angle change takes place about 0.5-1 second after the elevator-generated aerodynamic force. This delay is commonly observed in large transport airplanes derived from the airplane inertia and aerodynamic stability mainly due to the horizontal stabilizer.

b. The elevator angle is determined by the sum of the control column input and the LSAS command input, to be described later in 2.15.3, and generally well corresponds to the control column input.

c. Ground spoiler deployment generates nose-up pitching moment.

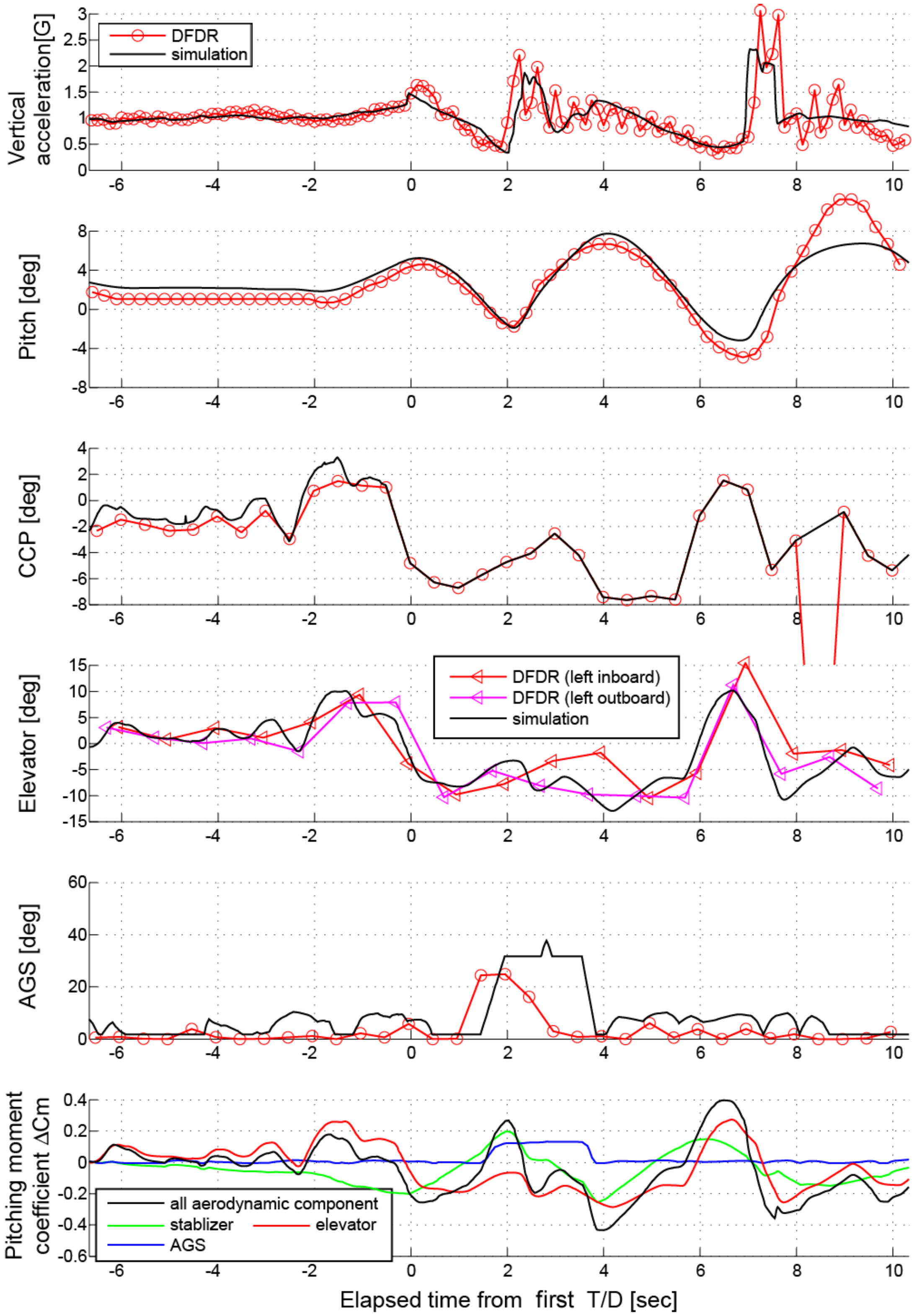


Figure 8 Factors Linked to Pitch Attitude Variation

2.14.5 Longitudinal Stability Augmentation System (LSAS)

2.14.5.1 Outline

LSAS is a system developed and installed for MD-11 series airplanes to augment the longitudinal stability. In December 1995, the pitch rate damper (PRD) function was added to the system to increase the stability at high altitudes; moreover, a software package (FCC-908) was introduced in May 2000 for the low altitude stability enhancement (LASE).

LASE mainly consists of the following three functions :

a. The PRD function which mitigates changes in the pitch angle (applicable at high altitudes and at low altitudes)

b. The pitch attitude protection (PAP) function which generates a nose down command when the pitch angle approaches the threshold value (9.5°) on touchdown to provide tail strike protection.

c. The positive nose lowering (PNL) function which generates a nose down command after the MLG touchdown and ground spoiler deployment to counter the pitch up effect of ground spoiler deployment

The NTSB concluded that FCC-908 software package will provide valuable improvements in safety during MD-11 landings as stated in the Newark Accident*[8] report. The NTSB issued a recommendation (A-00-96) requiring the installation, within a year, of the software package on all MD-11 airplanes. At present, the FCC-908 has been installed in all the airplanes of the same series.

2.14.5.2 Influence of LSAS

LSAS has the PNL function which issues nose down commands following the MLG touchdown and the deployment of the AGS. With the assumption that the LSAS had influenced the nose down motions during the two bounces, the influence of LSAS was examined using the flight simulation program made by the designer/manufacturer. The examination revealed the following. (Figures 9, 10)

a. In a simulation with LSAS on, the simulator exhibited almost the same aircraft motions as seen in this accident. The changes in the pitch attitude and the occurrence of the bounce almost matched the relevant DFDR records in this accident.

The PRD function to moderate the pitch attitude change has greater influence on the airplane than the PNL function. Therefore, a final LSAS command during the PNL function operation usually ended up in the nose-up direction.

b. In a simulation with LSAS off, the pitch attitude and the bounce after the second touchdown were larger, when compared to this accident. The sink rate at the third touchdown was also larger than 21.5 fps recorded in this accident.

c. It is highly probable that LSAS had eventually worked in pursuit of curbing the pitch attitude variations.

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*[8] The Newark Accident is the airplane accident which occurred at Newark International Airport in New Jersey, the United States of America, in July 1997, with the same type of airplane involved.

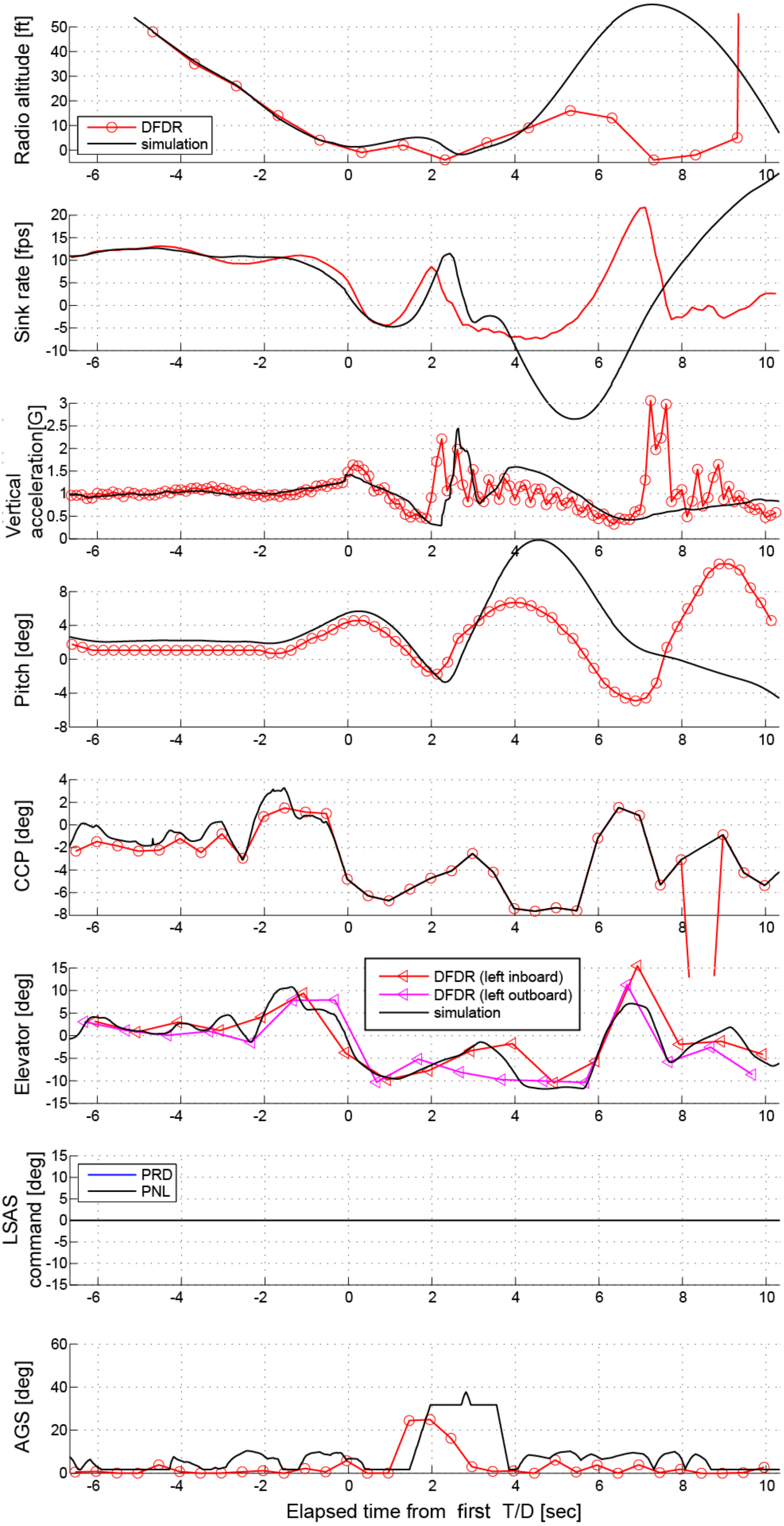

Figure 9 Simulation with LSAS Off

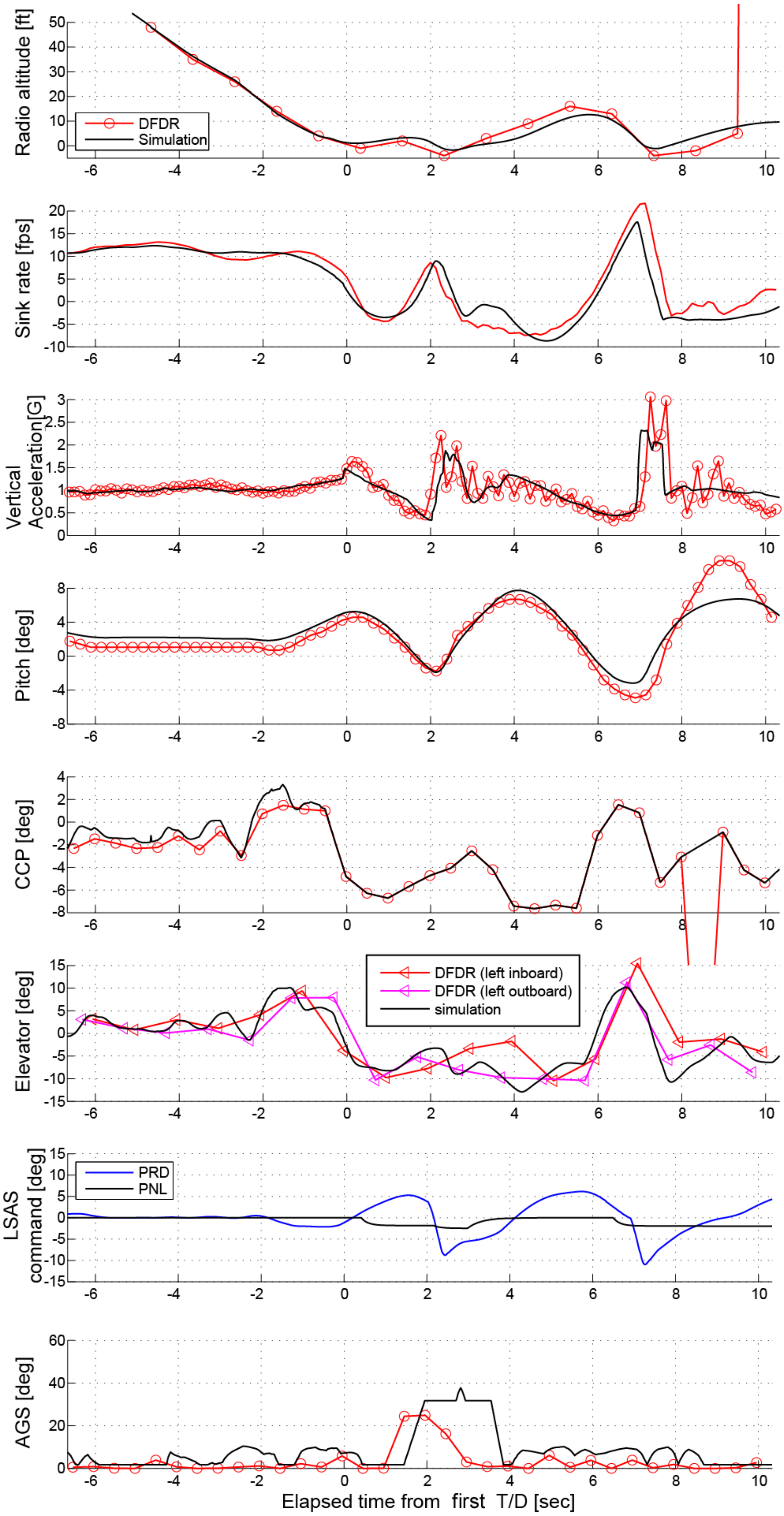

Figure 10 Simulation with LSAS On

2.14.6 CG and Cockpit Height Change Below 50 ft RA

The cockpit of MD-11 series airplane is far ahead (by 31 m) of the CG. Hence, when the pitch attitude variation is large, as was the case in this accident, it is possible that the cockpit height changes differently from that of the CG. Hence, the height of the CG, cockpit and MLG tires (height above runway) were examined with the flight simulation program made by the airplane manufacturer. As the compression of the landing gear strut is not taken into account, some MLG heights are shown below zero. (Figure 11)

The CG height and that of the MLG tire showed similar change; however, the changes of the cockpit height showed differently as shown below.

a. The pitch angle started to increase about 1.5 seconds before the first touchdown and this continued until the touchdown resulting in the smaller cockpit sink rate than that of the CG. When the airplane touched down, the cockpit sink rate was about 2 fps against the MLG tires' about 7 fps.

b. At the time of the first bounce, the CG and MLG tires moved up about 4 ft. Meanwhile, the cockpit sank about 9 ft not going up, due to the pitch angle decrease.

c. About 3 seconds after the second touchdown, the cockpit reached the highest point of about 40 ft. About 1 second later, the CG and the MLG tires reached the highest point of about 33 ft and 16 ft, respectively.

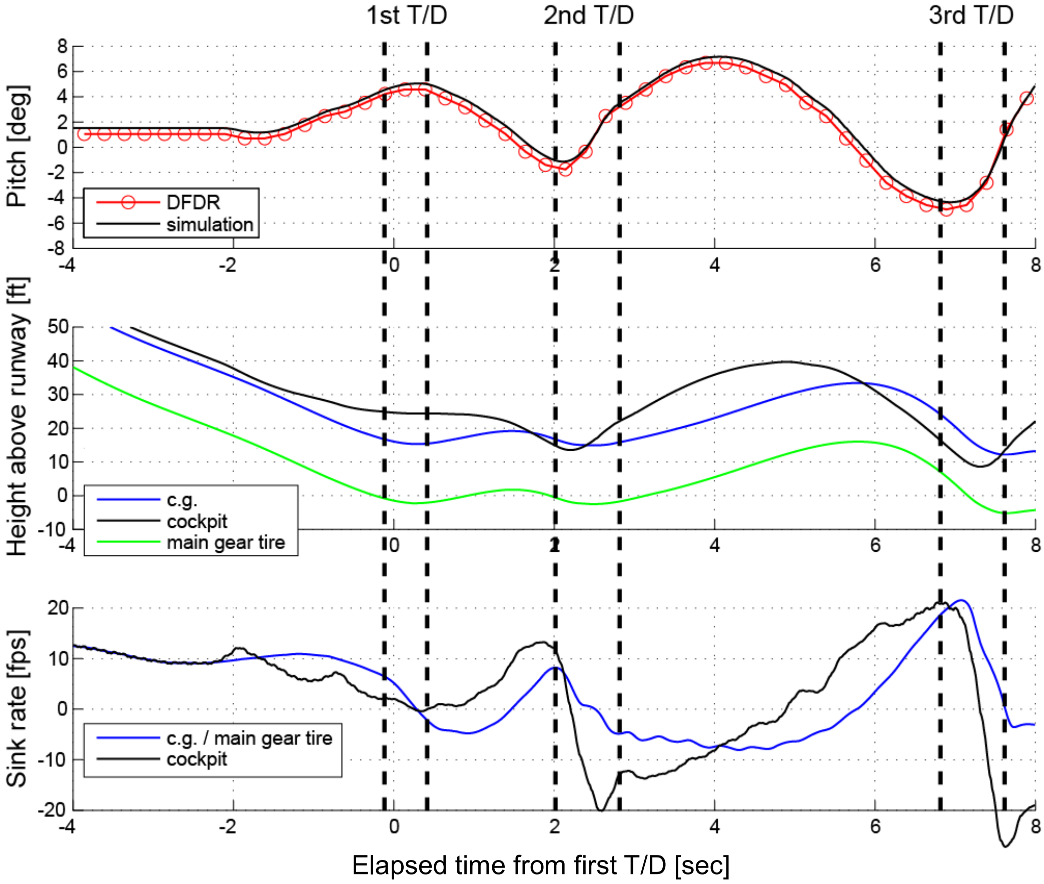

Figure 11 Analysis of Pilot's Eyes (Place) on Touchdown

2.14.7 AGS Deployment

When the AGS is deployed, the lift decreases and would contribute to reduce the height of a bounce. Therefore, the condition of the operation of the AGS was examined.

a. Required time for AGS deployment

(1) According to the airplane manufacturer, the estimated time from the touchdown on the MLGs to the start of the deployment of the AGS is 1.25 seconds to be broke down as:

(a) Wheel spin-up detection ………………………….. 50 msec
(b) FCC relay activation …………………………… 200 msec
(c) Mechanically activation of the spoiler deployment ………… 1,000 msec

(2) The required time to start the AGS deployment (the time from the increase in the vertical acceleration following the first touchdown to the extension of the AGS by 10° or more) was examined for the landing in this accident and in the previous 60 landings. (Figure 12)

The averaged time in the total 61 landings was about 1.4 seconds, with a dispersion of about 2 seconds. The required time in the accident landing was about 1.2 seconds, within a range of the observed dispersion. Note that these values may have errors due to the data recording intervals which are 0.5 seconds for AGS and 0.125 seconds for the vertical acceleration.

The JTSB requested the Company via NTSB to provide the other MD-11 airplanes data to survey the normal range of the required time for AGS deployment; however, owing to no cooperation from the Company, the JTSB was unable to confirm whether or not the AGS deployment value was normal.

b. Detailed AGS deployment sequence

The designer/manufacturer's manual states that the AGSs deploy up to 30° upon the MLG touchdown by sensing the MLG wheels spin-up, and continue to deploy to 60° maximum upon the NLG touchdown by sensing the compression of the NLG strut. The DFDR records show that the AGS angle in this accident was about 25° maximum.

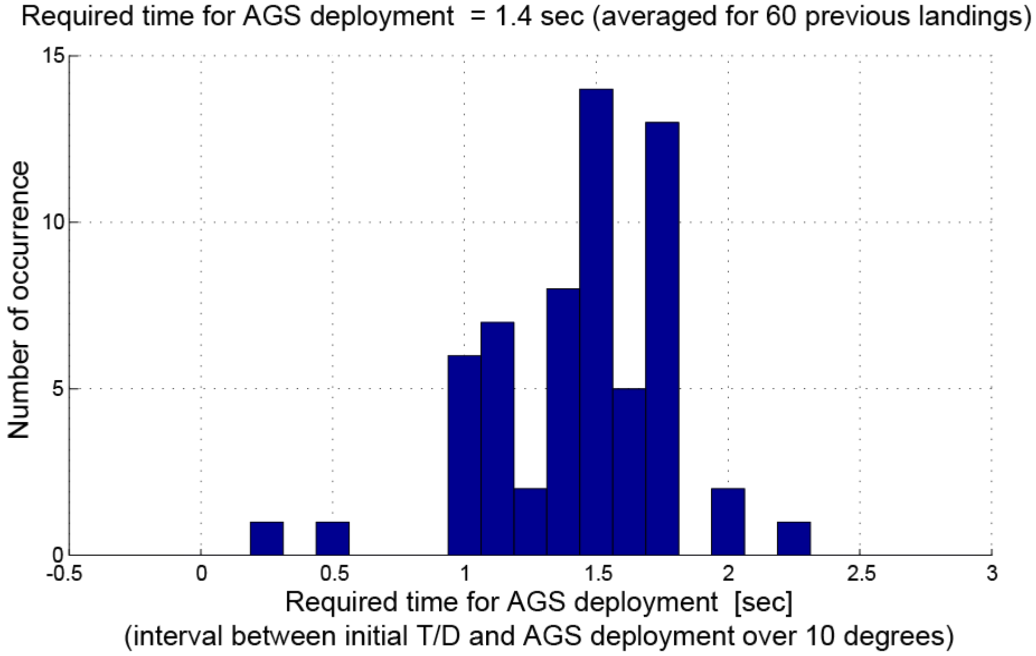

Figure 12 Observed Required Time for AGS Deployment in the Previous 60 Landings

c. AGS retraction sequence

According to the airplane manufacturer's manual, advancement of the No. 2 (central) engine thrust lever triggers the retraction of the deployed AGS. Because the DFDR does not record thrust resolver angle (TRA), we used the calculated TRA using the engine manufacturer's conversion program to know the relation between the thrust lever operations and AGS retraction. The examination revealed the following: (Figure 13)

(1) The DFDR records show that the AGS was retracted between 2.0 and 3.0 seconds after the first touchdown. Note that this value may have errors due to the data recording intervals which are 0.5 seconds for AGS and 0.125 seconds for the vertical acceleration.

(2) According to the TRA estimation, the No. 2 engine thrust lever was advanced about 3.2 seconds after the first touchdown.

(3) Above mentioned findings suggest that the AGS was retracted almost at the same time when the No.2 engine thrust lever was advanced.

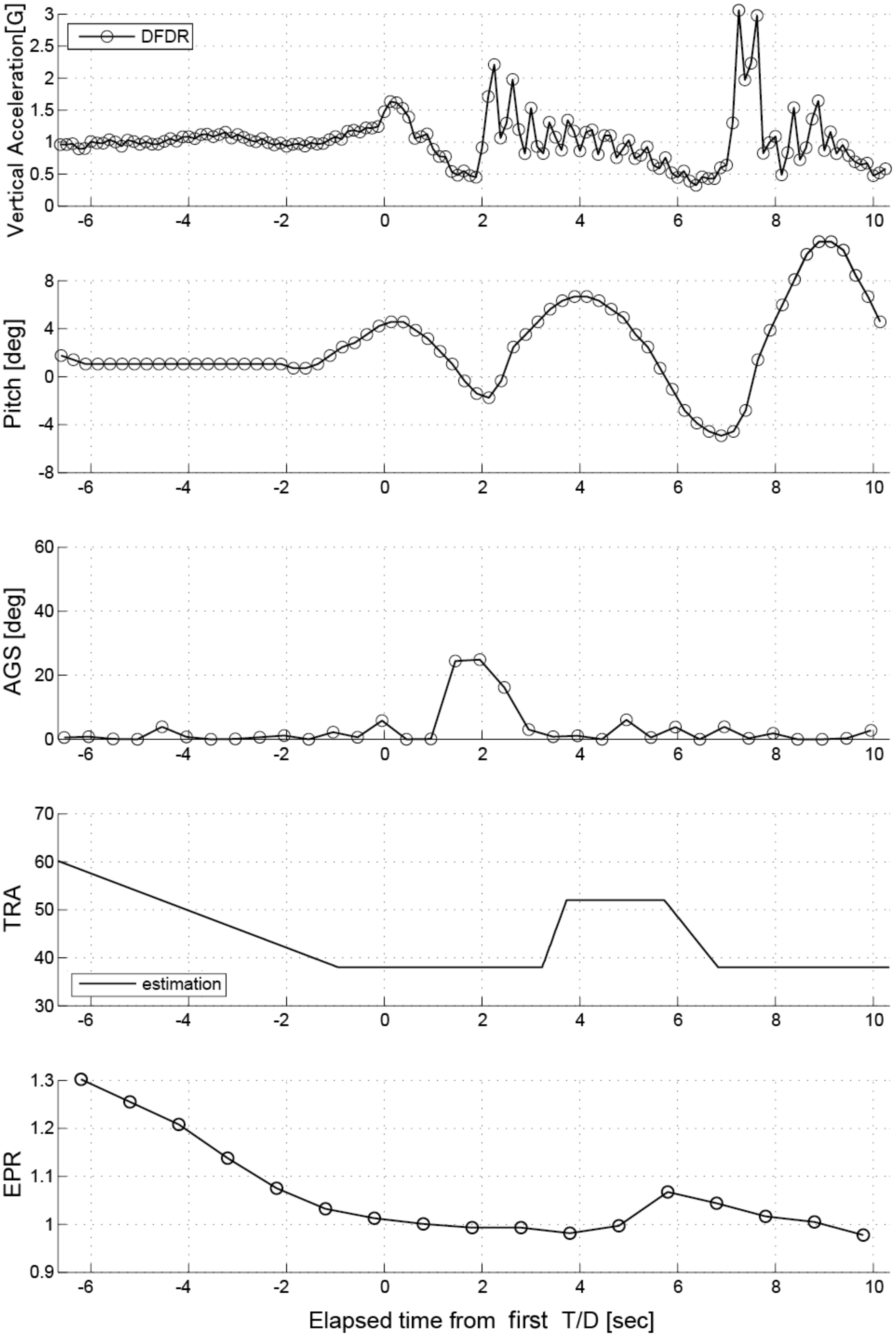

Figure 13 AGS Retraction

2.14.8 Estimation of Third Touchdown Status

The DFDR records and the Camera Images were used to estimate the process how the mechanical energies of the third touchdown were vertically absorbed into the landing gears and fuselage structure.

As the nose-down attitude for the third touchdown in Image “43” is shallower than that of Image “42,” it is estimated that the NLG touchdown took place between Images “42” and “43.” The nose-down attitude seen in Image “43” shows left MLG was still in the air, while the Image “44” shows the left wing being bent downward hard. Therefore, it is estimated that the left MLG touched down sometime between Images “43” and “44,” while the center and right MLGs touchdown between Images “43” and “45.”

These Images and DFDR records are synchronized to be shown in Figure 14. The synchronization was made by comparing calculated sink rate from the image analysis with that from the DFDR records.

The touchdown timing calculated from the Images corresponds to the attitude and acceleration data from the DFDR records; The following reasons made it impossible to get more detailed touchdown timing of each landing gear:

a. The Camera Images interval was about 267 milliseconds,

b. The number of pixels in each pictures was 672 by 224, and

c. The recorded time in the Camera Images had not aligned to JST/UTC, so there were some time errors.


42 6:48:26.6


43 3rd touch down on NLG 6:48:26.8


44 Just after 3rd touch down (MLGs) 6:48:27.1


45 Fuselage twists to the right 6:48:27.4

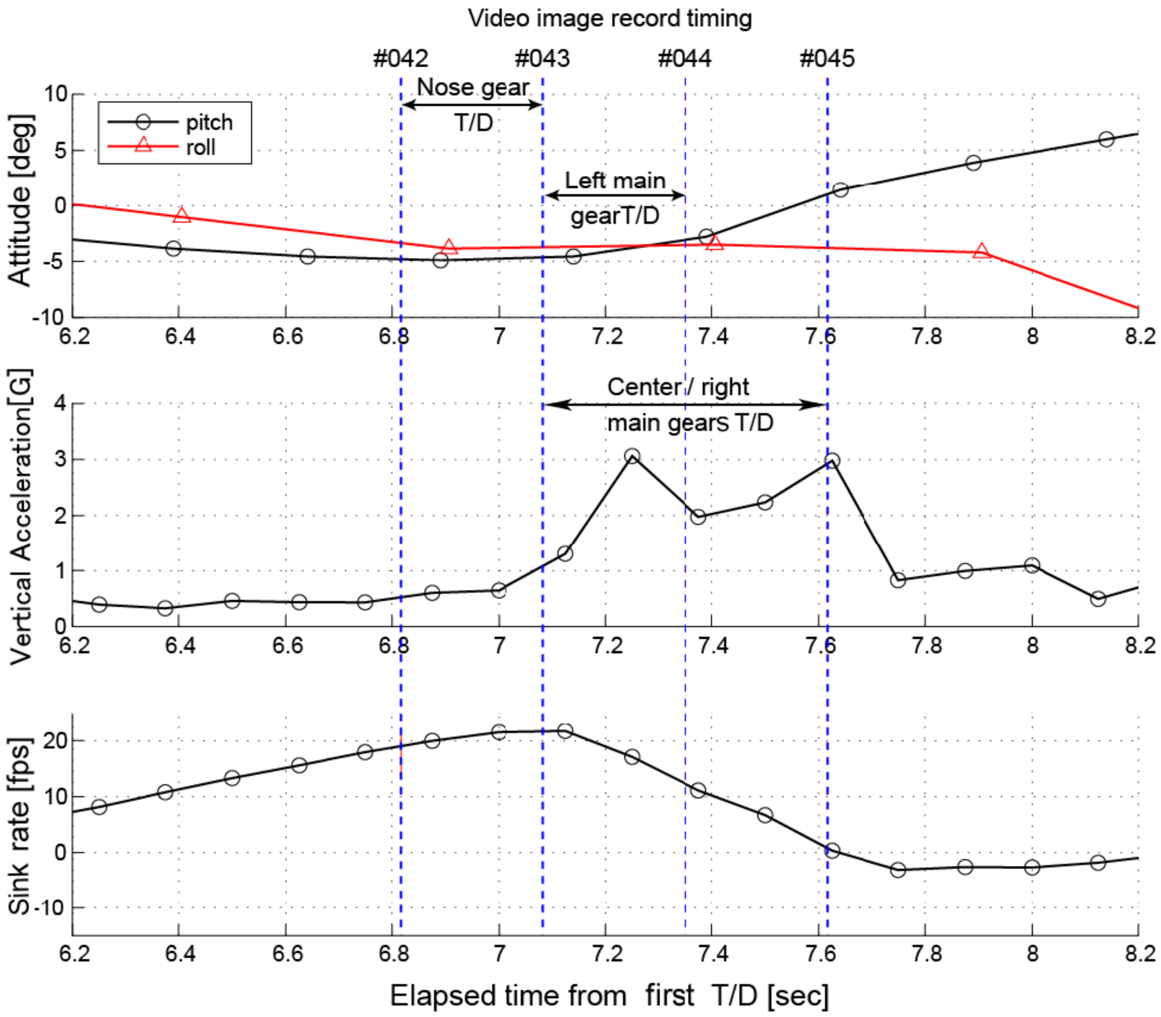

Figure 14　Estimation of Third Touchdown Status

2.14.9 Vertical Energies on Touchdowns

In order to estimate the energies absorbed by the landing gears and airplane structure upon the second and third touchdowns, the vertical kinetic energies (the sum of translational, rotational and potential energies) were calculated and compared to the related data about the Newark accident and the FAA requirements for certification (ultimate load) as well as the energy value (1,500,000 lb-ft) estimated by the airplane manufacturer, which will cause the wing rear spar to fail if transmitted into a single MLG, as shown in the NTSB Newark accident report (Table 2). For this calculation, the sink rate just before touchdown, the rolling rate (pitch/roll rate), the generated lift (vertical acceleration) were taken into consideration. The results are as follows:

a. The vertical energy of the airplane held at the second touchdown reached 2.1 times greater than the requirement for certification (ultimate load) specified by the FAA.

b. The vertical energy of the airplane at the third touchdown, in which the left wing was broken, had reached 2.1 times greater than the energy in the Newark accident, 6.8 times the FAA requirement for certification (ultimate load) and 2.2

times the energies estimated to cause the wing structure failure in the NTSB Newark accident report.

c. The CG displacement from the start to the end of the third touchdown was assumed to be 3 ft considering the maximum compression for the MLG struts and tires. Images "45" suggest that even after the MLGs compressed to the maximum extent, the airplane sank further downward as the structural failure progressed. It is possible that the vertical mechanical energies absorbed by the landing Gears and airplane structure upon touchdown had likely been greater than the estimates.

Table 2 The results of estimated vertical dynamic energies on touchdown

	2nd touchdown, Narita accident	3rd touchdown, Narita accident	Newark accident	FAA requirement for certification	Wing fracture (Note 2)
Landing weight (lb)	405,000	405,000	452,000	491,500 (Note 1) Maximum landing weight	–
Sink rate just before touchdown (fps)	7.2	21.5	11.0	12.0	–
Lift just before touchdown (G)	0.4	0.6	0.5	1.0	–
Roll rate just before touchdown (deg/s)	-3.4	-0.9	7.0	0.0	–
Pitch rate just before touchdown (deg/s)	1.5	1.2	0.0	0.0	–
CG movement from the start to the end of touchdown (ft) (The maximum landing gear compression assumed to be 3 ft)	3.0	3.0	3.0	3.0	–
Vertically translational energies (ft-lb)	329,948	2,911,516	849,255	494,553	–
Rotational energies (ft-lb)	20,491	7,034	46,499	0	–
Potential energies (ft-lb)	685,260	456,840	678,000		–
Vertical mechanical energies (ft-lb)	1,035,700	3,375,390	1,573,754	494,553	1,500,000
Vertical mechanical energies/Newark Incident (%)	66	214	100	31	95
Vertical mechanical energies/CFR specified values (%)	209	683	318	100	303
Vertical mechanical energies/Main wing destruction scenario (%)	69	225	105	33	100

(Note 1) It is assumed that 45% (221,175) of the maximum landing weight is loaded to one MLG.

(Note 2) According to NTSB Newark accident report (NTSB/AAR-00/02), section 2.5.1, Boeing estimates that the MD-11 landing gear strut will bottom and cause the wing rear spar to fail if approximately more than 1,500,000 ft-lbs of energy is transmitted into a single MLG.

2.14.10 Studies on Possible Means to Avoid This Accident

We studied on the following three cases to see how a flight develops to find the possibility to avoid this accident:

a. flare initiated at 30 ft RA as described in the flight manual;

b. nose down column input was held at the neutral position just before the first touchdown

c. bounce recovery executed during the second bounce

d. go-around executed during the second bounce; and
e. flight in a situation where the time required for AGS deployment is reduced, which is considered to be effective for moderating a bounce after touchdown

We used the flight simulation program made by the airplane manufacturer.

2.14.10.1 Flare initiated at 30 ft RA

The airplane behavior was examined for the case where the airplane approaches in the same manner as in this accident until 30 ft RA and starts flare at 30 ft RA. The examination revealed the following: (Figure 15)

a. The DFDR records show that the sink rate did not decrease until around 10 ft RA and it remained still 7 fps when the airplane touched down. Meanwhile, in the case of flare start at 30 ft RA, the sink rate began to decrease around 20 ft RA and the sink rate decreased to 2 fps at the time of touchdown.
b. When the flare started at 30 ft RA, the vertical acceleration on touchdown was about 1.1 G. The bounce height after the touchdown was limited, and the vertical acceleration on the second touchdown after the bounce was about 1.2 G. This means if the flare had started in an appropriate manner at 30 ft RA, large bounces after the touchdown, such as seen in the first and second touchdowns which triggered this accident, would have not occurred.

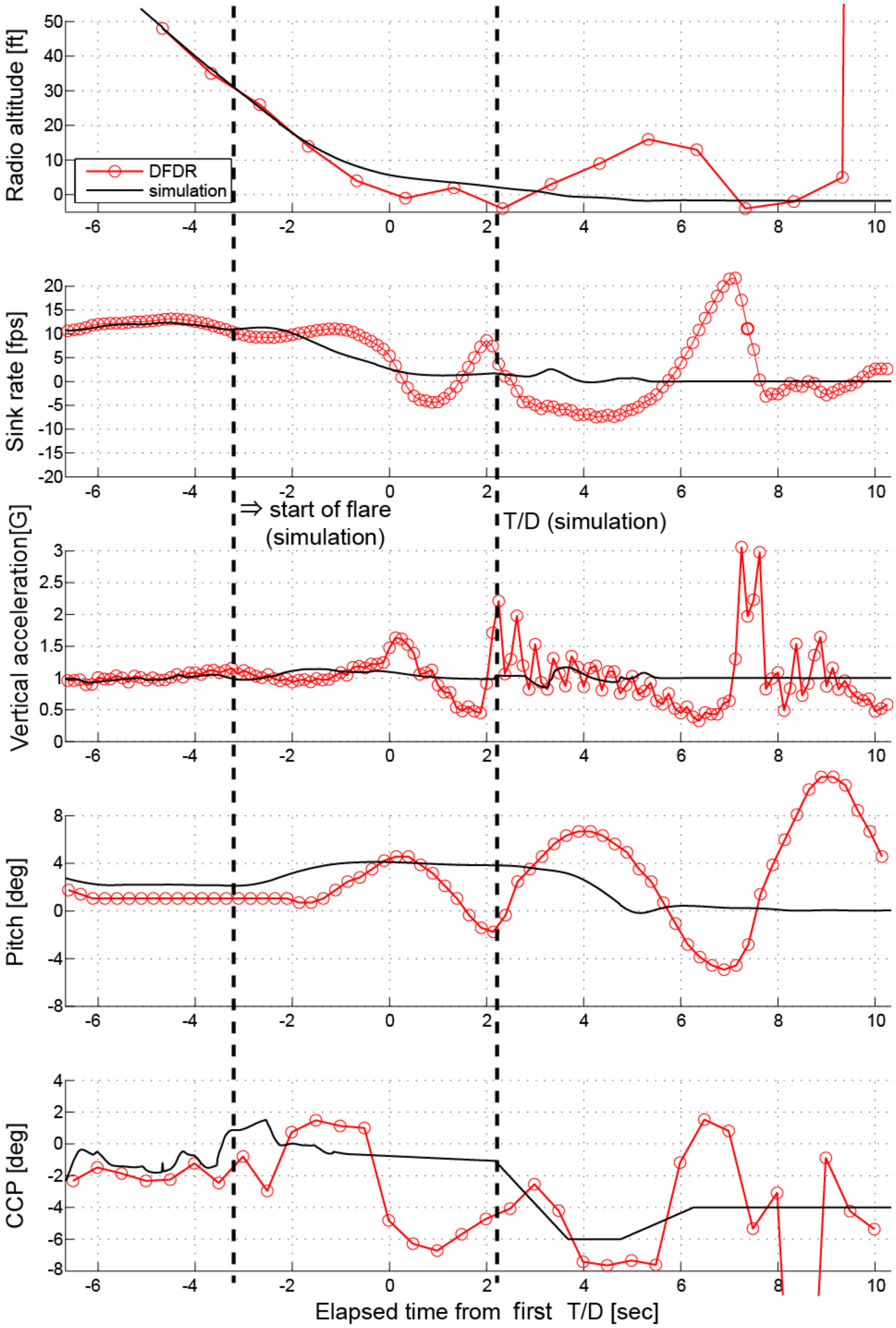

Figure 15 Simulation for a Case When the Flare is Started from 30 ft RA

2.14.10.2 Nose-Down Column Input Held at Neutral Position Just Before First Touchdown

As described in 2.14.4, the elevators deflections corresponding to the control column input, have the largest influence on the pitch attitude variations just before and after the first touchdown and the nose-down motions during the two bounces. The airplane behavior was examined in the case where the nose-down control column input just before the first touchdown is limited to the neutral position (-2°) and held it thereafter. The examination revealed the following: (Figure 16)

a. The maximum pitch angle after the first touchdown was 5.0º and there was no significant difference from that of 4.6º recorded in this accident.

b. Although the first bounce was larger than that of the accident, the second bounce was quite small. No large pitch attitude variations occurred, either.

c. The airplane landed on the MLG first at the second touchdown with almost the same sink rate of the second touchdown as that of the accident.

d. The maximum vertical acceleration (1.9 G) was observed upon the second touchdown, but it was far less than the airplane tolerance limit which leads to a destruction.

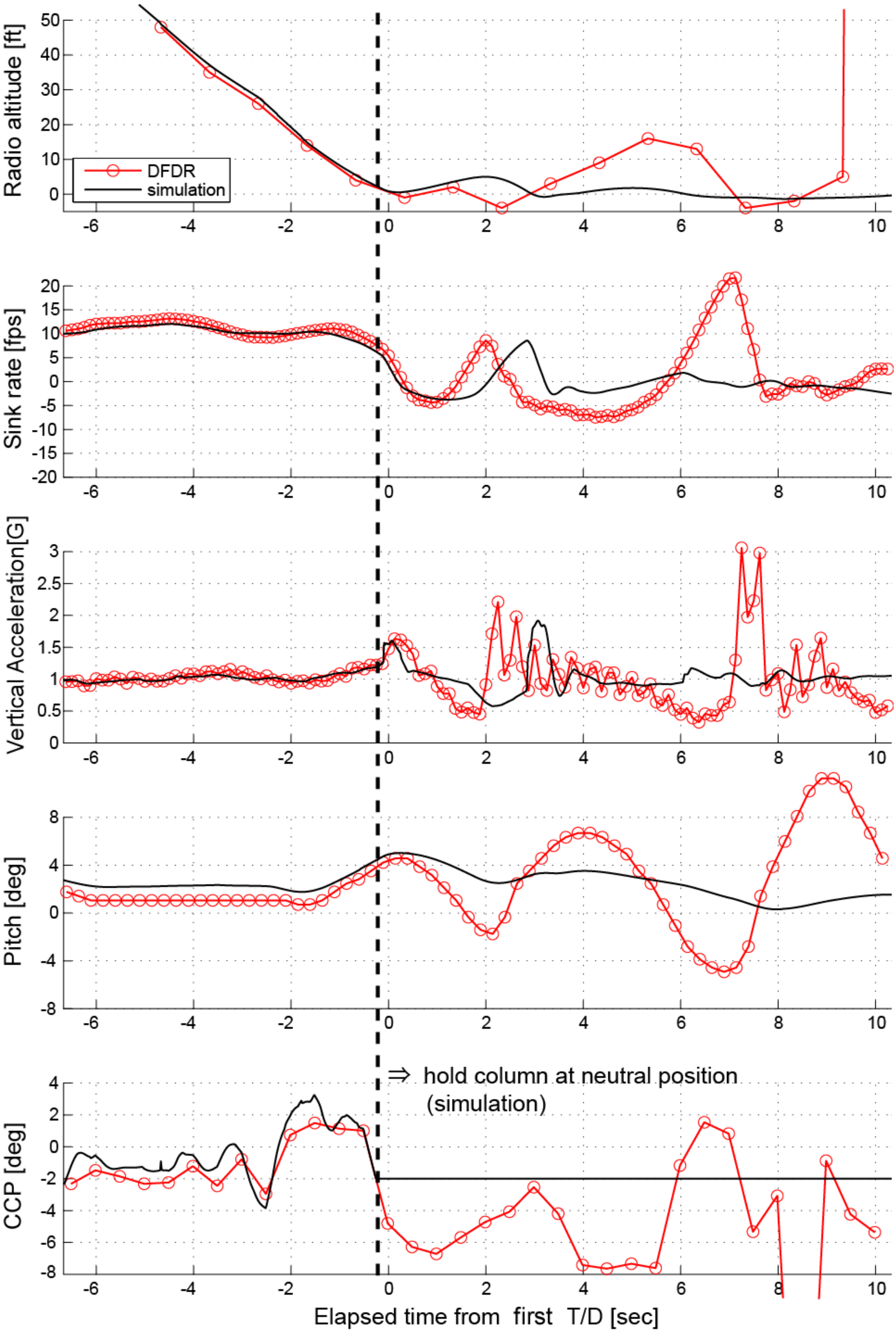

Figure 16 Simulation for a Case Where a Nose-Down Column Input Held at the Neutral Position Just Before First Touchdown

2.14.10.3 Bounce Recovery Operation During the Second Bounce

The airplane behavior was examined in the case where a bounce recovery is initiated at 5 ft RA during the second bounce. The results are as follows: (Figure 17)

a. The pitch angle had already begun to decrease at the time of the recovery initiation, but even at this stage the subsequent rapid nose-down motion could have been avoided by applying large backward column input, and negative pitch attitude could have been avoided.

b. Sink rate control by maintaining pitch angle 7.5° together with added thrust made it possible to limit the vertical acceleration on the third touchdown to less than1.2 G.

However, the timing of the third touchdown is prolonged until 22 seconds after the second touchdown by this bounce recovery. Considering that appropriate attitude and power control are necessary during that recovery operation and also additional runway length is required, the bounce recovery may not be practical.

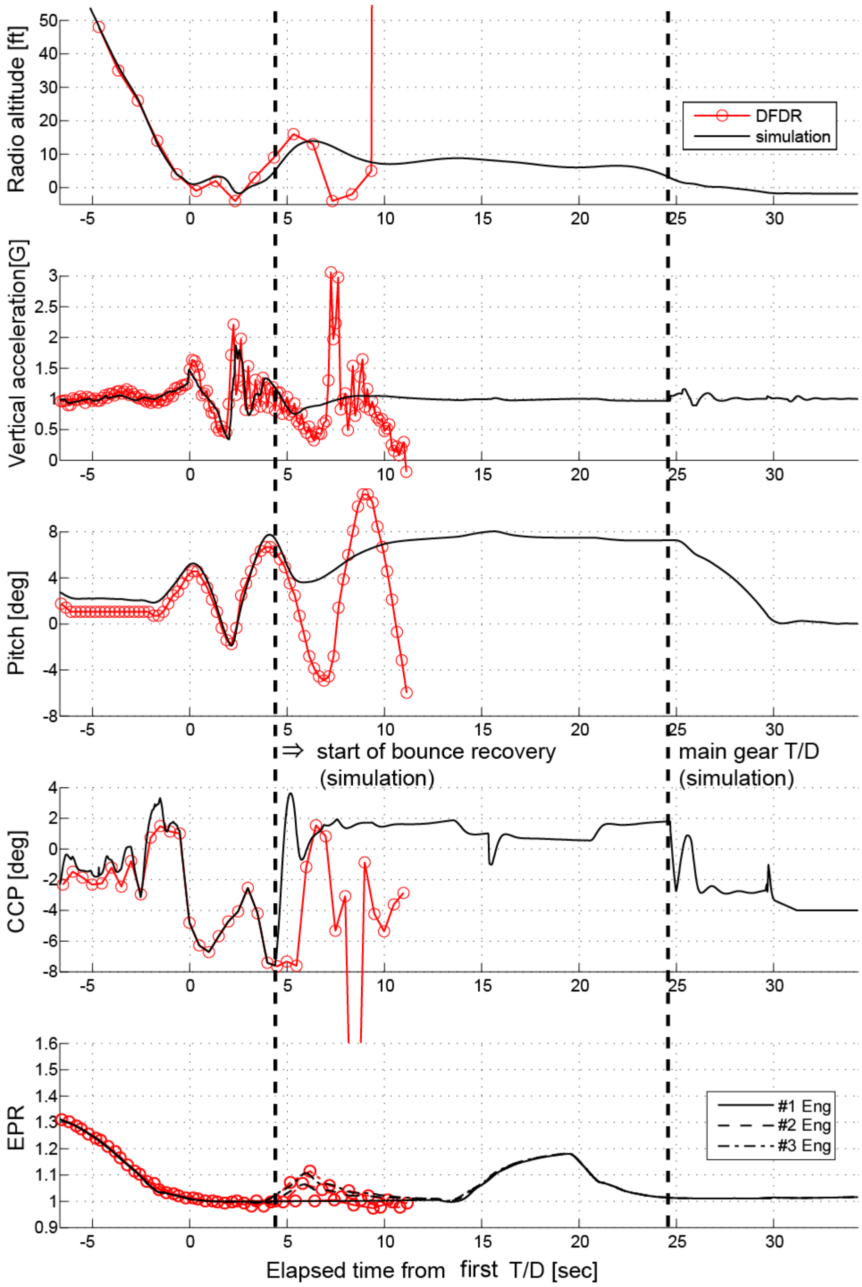

Figure 17 Simulation for a Bounce Recovery Operation during the Second Bounce

2.14.10.4 Go-around Operation During Second Bounce

The airplane behavior was examined in the case where a go-around is initiated at 5 ft RA during the second bounce. The results are as follows: (Figure 18)

a. The pitch angle had already begun to decrease at the time of the go-around initiation, but even at this stage the subsequent rapid nose-down motion could have been avoided with large backward column inputs, and negative pitch attitude could have been avoided.

b. A go-around was possible before the third touchdown by increasing the thrust simultaneously with a nose-up control column inputs mentioned above.

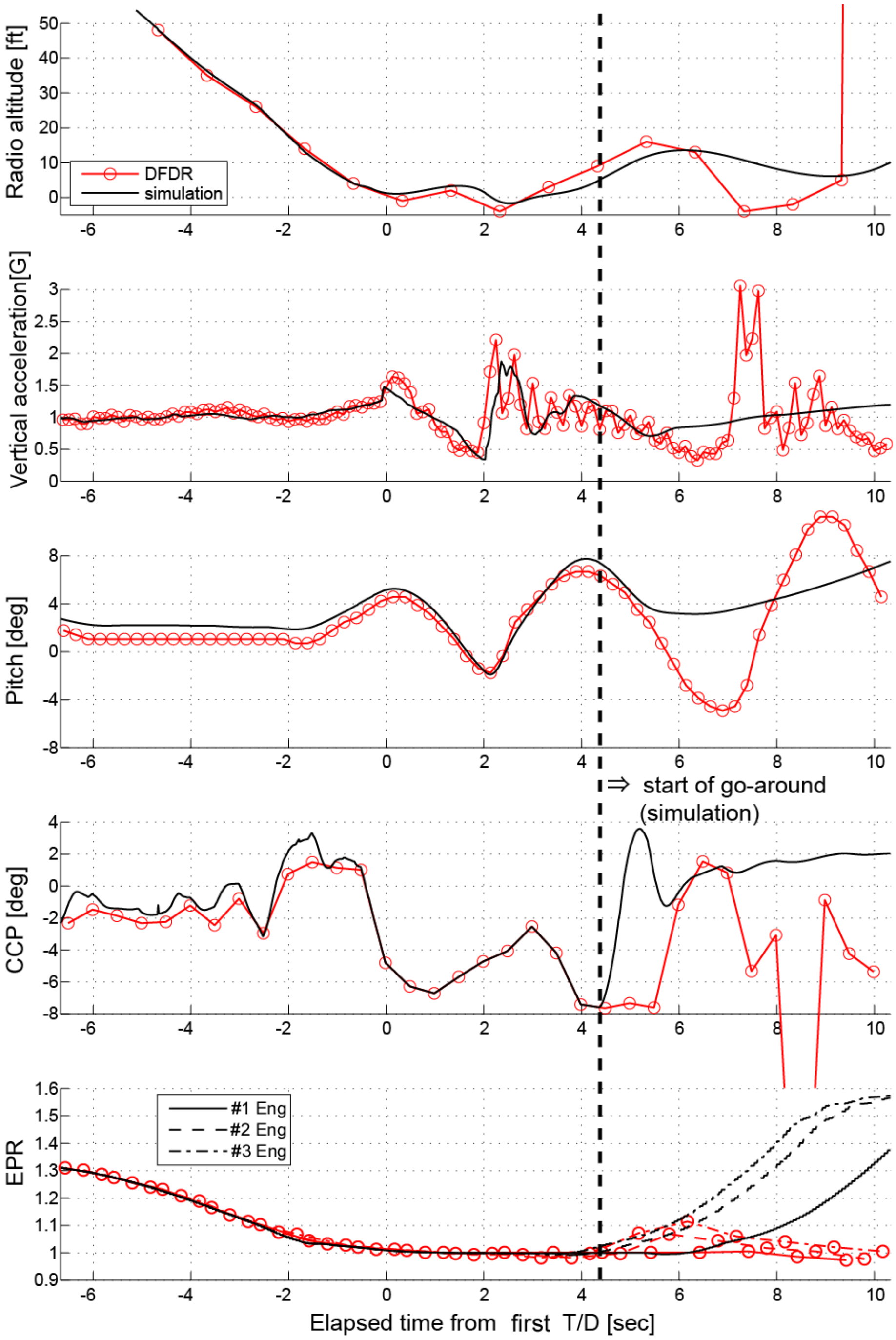

Figure 18 Simulation for Go-around during the Second Bounce

2.14.10.5 Reduced Required Time for AGS Deployment

We examined the airplane behavior in the case where the required time for AGS deployment is 0.61 seconds—almost the half of that observed in the accident. The results are as follows: (Figure 19)

a. The AGS deployment during the first bounce generated nose-up moment and restrained the nose-down motion. With reduced ASG deployment time, sooner deployment is possible and this provides longer nose-up moment durations, resulting in a large effect on nose-down restraint.

b. As the nose-down motion during the first bounce was restrained, the pitch angle upon second touchdown was positive—2.0º, and the airplane touched down on the MLGs. The loss of lift during the first bounce was also restrained since nose-down restraint brought a higher angle of attack. This resulted in a smaller sink rate at the touchdown—6 fps, smaller than 9 fps recorded in this accident.

c. Because the second touchdown was made on the MLGs, the NLG did not receive a bounce back from the runway surface resulting in very small nose-up moment after the second touchdown. On the other hand, the sink rate was smaller than that of the accident, so was the vertical acceleration on the second touchdown—1.5 G, smaller than that of the accident. These factors prevented any bounce from happening after the second touchdown.

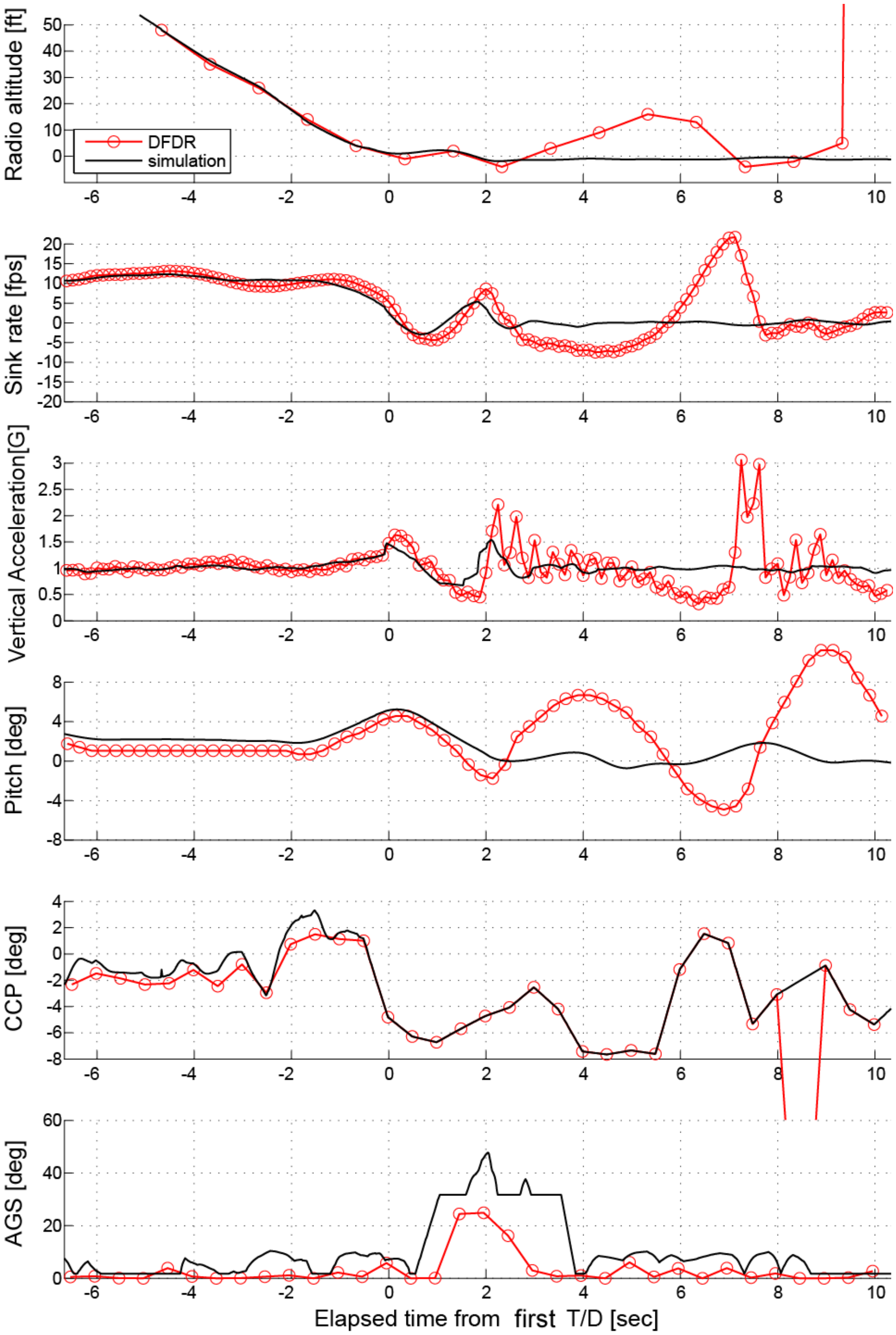

Figure 19　Simulation for a Case with Reduced Required Time for AGS Deployment

2.15 Items Described in the Company's Manuals, etc.

2.15.1 The Company's Flight Operations Manual (FOM)

2.15.1.1 Chapter 2, General Policies

a. *2.5 FATIGUE*

It is the crewmember's responsibility to be properly rested for each phase of the trip. However, if circumstances prevent this, no FedEx crewmember should feel pressured to fly when not properly rested. A crewmember who is fatigued should immediately notify Crew Scheduling if unable to complete a trip.

b. *2.67 LEG SWAPPING*

It has become customary for the Captain and First Officer to fly alternate legs. This is an acceptable practice under normal circumstances. There are times, however, when the Captain may elect to conduct takeoffs and landings "out of sequence" under unusual circumstances such as critical weather conditions or complicated departure or arrival procedures. It is also important for the Captain to consider landing currency when assigning flight legs.

(The rest is omitted)

2.15.1.2 Chapter 6, Arrival

a. *6.45 STABILIZED APPROACH CRITERIA*

(The forward part is omitted)

All flights must be stabilized by 1,000 feet above airport elevation when the airport is IFR and by 500 feet above airport elevation when the airport is VFR. The approach is considered stabilized when all of the following are met:

- *The airplane is in its final landing configuration.*
- *All briefings and checklists are accomplished.*
- *The engines are operating at a power setting appropriate to the airplane flight conditions.*
- *Descent angle and rate are appropriate for the type of approach being flown. All available landing aids (ILS, VASI, PAPI, etc) must be used.*
- *Vertical and lateral displacement from the normal approach path is in accordance with CFM defined instrument approach tolerances for type of approach in use.*
- *The sink rate is no greater than 1,000 fpm. If an approach requires a sink rate greater than 1,000 fpm, a special briefing shall be conducted.*
- *Airspeed is flown in accordance with the CFM (Vapp or target, as applicable), with a variance no greater than +10 knots and no less than −5 knots. Momentary and minor deviations are only tolerated if immediate corrections are made.*
- *As the airplane crosses the runway threshold it should be stabilized on target airspeed within +5 knots until arresting descent rate at flare and positioned to make a normal landing in the touchdown zone (first 3,000 feet or the first third of the runway, whichever is less).*

If at any time any of these parameters are exceeded and timely corrections are not made, the PM or S/O shall state that the airplane is not stable and identify the condition. The Captain shall command or initiate a go-around unless in his *judgment this would create a greater hazard to flight safety.*

b. *6.47 GO-AROUND PHILOSOPHY*

The decision to execute a go-around is both prudent and encouraged anytime the outcome of an approach or landing becomes uncertain. FedEx considers the use of the go-around under such conditions as an indication of good judgment and cockpit discipline on the part of the flight crew.

2.15.2 The Company Flight Manual (CFM)

CHAPTER 7-1-5 APPROACH

a. *STABILIZED APPROACH 7-1-5-1*

Good landing are the result of good approaches. The majority of landing accidents/incidents can be attributed to an unstable approach between the FAF and touchdown. Control of the variables that result in a stabilized approach should start prior to the FAF.

These variables are configuration, speed, rate of descent, power setting and approach profile.

b. *WIND ADDITIVE ON APPROACH 7-1-5-2*

Vapp is the greater of Vref+5 or Vref+wind additive. Wind additive is one half of the steady state wind greater than 20 kt or full gust whichever is greater (maximum 20 kt).

With ATS-OFF, the pilot manually maintains Vapp. With ATS-ON, the pilot may apply wind additive by any method:

(Omitted)

2.15.3 Longitudinal Stability Augmentation System (LSAS)

The following descriptions are included in AUTOMATIC FLIGHT DESCRIPTION AND OPERATION in the Company's Flight Manual (CFM): (There are similar descriptions in Boeing's MD-11 Flight Crew Operations Manual (FCOM))

LONGITUDINAL STABILITY AUGMENTATION SYSTEM (LSAS) (FCC-908)

Changes provide enhanced commonality between trijet-model approach/landing handling characteristics and control column force deterrent as the aircraft is rotated to near tail-strike pitch attitudes during takeoff and landing. These changes, referred to as Low Altitude Stability Enhancement (LASE), are as follows:

- *Modified Pitch Rate Damper (PRD) – The existing high-altitude PRD operates throughout the entire flight envelope. The PRD will continue to provide 30% of its high altitude pitch rate damping from 16,500 feet down to field elevations.*
- *New Pitch Attitude Protection (PAP) Sub-function – The LSAS control law will implement a pitch attitude limiting function that will be enabled below 100 feet radio altitude. As with all LSAS elevator commands, the PAP will be limited to a total of 5 degrees of elevator authority. The PAP sub-function will be further limited to only command nose-down elevator displacements. If the airplane approaches a tail strike pitch altitude, the pilot-flying will perceive the effect of PAP as an increase in the control column force required to maintain the pitch attitude. The pitch attitude limit used by PAP will vary linearly from 30 degrees at 40 feet radio altitude down to a minimum of 9.5 degrees at 0 feet radio altitude.*

The PAP sub-function will be active for both takeoff and landing.

- *New Positive Nose Lowering (PNL) Sub-function – This new sub-function will only be applied during landing phase, and will not affect AUTLAND operations or Auto Flight System (AFS) autoland performance. The PNL sub function will apply approximately 3 degrees of nose-down elevator command at main wheel spin-up, at the same time that the FCC commands the Auto Ground Spoilers (AGS) to extend. As the spoilers extend beyond 10 degrees, the second phase of PNL will increase the nose-down elevator command to approximately 4 degrees. This sub-function, in combination with the enhanced PRD, will control the elevator to avoid aircraft nose-rise after touchdown, and to assist in de-rotation.*

  These LSAS changes will not affect the maximum override forces for LSAS, which are dependent upon the position of the Elevator Load Feel (ELF) actuator for any given airspeed. For the takeoff and landing phases, where PAP and PNL are active, the control column forces required to override LSAS are approximately 10 to 15 pounds.

2.15.4 The Company's Flight Manual (CFM)

Chapter 8-10A FLIGHT CONTROLS DESCRIPTION AND OPERATION:

a. *SPOILER SYSTEM*

Auto Ground Spoilers (AGS)

After landing, all ten spoiler panels may be extended to maximum deflection by automatic operation of the SPOILER handle. In order for this to occur, the SPOILER handle must be armed and the flaps 31 degrees or more.

After main wheel spinup, spoilers extend between 2/3 and full speed brake position. After nose gear touchdown, spoilers move the GROUND SPOILER position or, in case no nose wheel spinup is detected, ground spoilers extend after nose gear touchdown with any two throttles moved into reverse thrust. Maximum ground spoilers are then deployed.

CAUTION

If the number 2 engine throttle is not at idle at main gear wheel spinup, it is possible that the AGS will initiate deployment, then immediately retract the spoilers. If this occurs, ground spoilers must be manually extended.

2.15.5 Allowable Maximum Cross Wind Value (During Takeoff and Landing Average)

The CFM includes the maximum cross wind value for the airplane as 35 kt.

2.16 Evaluation of Load Transferred from the Left MLG to Wing Structure

2.16.1 Structural Analysis Simulation Performed by the Airplane Manufacturer

The fracture of the wing rear spar, where the structural failure appears to have initiated nearby, is observed similarities to the relevant events in the past (Newark accident in the U.S.A., in 1997 and Hong Kong accident in China, in 1999). The airplane manufacturer conducted a structural analysis simulation based on the analysis method used in the past, as modified to be consistent with this accident. The validation for the analysis model and its modification was conducted using a general finite element program MSC-Nastran, in-house aircraft dynamic landing analysis certification program B7DC, and a general dynamic analysis program ADAMS used in the past two events. The analyses simulation was conducted using the following initial condition consistent with the airplane at the 3rd touchdown, and the time when the condition occurred was referred as zero time.

a. The airplane weight, 405,120 lb with the CG at 31 % MAC.

b. The DFDR data (pitch angle, -4.6°; left roll, 3.7°; left yaw, 8.7°; longitudinal acceleration, 0.15 G backward; lateral acceleration, 0.13 G to the left; vertical acceleration, 1.21 G upward (including a lift of 0.56 G).

The analysis model for this simulation has the following restrictions:

a. The data from the landing gear drop test is available up to 12 fps (the upper design limit) sink rate. Estimated landing gear loads above 12 fps sink rate include errors in that there is no reference data available beyond the design limit, where nonlinear effect comes out.

b. The behavior of the cylinder and piston of the strut after the bottoming is complex so that the analysis model does not take this into account.

c. Structural failures are not taken into account.

The analysis showed that the left MLG strut bottomed at 0.2 seconds after the left MLG contacted with the runway, considering the piston stroke. The right MLG strut bottomed at 0.25 seconds. Both MLG was subjected to a load of at least 800,000 lb or more and 950,000 lb maximum with errors included.

Based on the above load, it is estimated that the rear spar shear flow around the failed area exceeded the fracture load in 0.2 seconds.

As this analysis assumes no structural failure, the shear flow continued to increase to reach 135 % of the fracture load in 0.3 seconds.

2.16.2 Load Transferred Evaluated by JAXA

In the left MLG teardown examination, there is no visible damage due to bottoming. The JAXA conducted the finite element analysis on the left MLG track beam bolt for the residual deformation (described in 2.11.1), using Marc R2008, which is a general nonlinear finite element program. The bolt was assumed to be made of heat treated steel (MIL-S5059) due to the lack of material properties on the bolt. The forced displacement was simulated with the assumption that the material has a longitudinal stiffness of 26,000 ksi and a Poisson's Ratio of 0.27, and would completely yield at 94 ksi. When the maximum forced displacement was 0.7 mm, the residual deformation was 0.046 mm, which is close to a residual deformation observed on the left MLG track beam bolt, as described in 2.11.1. The maximum reaction force applied in the analysis program was 887,000 lb. The track beam was likely estimated to be exposed to the maximum load which is equivalent to this value.

Regardless of bottoming, the load transferred from the track beam to the strut worked to the piston and the oil. The oil pressure is transferred into nitrogen gas compressing force. Also oil made the resistance of fluid flow when the oil goes up and through the gap between the orifice and the metering pin. The compressed nitrogen gas pushes the cylinder, while the fluid resistance is transmitted to the cylinder via the orifice support tube. The load, equivalent to that was applied to the track beam, transferred from the left MLG to the wing structure.

The result of this analysis almost matched the structural analysis simulation conducted by the airplane manufacturer.

2.17 Landing Gear Design

2.17.1 Landing Gear Design Criteria and Certification

The design criteria*9 applied to the MD-11 airplane requires the MLG system to be designed so that, if it fails due to overloads during takeoff and landing assuming the overloads to act in the upward and aft directions, the failure mode is not likely to cause the spillage of enough fuel from any part of the fuel system to constitute a fire hazard. (14 CFR 25.721 (a))

One of the design method to satisfy with the requirement is to equip the MLG support structure with a fuse pin*10. In the design of the MD-11 airplane, the fuse pins had been already installed in the MLG support structure.

However, the accident involved the MD-11 airplane in Newark in 1997 is concluded that, as it is the case for this accident in which the opposite wing structure was destroyed, a vertical (upward) overload transferred from the right MLG fractured the right wing structure followed by fuel spillage. Regarding that the MLG was not separated by the vertical overload, the Newark accident report states that "MD-11 landing gear fuse pins were designed and positioned to allow the landing gear to fail under loads in the aft direction." The FAA explained, in its response to the NTSB safety recommendation A-00-102, that "in designing the landing gear to comply with 14 CFR 25.721(a), the MD-11 main landing gear was designed for an overload condition in which the drag load was the primary component. This landing gear was not designed to separate for a purely vertical overload."

The FAA's explanation for the reason why it assumed the primarily drag overload was that "this overload condition was assumed to occur as a result of striking an obstruction (pure drag load), combined with a range of vertical loads from 0 to 2 G's."

However, the FAA stated that "the MD-11 was certified to 14 CFR 25.721(a) under the interpretation at the time of certification (omitted) in current accepted practice, a more comprehensive range of up and aft load combinations is considered, in effect requiring vertical overload fusing of landing gear" and "The landing gear would not meet the requirement if the airplanes were being certified under the present interpretation."

As of April 2013, the FAA initiates rulemaking to revise the relevant airworthiness regulation, however, the proposed regulation does not include the overload condition in which the vertical load is the primary component, and the FAA plans not to revise the airworthiness regulation but to issue an advisory material (Advisory Circular) with regard to the present interpretation which is already being applied on all new transport airplane programs including the Boeing 787 and the Airbus 350. The European Aviation Safety Agency (EASA) has already revised, as described in 2.17.3, the Acceptable Means of

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*9 The airplane design criteria (including basic interpretations) apply requirements to aircraft, which are effective on the day of application. The applicant (or the certificate holder) and the certification (examination) authorities discuss to determine whether the requirements to be revised or added following subsequent revisions of the criteria.

*10 A fuse pin is a safety device designed to break away in the case of mechanical overload to protect important structures. A fuse pin used in the MLG breaks to separate the MLG from the wing to keep the fuel tank damage free when an overload is applied to the MLG.

Compliance (AMC) for the European Certification Specification (CS) 25.721(a) which correspond to 14 CFR 25.721(a). (The specification has also been revised, adding side loads as an acting overload directions.)

The means of compliance with standards that are described in the guidance material such as AMC and Advisory Circular of FAA illustrates the acceptable means. In addition, other means are not excluded. The sole issuance of the advisory material will not lead to a mandatory requirement to include the assumption of a primarily vertical overload, as observed in the accident at Narita and Newark airports.

2.17.2 Criteria Applied to the Airplane (Excerpt)

The following descriptions are included in 14 CFR 25. 721:

General

(a) The main landing gear system must be designed so that if it fails due to overloads during takeoff and landing (assuming the overloads to act in the upward and aft direction), the failure mode is not likely to cause—

(Omitted)

(2) For airplanes that have a passenger seating configuration, excluding pilots seat, of 10 seats or more, the spillage of enough fuel from any part of the fuel system to constitute a fire hazard.

2.17.3 Current Criteria and Interpretation Guidelines Revised by EASA (Excerpt)

2.17.3.1 Descriptions in CS 25. 721 General (See AMC 25. 963 (d))

(a) The landing gear system must be designed so that when it fails due to overloads during take-off and landing, the failure mode is not likely to cause spillage of enough fuel to constitute a fire hazard. The overloads must be assumed to act in the upward and aft directions in combination with side loads acting inboard and outboard.

(The rest is omitted)

2.17.3.2 Descriptions in AMC 25. 963(d) Fuel Tanks: General

1. PURPOSE

This AMC sets forth an acceptable means, but not the only means, of demonstrating compliance with the provisions of CS-25 related to the strength of fuel tanks in emergency landing conditions.

(Omitted)

e. Landing gear separation. (Compliance with CS 25.721(a) and CS 25.963(d)(5))

Failure of the landing gear under overload should be considered, assuming the overloads to act in any reasonable combination of vertical and drag loads, in combination with side loads acting both inboard and outboard.

(The rest is omitted)

2.18 Additional Information

2.18.1 Safety Recommendations Issued by NTSB After the Newark Accident

a. Outline of the Accident (excerpt from the NTSB accident report)

On July 31, 1997, about 01:32 eastern daylight time, a McDonnell Douglas

MD-11F, N611FE, operated by Federal Express, Inc., (FedEx) as flight 14, crashed while landing on Runway 22R at Newark International Airport. The scheduled cargo flight originated in Singapore on July 30 with intermediate stops in Penang, Malaysia; Taipei, Taiwan; and Anchorage, Alaska. On board this airplane were the captain, the first officer who had taken over the flight in Anchorage for the final leg to Newark and three passengers. All five occupants received minor injuries in the crash and during subsequent egress through a cockpit window. The right wing separated from the fuselage just inboard of the wing MLG near WS264 followed by fuel spillage. The right engine and the right MLG were separated from their attach points. A fire broke out.

The FDR data indicated that after the airplane's initial touchdown, it became airborne and rolled to the right as it touched down again. The airplane continued to roll as it slid down the runway, coming to rest inverted about 5,126 ft beyond the runway threshold and about 580 ft to the right of the runway centerline.

b. Safety Recommendations

(1) A-00-092: to FAA: Convene a joint task force to develop a pilot training tool to include information about factors that can contribute to structural failures involving the landing gear, wings, fuselage, etc.

(2) A-00-093: to FAA: Convene a joint task force to develop a pilot training tool to provide a syllabus for simulator training on the execution of stabilized approaches to the landing flare, the identification of unstabilized landing flares, and recovery from these situations, etc.

(3) A-00-094: to FAA: Convene a joint task force to develop a pilot training tool to promote an orientation toward a proactive go-around.

(4) A-00-095: to FAA: Require principal operations inspectors assigned to Part 121 carriers that use auxiliary performance computers to review and ensure the adequacy of training and procedures.

(5) A-00-096: to FAA: Require the installation of the MD-11 flight control computer-908 software upgrade on all MD-11 airplanes.

(6) A-00-097: to FAA: Require on all MD-11s equipped with the flight control computer-908 software, the retrofit of DFDR systems with all additional parameters required to precisely identify and differentiate between pilot and LSAS elevator control activity.

(7) A-00-098: to FAA: Review and, if appropriate, revise the DC-10 and MD-11 throttle resolver angle (TRA) driven ground spoiler knockdown feature to ensure that it does not prevent ground spoiler deployment at moderate TRAs.

(8) A-00-099: to FAA: Require DC-10 and MD-11 operators to provide their pilots with information and training regarding the ground spoiler knockdown feature and its effects on landing characteristics and performance.

(9) A-00-100: to FAA: Sponsor NASA studies regarding the stability and control characteristics of widely used, large transport-category airplanes to identify undesirable characteristics, etc.

(10) A-00-101: to FAA: Implement improved certification criteria for

transport-category airplane designs based on the study results of recommendation A-00-100.

(11) A-00-102: to FAA: Conduct a study to determine if landing gear vertical overload fusing offers a higher level of safety than when the gear is overdesigned. If fusing offers a higher level of safety, revise 14 CFR Part 25 to require vertical overload fusing of landing gear. (The FAA had earlier approved the designs which have no assumption of an overload failure mode in which an upward load is outstanding, but in reply to this safety recommendation, the FAA expressed its view that these designs had satisfied airworthiness requirements under the interpretation at that time, but they were not compatible under the interpretation as of 2004.)

(12) A-00-103: to FAA: Require manufactures of CFR Part 23 and Part 25 airplanes and Part 121 operators to revise their hard landing inspection and reporting criteria to account for all factors that can contribute to structural damage; instruct principal maintenance and operations inspectors assigned to Part 121 operators to ensure that these changes have been made to operator maintenance manuals and Flight Operations Quality Assurance exceedence monitoring programs.

(13) A-98-80: to RSPA (The Research and Special Programs Administration): Require that air carriers transporting hazardous materials have the means to quickly retrieve and provide consolidated specific information of all hazardous materials on an airplane in a timely manner to emergency responders.

2.18.2 Safety Recommendation Letter Dated on July 12, 2011 Issued by NTSB

On July 27, 2010, a McDonnell Douglas MD-11F, registered D-ALCQ, operated by Lufthansa Cargo AG as Flight 8460, repeatedly bounced during landing on runway 33L at King Khalid International Airport, Saudi Arabia. The aft fuselage ruptured behind the wing trailing edge following the third touchdown. The fire broke out when the leaked fuel from the ruptured fuel lines went into the left hand wheel well and caught fire.

The NTSB issued the safety recommendation mentioned below.

a. Background of developing the Safety Recommendation

The MD-11 has had at least 14 hard landing events (the D-ALCQ accident inclusive) of such severity that the airplane sustained substantial damage since it was entered into service in 1990. In three cases, the wing spar was broken, rolled over and caught fire. (See Table 3)

The NTSB noted that seven of those events have taken place since 2009, about 9 years after the introduction of the LASE function for the LSAS in 2000. It raised concerns that MD-11 flight crews are not effectively trained to recognize and arrest high sink rates during landing or to properly control the pitch attitude following a hard landing. It noted that FedEx conducted a study of 6,300 MD-11 landings and determined that derotation rates averaged about 1° per second.

Therefore, the NTSB issued the safety recommendations to the FAA as in the next paragraph.

Table 3 Hard Landing Cases with Structural Failures Involved for MD-11 Series Airplanes (From 1993 to 2010)

Date	Airport	Operator	Event
4/30/1993	Los Angeles	Delta Air Line	Bounced hard landing
8/19/1994	Chicago	Alitalia	Landing bounce and porpoise
7/31/1997	Newark	FedEx	Wing spar break and rollover
8/22/1999	Hong Kong	China Airlines	Wing spar break and rollover
5/22/2000	Taipei	Eva Air	Hard landing and go around
11/20/2001	Taipei	Eva Air	Bounce and nose landing gear (NLG) strike
6/7/2005	Louisville	UPS	Hard NLG strike
3/23/2009	Narita	FedEx	Wing spar break and rollover
6/3/2009	Urumqi	China Cargo	Hard landing and tailstrike
9/6/2009	Khartoum	Saudi Arabian Airlines	Hard landing
9/13/2009	Mexico City	Lufthansa Cargo	Hard landing and NLG strike
10/20/2009	Montevideo	Centurion	Hard landing and main landing gear collapse
7/27/2010	Riyadh	Lufthansa Cargo	Hard landing and fuselage failure
9/22/2010	Kabul	World Airways	Hard NLG strike

(Source : NTSB)

b. Safety Recommendations to FAA:

(1) A-11-68: Require Boeing to revise its MD-11 FCOM to reemphasize high sink rate awareness during landing, the importance of momentarily maintaining landing pitch attitude after touchdown and using proper pitch attitude and power to cushion excess sink rate in the flare, and to go around in the event of a bounced landing.

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(2) A-11-69: Once Boeing has completed the revision of its MD-11 FCOM as recommended in Safety Recommendation A-11-68, require all MD-11 operators to incorporate the Boeing-recommended bounce recognition and recovery procedure in their operating manuals and in recurrent simulator training.

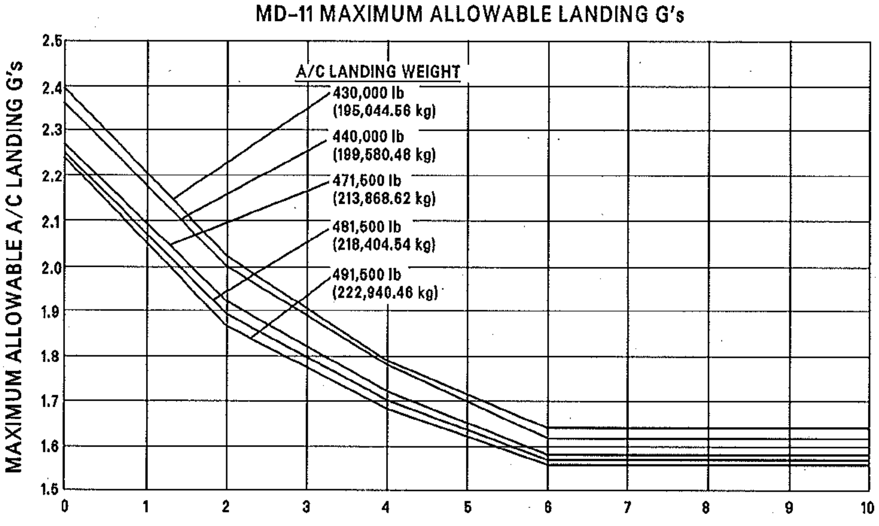
2.18.3 Standard for Judgments about Hard Landing Inspection in AMM

The following descriptions about a standard for judgments about hard landing inspection are included in AMM 05-51-03:

B. A hard landing condition occurs when the airplane lands at a sink-rate of more than 10 ft (3.048 m) for each second, at or below the maximum design structural landing weight. The minimum G-load with a sink-rate of 10 ft (3.048 m) for each second, at or below the maximum design structural landing weight, is 2.2G. Also, a hard landing condition occurs when the airplane lands at a sink-rate of more than 6 ft (1.8288 m) for each second, at a weight more than maximum design structural landing weigh of 491,500 lb (222,941 kg). If the sink-rate cannot be found when the airplane lands, do the hard landing inspection.

C. In addition to the effects of sink-rate, severity of the landing depends on the vertical *accelerations at the beginning of the touchdown, and the airplane roll and pitch attitude effects on the number of effective landing gears that absorb the landing energy. If the vertical acceleration at the beginning of the landing is less than 1G, the potential energy that is normally accommodated by wing lift may instead be transmitted into the landing gear.*

D. *Operators should evaluate the effects of pitch and roll and determine if a singular landing gear may have absorbed significant loading. To determine if such loading has occurred, use the landing G's vs roll angle graph. If still undetermined, operator may submit landing parameter to their Boeing Field Service Representatives of Boeing Service Engineering for analysis.*



(Source: AMM)

Figure 20 Landing G's vs Roll Angle

3. ANALYSIS

3.1 Airmen Competence Certificate and Others

3.1.1 Crew Qualification

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

3.1.2 Physical Condition and Training

a. As described in 2.5.3 a, the PIC had pains in the sacrum, but he submitted a medical certificate stating that he had made a full recovery.

b. As described in 2.5.7 a, it is highly probable that the PIC returned to his flight duties after having missed a chance of receiving periodic training during the extended sick leave.

However, he received the requalification training and his skill was evaluated as appropriate in the proficiency check.

c. As described in 2.5.7 b, it is highly probable that the FO received scheduled training and passed the examination.

d. The description in 2.13.4 shows that the Company provided bounce recovery training to all MD-11 pilots after the Newark accident in 1997. It is highly probable that this training was later provided only on the occasion of initial training and transition training. In light of the personal history of the PIC and the FO described in 2.5.7, it is highly probable that they had received bounce recovery training in 2006, respectively.

e. As described in 2.5.2.2, the sequence of flying by the PIC and the FO started with the flight from Anchorage to Narita on March 15, and the time difference between the two places was large. Subsequent flights on and after March 17 were conducted within the Asia region, and the time difference of those flights was one hour.

There was a long period of no documented activity for both the PIC and the FO from the evening two days before the accident until the morning the day before the accident. It is probable that they obtained sleep during that period. On the day before the accident, the PIC told his spouse that he planned to go to bed by 15:00 to rest for the upcoming flight and there was a corresponding period of no documented activity. It is probable that the PIC obtained sleep during that period.

There were three fragmented periods of no documented activity for the FO. It is probable that the FO obtained sleep during that period. Therefore, it is probable that the adequate rest layover time was provided to the PIC and the FO.

f. As described in 2.5.4, the PIC and the FO had conversations about feeling tired. It is probable that they were fatigued to some extent. However, the subsequent conversations in the cockpit were as usual, and their rest layover time was considered adequate according to the last 72-hour history (See Attachment 5-2). It is probable that their fatigue level was such as the crew feels during the usual international flight. Although their fatigue level at the time of the accident might not be so high as to adversely affect their maneuvering performance or judgment, it could not be conclusively determined to what extent the fatigue influenced their maneuvering performance or judgment at that time.

According to the statements of their family members and other flight personnel, it is probable that there were no problems with their physical condition and they were not fatigued.

However, in case of the accident flight, the PIC and the FO engaged in two duty flight during a period of time to obtain sleep, and the accident occurred during early morning hours, i.e., the time to wake up in Asia. It is probable that the alertness and concentration of the PIC and the FO was lowered.

g. As described in 2.5.6 a and c, the temazepam which is not allowed to use on a regular basis before operating an aircraft was detected in the PIC's urine.

Temazepam is a metabolite of diazepam, which is contained in Mylan. However, nordiazepam is a major metabolite of diazepam and was not detected in the PIC's urine. It is highly probable that he was carrying the temazepam medication and had taken the medication on this flight duties accompanying with an overnight stay.

The detected results didn't reveal the medicine amount taken and how many hours before the flight duty. But, this substance was detected in the PIC's urine but not in his blood. It is highly probable that the medication did not influence his performance in his duty flight. According to the statement of a line check airman who flew with him just before the accident, described in 2.5.4, as well as the CVR records, it is probable that the PIC was not under influence such as drowsiness caused by the medicine. It could not be determined that the PIC took the medication in a manner consistent with FAA guidance.

3.2 Airworthiness Certificate of the Airplane

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

As described in 2.6.3, the airplane experienced a tail strike when it executed a go-around on May 19, 1999. But the airplane was conducted no major repair work other than the aft lower fuselage. It is highly probable that the tail strike accident had no affect to this accident.

3.3 Relations to Meteorological Phenomena

It is highly probable that the weather condition at the time of the accident had influenced the control operations of the FO, as described below.

a. As described in 2.7.2, 2.7.4 and 2.7.5, the average wind direction at the time of the accident was almost a head wind with small cross wind component from the left. The reported gust component around average wind velocity reached about ±15 kt. Therefore, it is highly probable that the final approach was rough air condition, but the magnitudes of the average wind and the gust were within the authorized range stipulated in the manual.

It is highly probable that large attitude and airspeed fluctuations due to the rough air required keen attention and appropriate, deliberate response to maintain attitude and flight path especially after disconnecting the autopilot.

Flare and de-crab maneuver to correct for the cross wind component from the left and align the longitudinal axis with the runway centerline were necessary prior to touchdown. It is highly probable that keener attention and appropriate, deliberate handling under the rough air conditions were required, compared to those under the calm air conditions.

b. As described in 2.14.1, the wind velocity at 1,000 ft was about 60 kt; 500-1,000 ft, about 50 kt; and near the ground, about 25 kt. It is highly probable that there were wind velocity difference of about 25 kt between the surface and 500 ft and above. Therefore, it is highly probable that this wind condition forced flight crew to control the airplane using thrust lever to maintain airspeed. However, it is highly probable that the wind velocity change didn't reach the threshold value for the windshear warning to be issued.

   It is highly probable that the vertical wind profile existed not only for the accident airplane but also preceding airplanes.

c. As described in 2.7.3, in the absence of microburst warning by the Doppler LIDAR and cumulonimbus observations, it is highly probable that windshear caused by localized microbursts was absent at the time of the accident.

3.4 Accident Scenario

3.4.1 From the First Communication Established with Narita Tower

It is highly probable that in the flight from Guangzhou Airport to Narita Airport, the FO was on the PF duties in accordance with the leg swapping practice.

As described in 2.1.1 a., the airplane contacted the Narita Tower at 06:41:35 and received a landing clearance at 06:46:29. It received wind information from time to time while it was approaching and it is highly probable that based on the information, it had set Vapp at 164 kt (Vref plus 10 kt) as described in 2.1.1 a.

The selection of Vapp was based on the rules mentioned in 2.15.2 b, while the condition of the winds was changing momentarily at the time of the accident. As the selection of Vapp is finally left to the PIC's judgment, it is highly probable that the crew had chosen 10 kt for the additive value.

3.4.2 From 1,000 ft RA to Autopilot Off

Judging from the following three reasons, it is highly probable that the airplane was unsteadily flying through rough air so that even with the help of autopilot and autothrottle, it was difficult to control airspeed and attitude.

a. As described in 2.1.1 b, the control inputs (the CCP, CWP and rudder) were steadily changing after descending through 1,000 ft RA until AP was disconnected.

b. The attitude and CAS were largely fluctuated.

c. The PIC, who was operating as the PM, uttered "Yee haw ride' em cowboy."

At 06:47:40 the CAWS announced 500 ft. As mentioned above the CAS was frequently fluctuating and at this moment the CAS was (172, 178 or) 179 kt. The range of CAS fluctuation was from 152 to 180 kt (12 kt slower and 16 kt faster than the selected 164 kt), exceeding "stabilized" approach criteria (plus 10 kt from the selected speed) mentioned in 2.15.1.2 a. It is highly probable that this airspeed deviation had stemmed from the effects of gusty winds and a delayed response of the autothrottle. The PM called "stabilize" and most likely let the PF continue approaching, disregarding airspeed deviation of more than Vapp plus 10 kt, while the PF agreed this call to continue to do so.

3.4.3 From AUTOPILOT OFF Onward

3.4.3.1 From Autopilot Off to About 100 ft RA

a. The PF's control and the airplane's behavior

As described in 2.1.1 c, the autopilot was disconnected at 198 ft RA, while the autothrottle remained engaged. The pitch angle then was decreasing from 1.4° while the CAS was 178.5 kt (faster than Vapp by 14.5 kt). It is highly probable that the glide slope deviation of GS 0.19 dot indicates that the airplane was almost on the glide slope. Just after the autopilot was disconnected, the pitch angle temporarily decreased as low as 0.4° but it increased to 3.5° by the time the airplane descended to 92 ft RA. In the meantime, the CAS decreased as low as 154 ft (Vapp minus 10 kt) and it was flying below the glide slope with the deviation of GS -0.54 dot. The EPR remained near 1.0 (idle thrust) until it descended to 130 ft RA. It is highly probable that this large speed decrease stemmed from the inability of the autothrottle system to counteract the large wind velocity change (decreasing head wind component) during the descent as described in 2.14.1, and the fact that the thrust was kept at idle during the increment of the pitch angle to 3.5°. The increased pitch angle and corresponding column input indicates the PF's intention to correct the lowered flight path.

It is highly probable that the delayed counter action against temporarily decreased pitch angle following the disconnection of the autopilot, and the decreased airspeed deriving from the wind velocity change and airplane control without thrust increase, most likely caused downward deviation from the glide slope. Under these circumstances, it is highly probable that overriding the autothrottle to increase thrust while increasing nose-up elevator input would prevent airspeed decrease and downward deviation from the glide slope. But it is highly probable that the PF did not take these responsive actions and this inaction influenced his control operations in the next stage. It is highly probable that the PF judged it possible to land safely while approaching the runway by mainly watching the runway and PAPI.

b. The PM's Response

As described in 2.1.1 c, the fact that the CVR records did not include the voices of pilots during the last phase of the approach indicates that the PM had not made any calls or advice to the PF. As described in 2.5.1 b, the PF was a well experienced MD-11 pilot; however, he needed to be very alert to stabilize the airplane for the final approach against external disturbances. The PM should have made advice to the PF about the airplane attitude and called out the deviation from the glide slope and the CAS.

Further, overriding or taking over the control of the airplane to execute a go-around was one of the options for the PM as he was the PIC.

3.4.3.2 From About 100 ft RA to About 50 ft RA

a. The PF's control and the airplane behavior

As described in 2.1.1 c and 2.1.1 d, the pitch angle, which had been 3.5° at about 92 ft RA, gradually decreased, and the angle had become 1.1° at about 48 ft RA. The CAS increased to 161.0 kt from 154.0 kt, but it was still slower than Vapp (164 kt). The deviation from the glide slope had increased to GS -1.11 dot from GS -0.54 dot.

As described in 2.1.1 c and 2.1.1 d, the heading changed from 331 ° to 333 ° when descending through 100ft RA, and continued to keep around 333 ° until the touchdown. It is highly probable that the de-crab maneuver started about 100ft RA and continued to correct for the cross wind component from the left and align the longitudinal axis with the runway centerline.

As described in 2.13.1 a and 2.13.3, an operation which should be done at this stage was to maintain an appropriate approach attitude (particularly, the pitch angle) while staying on the glide slope. In order to stay on the glide slope amid strong head winds as in the accident, it is probable that an airplane needs to use more thrust and higher pitch attitude than ordinal landing situations. (as described in 3.4.1, the pitch angle cannot be so high because Vapp in this accident had been set at Vref plus 10 kt).

As described in 2.14.2, the profile of previous 60 landings suggests that a pitch angle of about 2° to 3° is necessary for a proper approach. But it is highly probable that the actual pitch angle decreased as low as 1.1°, followed by the increased CAS and descent rate, increasing the downward deviation from the glide slope.

It is probable that the decreased pitch angle, the deepened flight path and the thrust control by the autothrottle made it difficult to flare subsequently.

b. The PM’s Response

The PM should have made appropriate advices to the PF about the decreased pitch angle, deepened flight path and the need to maintain the speed, and if need be, he, as the PIC, had to override or take over the control of the airplane anticipating a go-around.

3.4.3.3 From About 50 ft RA to First Touchdown

a. The PF’s control and the airplane behavior

(1) Descending through 50 ft

As described in 2.1.1 d and 2.14.2, when the radio altimeter indicated about 48 ft, the pitch angle was 1.1° and a sink rate was about 13 fps. As described in 2.14.2, it is highly probable that compared to the previous 60 landings (the pitch angle of 2-5° and the sink rate of 5-10 fps), the pitch angle was low and the sink rate was large when this accident occurred.

(2) Thrust Lever operation

It is highly probable that the DFDR records show that autothrottle was engaged, and the thrust levers were in the retard mode which started to automatically decrease the thrust below 50 ft, reaching idle when descending through 20 ft.

It is probable that, taking into account the strong head wind, the large sink rate and the deepened flight path, the PF should have delayed the timing to retard the thrust levers or should have slowly retard the lever to delay to be idle, by way of overriding autothrottle. It is highly probable that the PF did not control the thrust actively and properly by overriding the autothrottle.

(3) Flare

As described in 2.13.1 a, the Company's flight manual describes the normal landing as follows:

> *"Maintain a stabilized flight path through the 50 and 40 foot CAWS callouts (unless sink rate is high). At 30', a smooth 2.5 degree flare should be initiated so as to arrive below 10' in the landing attitude. Elevator back pressure should be relaxed, and a constant pitch attitude should be maintained from 10' radio altitude to touchdown."*

As described in 2.14.10.1, if an appropriate flare had been initiated at 30 ft RA as stipulated in the manual, two large bounces which triggered this accident could have been avoided.

Nevertheless, as described in 2.1.1 d, it is highly probable that the PF initiated the flare later than usual at 20 ft, not at 30 ft. Rapid and large column input during flare indicates the PF's recognition of the late flare. The pitch angle remained 1.1° (about 2° smaller than usual) until the flare, and the pitch angle temporarily decreased to 0.7° (below 20 ft) followed by the quick increment of the pitch angle to 4.6° in 2 seconds before touchdown. A nose-down CCP input (-0.7° to -3.0°) just before the flare probably affected the temporary decrease of the pitch angle.

In order to ensure that "*Elevator back pressure should be relaxed, and a constant pitch attitude should be maintained from 10' radio altitude to touchdown*" as described in 2.13.1 a, a pilot should not push or pull the control column, having a full picture of the airplane attitude and maintaining the attitude properly. When the back pressure is relaxed, the CCP might shift slightly forward. But as described in 2.1.1 d, it is highly probable that the control column was pushed largely forward (-4.9°) just before the touchdown.

It is highly probable that, due to the failure to reduce sink rate to an allowable level, the airplane consequently experienced the large sink rate upon the first touchdown as high as 7 fps, much larger than the average of the previous 60 landings, as described in 2.14.2. It is highly probable that strong ground reaction caused by the large sink rate (vertical acceleration spiked to 1.63 G) and generated lift corresponding to the quick increase of the pitch angle, were strong enough to bounce the airplane off the ground (vertical acceleration before touchdown : 1.24G).

The reasons for the forward control column input just before the touchdown were not determined although we have following scenarios:

- The PF became concerned about the possible tail strike as a result of the rapid flare initiated at 20 ft RA,

- The PF was excessively concerned about possible nose-up motion due to the AGS deployment; or
- The PF hoped to put the NLG on the runway as soon as possible due to the landing amid strong winds.

The PF shouldn't have made a large nose-down elevator input (1.1° to -4.9°), considering the fact that the tail strikes pitch angle is 10°, and LSAS PNL function controls the possible nose-up motion upon AGS deployment.

The forward control column input was started at just after the call-out of 10ft. This input is, therefore, not considered as derotation, which is typically made after touchdown. It is somewhat likely that the forward control column input continued after touchdown was the reflection of the PF intent to have all landing gears touched down and have the airplane stabled on the ground.

As the airplane was landing under gusty wind conditions with high airspeed, the flare should have been conducted more cautiously than usual. As the changes in the airspeed and the descent rate cannot be fully compensated only by changing the airplane attitude, the PF should have used thrust without delay, foreseeing airplane behavior rather than handling the situation with the sole control column input.

b. The PM's Response

It is highly probable that the PM was able to expect the bounce, considering the high airspeed and high sink rate indicated by the constant CAWS call-out intervals as described in 2.14.3. The PM, as the PIC, should have been prepared for a takeover in case of bounces, with a possible go-around option in mind.

3.4.3.4 From First Touchdown to Second Touchdown

a. The PF's control and the airplane behavior

As described in 2.1.1 d and 2.14.3, the CAWS call-out interval every 10 ft from 50 ft almost remained at about 1 second and did not increase. Further, the airspeed on touchdown was fast. As described in 2.13.3, the PF should have been prepared for a bounce recovery, and he should have initiated the bounce recovery.

As described in 2.13.1 b, the CFM describes the bounce recovery as—"the PF should establish a 7 1/2° pitch attitude and increase thrust until the sink rate has been arrested and/or a normal landing is accomplished," and it does not require a complex operation. It is highly probable that the PF had not actually done a bounce recovery operation, because, as described in 2.1.1 e, the PF pushed the control column to -4.9° just before the touchdown; pushed further to -6.7° 1 second after the touchdown; and the EPR remained at 1.0.

The forward control column input just before and during the touchdown most likely resulted in the rapid derotation—from 4.6° at the first touchdown to below zero in 1.5 seconds. The decreasing pitch angle, with the MLGs still in the air, may have made it difficult for the PF to recognize the need for bounce recovery due to his lowering eye point as described in 2.14.6. It may be possible that he didn't realize the airplane had bounced.

As described in 2.1.1 e, the control column was pulled backward slightly (by 1°) from the negative peak value of -6.7°, but still remained in nose-down position (about -2° or lower). In this process, it is highly probable that LSAS issued nose-up command in line by the PRD function, as described in 2.14.5.2; however, because of the large nose-down control input the ultimate elevator angle remained in the nose-down (negative) position. It is highly probable that the nose consequently continued to go down, and the airplane touched down on the NLG with the pitch angle of -1.8°.

After the first touchdown, the pitch angle decreased by 6.4° in 1.75 seconds, from 4.6° to -1.8°, meaning the derotation rate was 3.6° per second. This rate is extremely high compared to the average derotation rate of 1° per second for the Company's MD-11 series airplanes, as described in 2.18.2. If, as described in 2.14.10.2, a forward control column input had been stopped at the neutral position (-2°), a bounce after the first touchdown would have been larger than in this accident, leading to the second touchdown on the MLGs due to the absence of negative pitch attitude, followed by very small bounce.

The AGS had deployed to 25° just before the second touchdown and generated a nose-up moment. However, it is very likely that mitigating effect of nose-down motion was small, because nose-down moment generated by elevator angle corresponding to the control column forward input was much larger than AGS nose-up moment as described in 2.14.4; and the AGS deployed just before the second touchdown since it took 1.2 seconds from MLG touchdown as described in 2.14.7. As described in 2.14.10.5, with the required time for AGS deployment of 0.61 seconds (about half the actually required time) would have given longer effect on nose-up motion, resulting in the prevention of the negative pitch attitude.

b. The PM's Response

It is highly probable that it would be difficult for the PF, who had been absorbed in the airplane control, to have recognition of the large bounce which required a bounce recovery. Therefore, it is probable that the PM should have taken an action actively in response to the situation because he was calmly monitoring the airplane attitude, the airspeed and other parameters.

In case of bounce as seen in this accident, the PM, after carefully monitoring the situations, should have decisively taken over the PF duties as the PIC to execute a bounce recovery or go-around.

3.4.3.5 From Second Touchdown to Third Touchdown

a. The PF's control and the airplane's behavior

(1) Second touchdown and bounce after that

As described in 2.1.1 e and 2.1.1 f, the second touchdown was made on the NLG followed by the MLGs. It is highly probable that because the NLG touched down before the MLGs, the NLG rebounded off to quickly increase the pitch angle, leading to increased lift, resulting in the high bounce.

Responding the increased pitch angle, the PF continued to make nose-down elevator input (CCP: -7.4° to -7.7°) and the pitch angle began to decrease through the peak value of 6.7°. It is highly probable that as described in 2.14.4, the nose-down elevator input had influenced the nose down motion during the second bounce.

Because the PF further continued to make forward control column input to -7.6° even after the onset of nose-down, the nose-down motion became conspicuous. It is highly probable that in this process, LSAS had issued a nose-up elevator command by PRD function as described in 2.14.5; however, the ultimate elevator remained in the nose-down configuration due to the larger amount of nose-down elevator input.

After the pitch angle went into negative range, the PF made nose-up elevator input (CCP: -1.1° to 1.6° to 0.9°), and this began to slow the nose-down motion. But it did not return to positive range before the next touchdown. It is highly probable that it took about 1 second to change pitch angle from 0° to -4.9°, and the airplane touched down again on the NLG. The sink rate reached 21.5 fps as described in 2.14.9 (Table 2).

After the first touchdown, the airplane fell into so-called porpoising; a phenomenon in which the airplane repeats bounces with increasing oscillatory pitch motions. The possible major causes of porpoising were; the PF's large elevator input intended to stabilize the airplane by pitch control only; and the second touchdown was made on the NLG, followed by the large nose-up attitude.

(2) Changes in EPR and AGS during the second bounce

As described in 2.1.1 f, the EPR for the No. 2 and No. 3 engines temporarily increased to 1.1 during the second bounce, but it returned to 1.0 by around the time when the third touchdown was made. No go-around call-out and no elevator nose-up input to establish the pitch angle of 7.5° indicate that the PF's action was not intended for a bounce recovery or a go-around.

The AGS was retracted after the second MLG touchdown and the retraction possibly made the second bounce even larger. As described in 2.14.7 c, The No. 2 engine thrust lever advancement was the possible cause of the AGS retraction; however, it was difficult to specifically determine the timing of the AGS retraction and the thrust lever operation. The reason of AGS retraction was therefore remained to be unknown.

(3) The possibilities of bounce recovery and go-around

As described in 2.14.10.3 and 2.14.10.4, it is highly probable that this accident could have been avoided with bounce recovery or go-around if either of them had been initiated during the second bounce. It was possibly difficult for the PF to have a precise picture of the pitch angle and the altitude during the bounce due to the reasons described below. The PF had thought that it would be possible to manage the situation only by the elevator input, without the thrust lever control.

(a) As described in 2.14.6, the airplane MLG tires reached the highest point (about 16 ft) about 4 seconds after the second touchdown with the pitch angle about 0°. Under normal situation an airplane does not fly at 16 ft above the runway with 0° pitch angle. The cockpit height from the runway in this condition (about 33 ft) is equal to a condition where a MLG tire is about 4 ft high with a pitch angle of 6.7° (a maximum pitch angle during the bounce) or to a condition where a MLG tire is about 3 ft high 7.5° pitch angle (a pitch angle recommended for a bounce recovery operation).

(b) With the fact that the pitch angle rapidly oscillated from "up" to "down" during the second bounce, and the assumption that the PF was absorbed in the airplane control with his eyes on the runway, it was difficult for him to have correct understanding of the pitch angle and the height of the MLG tires.

b. The PM's Response

When the NLG rebounded off the runway and the nose moved upward, the PM, with calm monitoring of airplane behavior as PM and PIC, he could have chosen bounce recovery or go-around, taken over the PF without delay, done either operation. This was possibly the last opportunity to avoid the accident.

3.4.3.6 From Third Touchdown On

a. The PF's control and the airplane's behavior

As described in 2.1.1 g and 2.14.8, the airplane, with its negative pitch attitude, landed on the NLG followed by the MLGs. As the airplane was rolling to the left, the left MLG first touched down, followed by the center landing gear and the right MLG. The recorded vertical acceleration at this time was 3.06 G.

As described in 2.14.9 (Table 2), the airplane sink rate was estimated to be 21.5 fps at the third touchdown. It is highly probable that the airplane's kinetic energies at the third touchdown reached a level—6.8 times greater than the FAA requirement for certification (an ultimate load).

The pitch angle surpassed 8° about 1 second after the left MLG touched down, and the left wing attachment point to the fuselage fractured. The fuselage rolled to the left (over 12° roll angle) with the lift generated by the right wing. The large control wheel input to the right around this time did not work to control the airplane.

b. The PM's Response

The accident could not have been avoided at this stage even if a well experienced pilot had taken over and tried to control the airplane.

3.5 The Load on Landing Gear at Touchdown and Structural Failure Sequence

3.5.1 Before Touchdown

As described in 2.6.3, judging from the history of airplane maintenance and the condition of its flight until just before touchdown, it is highly probable that the airplane was flying in a normal condition until the first touchdown.

3.5.2 Around First Touchdown

As described in 2.1.1 d, it is probable that when the first touchdown was made, the airplane touched down initially on the right MLG with 4.2° nose-up and 0.4° roll to the right, followed by the center and left MLGs touch-down. The maximum vertical acceleration recorded in the DFDR was 1.63 G (near the airplane CG). It is highly probable that the airplane structure sustained no damage at this point because; as described in 2.18.3, this value was less than 2.15 G (the value read from Figure 20) specified as a hard landing condition in the AMM; the airplane weight at the time of the accident was less than the maximum landing weight; and the airplane touched down with small roll angle resulting in shared aircraft load among three landing gears; and no unusual thing was seen from the Camera Images. There were no damages at this time.

3.5.3 Around Second Touchdown

The airplane bounced upon the first touchdown and, as described in 2.1.1 e, the second touchdown was made on the NLG with nose-low pitch attitude followed by the MLGs with 0.4° roll to the left. There were traces of grease near the NLG touchdown point, and a wheel cap was left there.

As described in 2.1.1 e, the maximum vertical acceleration recorded in the DFDR at this time was 2.21 G. It is probable that the NLG wheels and the support structure were damaged due to the applied load exceeding the design load, taking into account that: the accident airplane's vertical energy assumes to be 1,035,700 lb-ft at the landing weight of about 405,000 lb, as described 2.14.9; the NLG first absorbed the airplane load upon the second touchdown; and some NLG parts were found detached from the gear. The JTSB could not determine the specific damage at this moment because the load at the third touchdown is estimated to have been larger.

It is highly probable that the load applied to the MLGs did not reach the limit load and the structure which transfers a load from the MLGs was not damaged because: when the MLGs touched down with the left roll angle of 0.4°, the sink rate was estimated at 7.2 fps, which is less than the design limit of 10 fps (600 fpm); and the airplane was lighter than the maximum landing weight.

As described in 2.1.1 f, the vertical acceleration reached the maximum value on this second touchdown, followed by large vertical 3 Hz vibrations with a damping tendency. This vertical vibration was caused by the first natural vibrations generated at the impact of the touchdown because this frequency almost equals to the first natural frequency of the fuselage structure as described in 2.6.7.

3.5.4 Around Third Touchdown

The airplane bounced again upon the second touchdown and, as described in 2.1.1 f, the airplane then reached 16 ft above the runway. As the nose-down movement continued, the airplane attitude at the third touchdown on the NLG was -4.6° pitching, 3.5° rolling to the left. As described in 2.10.1, there were two nose tire scrape marks (about 9 m), followed by two nose wheel scratch marks (about 10 m on the right and about 28 m on the left), and the traces veered to the left. Broken pieces of the nose wheels scattered along, while the two damaged nose tires were detached and found on the right side of the runway.

These findings and the traces show that the nose wheels broke upon the third touchdown, followed by the tires being detached. The wheel grinded shape and the airplane's inclination to the left show that the NLG and its attachment structure were deformed and leaned to the right against the airplane axis.

As described in 2.1.1 g, it is highly probable that the airplane landed on the NLG with the left roll of 3.5°, followed by the left, center and right MLGs.

As described in 2.14.9, with the sink rate of 21.5 fps upon touchdown, the vertical energy at the landing weight (about 405,000 lb) assumes to be 3,375,390 lb-ft—6.8 times greater than the requirement for certification (ultimate). As described in 2.1.1 g, the DFDR records show that the vertical acceleration reached a maximum of 3.06 G, decreased to less than 2.0 G (1.97 G on the records), and increased again to 2.98 G.

As described in 2.14.8, compared with the Camera Images, when the vertical acceleration reached the maximum level of 3.06 G, it is assumed that the NLG and left MLG had already touched down; however, the JTSB could not determine whether the center and right MLGs had touched down. This and the fact that the structure had been fractured in the process induced that it is difficult to clarify how much vertical mechanical energies were absorbed by two or more Landing Gears.

As described in 2.16.2, it was estimated that the upward load transferred from the left MLG to the left wing structure had been about 887,000 lb. This value corresponds to the result of a structural analysis simulation performed by the airplane manufacturer, and it was larger than the estimated load by the airplane manufacturer in the design for the type certification as a load to be applied when the landing gear strut has bottoming, and this fact shows that the wing structure which transfers a load from the MLGs had not been strong enough to withstand such a load.

These findings show that the left wing structure could not withstand the load transferred through the left MLG, resulting in the structural fracture.

The rear spar web fracture surface shows that the structural failure took place within a very short time under the applied load.

The JTSB could not identify the origin of the fracture, because the fire damaged the fracture surface leading to the failure of precise examination of the fracture surface, and the structural analysis in the JAXA using a simplified model didn't lead to the precise structural failure sequence because all of the necessary information for a structural analysis except for the rear spar could not be fully obtained.

3.5.5 Fracture of Left MLG Attachment Structure

As described in the previous paragraph, it is highly probable that the destruction of the left wing structure initiated around the left MLG attaching structure. As described in 2.10.2 b, the lower wing skin was bent as if it were torn off from the spar while the inboard skin exhibited no such signs only with some cracks in the rear spar. (The fire consumed the inboard upper skin.) The rear spar web fracture was at about 45° degree angle, connecting the lower end near WS230.6 and the upper end near WS197.2 (both stations between the MLG attachment point and the wing root). Bends and cracks perpendicular to the fracture line were observed at the mid section. As described in 2.10.2 b, the double-plated rear spar, each the same thickness, was fractured almost at the same place. If the one of the two plates fractured first, it is hard to believe that the other plate would break at the same place, because of the load redistribution as a consequence of the first plate failure. The second plate would be broken somewhere else. An excessive load that was applied on the plates fractured the double plate almost at the same time.

The front spar exhibited a vertical fracture surface. Its lower spar and the rib cap had been torn off and broken and the upper skin exhibited torn-off near the ribs.

Given these findings, it is highly probable that left wing fracture scenario is as follows:

> When an overload from the left MLG attachment point was transferred to the fuselage via the left wing, the rear spar deformed and fractured, causing the loss of support for the fuselage. The fuselage slid downward and the left MLG attachment point of the side brace was displaced downward.
>
> The side brace pushed the left MLG outboard and the landing gear actuator was extended, followed by the fracture of the lower end of the bearing. The landing gear strut structure was pushed against the lower end of the MLG attachment brackets, creating dents in the brackets. As the wing still remained attached to the fuselage with its front side and it was twisted forward, it caused the engine cowl to touch the ground.
>
> As the airplane lost support from the left wing, it is highly probable that it rolled over to the left due to the lift generated by the right wing. At this moment, the ends of the left MLG side brace remained connected to the wing body and the left MLG which remained attached to the wing. As the left roll became larger, the fuselage pulled the side brace and the left MLG inboard. The left roll of the fuselage continued pulling the left MLG more. The MLG attachment point on the fuselage surrendered to the applied load and fractured. The left MLG was separated from the fuselage, and the wing structural failure from the trailing edge spread to the leading edge including the front spar, causing the left wing to fracture. (The fractured wing was different, but the left wing failure process was very similar to that found in the Newark accident investigation.)

3.5.6 After the Fracture of the Left Wing

When the left wing fractured and caught fire, the right wing and the fuselage continued left roll to be inverted. As the left engine cowl was smeared with fuselage paint, it is highly probable that the fuselage fell on the left wing and damaged the outside of the engine cowl. The airplane slid on the runway in an inverted posture swerving from the runway toward the left grass area. It is probable that the vertical stabilizer and other components fractured during the course of the swerving.

The fire continued even after the airplane came to a halt. As the fire consumed the right wing and most part of the fuselage including the floor, it is unable to clarify how the cargoes had been fixed to the floor.

3.6 Fire

As described in 2.1.1 g, the fire broke out near the left engine rear at 06:48:29.

As the rear spar and the wing outer skin form the fuel tanks, it is highly probable that the fuel leaked upon the fracture of the structure and caught fire. Possible source of ignition are: sparks generated from the scratching engine cowl against the runway; sparks from electric wires following the fracture of the left wing; or non-explosion-proof electric appliances installed nearby. It is unable to determine the specific source of the fire.

It is highly probable that about 28,000 liters of fuel remained in the fuel tanks spilled, just like flowing along the fuselage as the airplane rolled to the left, strengthened the fire.

3.7 Spillage of Fuel Due to Structural Destruction

As described in 2.17.1, the MD-11 series airplane is certified to 14 CFR 25.721 (a) in its type certificate, which requires the MLG system to be designed that if it fails due to overloads during takeoff and landing, the failure mode is not to cause the spillage of enough fuel to constitute a fire hazard. The airplane's MLG support structure had a fuse pin installed. It is somewhat likely that, if the fuse pin had failed due to the vertical overload and the MLG had been separated, that would have mitigated the situation where the structure which forms the integral fuel tank around the landing gear sustained damage in the first place, resulting in rapid fuel spillage from the body fuel tank. It is probable that, if the wing were not destroyed due to the above structural damage and the airplane did not roll inverted due to the difference in lift between the left and right wing, the possibility of the pilots' evacuation by themselves would have been enhanced. However, it is somewhat likely that, in case of such a significantly high vertical kinetic energy as this accident, the energy was not able to be absorbed by MLG, and it was impossible to prevent the wing failure in the end, considering that, for example, the fuse pin at the pylon of the engine would fail due to the engine nacelle striking the runway, and the lower fuselage would strike the runway and sustain significant damage.

As described in 2.17.1, an overload condition in which the MLG is separated is assumed to be a drag overload as a result of striking an obstruction.

As described in 2.18.2, as observed in MD-11 series airplane hard landing events resulting in substantial damage, an overload applied on the MLGs has been occurred not only by striking against an obstruction, but also by landing with a high sink rate in this accident as well as the Newark accident. It is probable that in such an event, the vertical load rather than a drag is primary component in the overload condition.

It is highly probable that the maximum acceleration recorded on the third touchdown, at which the MLG structure is believed to have fractured in this accident, was 3.06 G in the vertical direction, 0.39 G in the backward direction and 0.5 G in the lateral direction, as described in 2.1.1 g. The vertical acceleration was overwhelming at the third touchdown. As described in 2.14.9, it is highly probable that the airplane had received very large vertical kinetic energy on top of the potential energy in the vertical direction, and the contribution of the drag and side load to the left MLG fracture was rather minimal, compared with the vertical load.

As analyzed in 3.5, it is highly probable that the vertical overload transferred from the left MLG was caused of the fracture of the left wing structure.

It is assumed that the present interpretation of the requirement is already being applied on new transport airplane programs including the Boeing 787 and the Airbus A350 and its MLG system is designed so that a failure mode is not to cause the spillage of fuel to constitute a fire hazard if it fails due to overloads to act in the vertical directions. As far as MD-11 series airplanes are concerned, the airplane manufacturer had begun an evaluation in the net safety benefit of installing a fuse pins for vertical overload. However, the MD-11 MLG structure remains unchanged.

According to the past accidents involving MD-11 series airplanes, it is desirable to change the design to allow the same level of safeness as that of the new transport airplane to address the primarily vertical overload applied to the MLG support structure. Otherwise, effective measures should be taken to reduce the occurrence of hard landings and bounces as much as possible.

As described in 2.18.2, NTSB issued the recommendation that required revising the manual and mandating the training from the operations point of view. But, even if the occurrence of human errors may be reduced with a revision of the manuals or improved training, the possibility cannot be reduced to zero. It is probable that measures should be taken to improve the airplane system itself.

As described in 2.14.5 and 2.14.10.5, LSAS PRD function and AGS deployment are effective to moderate the rapid nose-lowering tendency after touchdown. It is probable that the improvement of these functions lead to moderate the rapid nose-lowering tendency after touchdown, which is commonly observed in hard landing events including this accident. Furthermore, as described in 2.14.10.3 and 2.14.10.4, the bounce recovery or go-around after the bounce is effective to prevent hard landing after the bounce. It is likely that adding the function to assist such operations contribute to the reduction of hard landings and bounces.

3.8 Fire Fighting and Rescue Operations

As described in 2.12 b, it is certain that the first fire engine arrived at the accident site within 1 minute after the occurrence. The first water discharge started within 2 minutes after the occurrence and soon after that, several fire engines started discharging water.

The winds then were blowing from the direction of the airplane nose. The Camera Images show that the nose section was not covered with black smoke, but about that time when the fire-fighting started, occasional flames were rising from behind the nose section, too. This fact shows that the fire spread to the front part of the airplane at an early stage after the airplane became stopped. It means that it was difficult for the fire fighters to rescue the two crewmembers out of the cockpit.

As described in 2.12 a, the fire fighters and rescuers tried to enter the cockpit at 07:03, but they concluded it difficult to do so due to heat and smoke. Then the demolition rescue vehicle started cutting open the rear part of the cockpit on both sides of the fuselage by the rescuers using the engine cutter.

The fire fighters and rescuers started entering the cockpit at 07:25 and, they rescued the PIC at 08:00and the FO at 08:16 and transported them to the hospital. It is assumed that their heart and lungs had already stopped functioning.

As described in 2.5.6, the autopsy of the FO revealed burns of the respiratory tract. Therefore, it is highly probable that he was alive just after the occurrence of the accident. But, as described in 2.12 a, when the fire fighters and rescuers tried to enter the cockpit for rescue about 15 minutes after the occurrence, the heat and smoke had already hindered their entrance. Therefore, it is highly probable that it had been difficult at that time to rescue them. As described in 2.12 b, flames had already been observed at the rear part of the cockpit at the time when the fire engines started pouring water. Therefore, it is possible that heat and smoke had already reached the cockpit at an early phase after the occurrence of the accident.

3.9 Active Use of Camera Images

In the investigation of this accident, camera images recorded by a camera installed at the airport made a great contribution to clarify the cause of the accident. These images provided information on white smokes from the landing gear tires at touchdowns, the airplane attitudes and wing positions, how the fuselage twisted and how the left wing bent, when and from where the fuel spilled, the process of the structure destruction, and how the fire spread. As these important pieces of information could not be obtained from the DFDR records, they were indispensable for clarifying the cause of the accident and planning measures to prevent the reoccurrence of similar accidents.

Not only this Narita accident investigation, recent airplane accident/incident investigations during take-off and landing often obtain very important information from image data taken by the cameras installed in the airport.

These cameras are not installed for the analysis of aircraft accident/incident and for that reason their installation points are not always suited for the investigation; however, it is desirable to improve the camera installations to enhance the use of camera images for investigations into accidents/incidents for the safety of aviation.

4. CONCLUSIONS

4.1 Findings

a. The PIC and the FO held both valid airman competence certificate and aviation medical certificates and both of them had received training and examinations as prescribed.

The airplane had a valid airworthiness certificate and had been maintained and inspected as prescribed. It had been flying with no preexisting damage or degradation in terms of functions and structures until the occurrence of the accident. (3.1, 3.2, 3.5.1)

b. The substance which must be taken in accordance with the FAA guidance was detected in the PIC's urine but not in his blood. It is probable that the medication did not influence the PIC's performance in his duty flight. It could not be determined that the PIC took the medication in a manner consistent with the FAA guidance. (3.1.2 g)

c. The Airplane was flying almost on the glide slope during its approach until 200 ft RA, with autopilot and autothrottle engaged. In view of the large fluctuations of the airspeed and the three control surfaces input, it is highly probable that it was gusty wind condition but it was not accompanied with severe windshear which is hazardous to flight operations.

Both the PIC and FO had physical awareness of this gusty wind condition, in addition to the information obtained from air traffic controllers. (3.3, 3.4.1, 3.4.2)

d. At about 200 ft RA, only autopilot was disconnected. Since then, it is highly probable that the FO, as PF, manually controlled the airplane. The autothrottle remained engaged, it is highly probable that he had difficulty in maintaining the proper airspeed amid gusty wind conditions because he depended on the autothrottle and did not properly and actively override the autothrottle to control airspeed. The pitch angle also varied between 0.4° and 3.5°. It is highly probable that these airspeed, pitch attitude fluctuations, the large descent rate and the de-crab maneuver to correct for the cross wind component from the left to align the longitudinal axis with the runway centerline made it difficult to flare. (3.4.3.1 a, 3.4.3.2 a)

e. The CFM recommends starting the flare at 30 ft RA, but it is highly probable that the flare was delayed until the airplane descended down to 20 ft RA. The flare was rapid with a large elevator input. The maximum vertical acceleration on the first touchdown was about 1.63 G, smaller than 2.15 G (the threshold value for hard landing inspection specified in the AMM). It is highly probable that no damage was caused to the airplane structure at this point. The airplane bounced upon touchdown, because: the delayed flare did not arrest the sink rate and the airplane touched down with a high sink rate (about 7 fps), receiving a large ground reaction force; rapid flare with large elevator input generated the lift large enough (the vertical acceleration just before touchdown was about 1.24 G) at the touchdown to rebound. (3.4.3.3 a and 3.5.2)

f. The forward control column input was started at just after the call-out of 10ft. This input is, therefore, not considered as derotation, which is typically made after touchdown. It is somewhat likely that the forward control column input continued after touchdown was the reflection of the PF intent to have all landing gears touched down and have the airplane stabled on the ground.

Because of the large nose-down elevator input just before and during the first touchdown, the airplane nose dropped rapidly (the pitch angle decreased at 3.6° per second) during the bounce, and the pitch angle was -1.8° when the second touchdown was made. It is highly probable that the second touchdown was made on the NLG immediately followed by the MLGs touchdown.

It is highly probable that at this time, the NLG was exposed to large load and its components detached.

Executing bound recovery or go-around was the appropriate option at this time; however, decreasing pitch angle during the bounce caused the pilot's eye point to lower toward the ground and the PF probably didn't realize that the airplane had bounced. Accordingly, it is highly probable that any operation to cope with the bounce was performed. (3.4.3.4 a and 3.5.3)

g. Because the NLG received ground reaction force upon the second touchdown, it is highly probable that the pitch angle quickly increased and so did the lift, causing the second bounce to become larger. Following the nose-down elevator input, the pitch angle quickly decreased resulting into a descent.

The airplane fell into so-called porpoising; a phenomenon in which the airplane repeats bounces with increasing oscillatory pitch motions after the first touchdown. The large elevator input intended to control the airplane and large nose-up attitude after the second touchdown was a major contributing factor to the porpoising.

The last means of accident prevention was to execute a bounce recovery or go-around during the second bounce; however, large pitch attitude change possibly made it difficult for the PF to have a correct picture of the pitch attitude and altitude during the bounce. (3.4.3.5)

h. The pitch angle was -4.9° and the sink rate was 21.5 fps at the time of the third touchdown, while the vertical kinetic energy of the airplane reached about 6.8 times greater that the requirement for certification (an ultimate load) against the structures. This energy damaged the NLG wheels and the inner parts of the strut upon the touchdown of the NLG.

Just after the NLG touchdown, the left MLG touched down ahead of the center and right MLGs. The overwhelming vertical load was transferred from the left MLG to the left wing structure surpassing the ultimate load. This fractured left wing near the left MLG attachment point, followed by the left roll due to the lift generated by the remaining right wing. (3.4.3.6, 3.5.4)

i. It is highly probable that the fuel spilled out from the fractured part of the left wing caught fire, but ignition source was not identified. (3.6)

j. It is somewhat likely that if the fuse pin in the MLG support structure had failed and the MLG had been separated in the overload condition in which the vertical load is the primary component, the damage to the fuel tanks would have been reduced to prevent the fire from developing rapidly. It is probable that the fuse pin did not safely fail because the failure mode was not considered under an overload condition in which the vertical load is the primary component due to the interpretation of the requirement at the time of type certification for the MD-11 series airplanes. (3.6, 3.7)

k. It is highly probable that the PIC, as the PM, did not advise about the deviations from the glide slope and proper flight status, nor did he provide effective assistance or take over the control. (3.4.3.1 (b), 3.4.3.2 (b), 3.4.3.3 (b), 3.4.3.4 (b), 3.4.3.5 (b))

l. Although the fire engines started discharging water 2 minutes after the accident, the fire had most probably spread to the front part of the fuselage and this made it difficult to immediately enter the cockpit to rescue the two crewmembers. (3.8)

m. It is desirable to improve the camera installations at airports to enhance the use of camera images for investigations into accidents/incidents for the safety of aviation. (3.9)

4.2 Probable Causes

In this accident, when the airplane landed on Runway 34L at Narita International Airport, it fell into porpoising. It is highly probable that the left wing fractured as the load transferred from the left MLG to the left wing structure on the third touchdown surpassed the design limit (ultimate load).

It is highly probable that a fire broke out as the fuel spillage from the left wing caught fire, and the airplane swerved left off the runway rolling to the left and came to rest inverted on the grass area.

The direct causes which the airplane fell into the porpoise phenomenon are as follows:

a. Large nose-down elevator input at the first touchdown resulted in a rapid nose –down motion during the first bounce, followed by the second touchdown on the NLG with negative pitch attitude. Then the pitch angle rapidly increased by the ground reaction force, causing the larger second bounce, and

b. The PF's large elevator input in an attempt to control the airplane without thrust during the second bounce.

In addition, the indirect causes are as follows:

a. Fluctuating airspeed, pitch attitude due to gusty wind resulted in an approach with a large sink rate,

b. Late flare with large nose-up elevator input resulted in the first bounce and

c. Large pitch attitude change during the bounce possibly made it difficult for the crewmembers to judge airplane pitch attitude and airplane height relative to the ground (MLG height above the runway).

d. The PM's advice, override and takeover were not conducted adequately.

It is somewhat likely that, if the fuse pin in the MLG support structure had failed and the MLG had been separated in the overload condition in which the vertical load is the primary component, the damage to the fuel tanks would have been reduced to prevent the fire from developing rapidly.

It is probable that the fuse pin did not fail because the failure mode was not assumed under an overload condition in which the vertical load is the primary component due to the interpretation of the requirement at the time of type certification for the MD-11 series airplanes.

5 SAFETY ACTIONS

5.1 Actions for Accident Prevention Taken After the Accident

5.1.1 Actions Taken by the Airplane Manufacturer

The airplane manufacturer of the airplane convened the MD-11 operators' conference in October 2010. Participants at the conference exchanged their views about problems related to training and flight operations of the MD-11 following a series of hard landing accidents accompanied by structural destruction. In February 2011, the airplane manufacturer revised the MD-11 manual (FCOM); The revised manual stresses matters to be kept in mind in flying the MD-11 and in particular, called for caution against an excessive descent rate during an approach.

5.1.2 Actions Taken by the Company

The Company has taken proactive measures to prevent the recurrence of similar accidents since this accident.

The following are major preventive measures. The Company:

a. Removed references which allow the nose-down elevator input during landing from the manual.
b. Revised the manual to initiate flare between 40-30 ft.
c. Revised the manual to execute a go-around in the event of a bounced landing.
d. Improved academic training were designed and implemented to make crews more aware of how to land a "long body" airplane with specific focus on the MD-11.
e. Provided the results of the accident investigation to its crews.
f. Provided a post-flight print-out of maximum G and pitch angle on landing to be used in their debrief.
g. Designed and implemented improved landing training in all simulator training sessions and line operations to reinforce the relationship between power, pitch and rate of descent.
h. Continually reinforces the following five important points:
    (1) Fly a stable approach
    (2) Control rate of descent with power (especially below 50 ft)
    (3) Flare between 40-30 ft (Late flares are unacceptable)
    (4) Maintain proper landing attitude until on the ground
    (5) Bounce = go-around (go-around required for a bounce)
i. Studies on the use of Mixed mode and safety benefit to be gained by using Mixed mode. Continuous monitoring and studying on Mixed mode operations
j. Aggressively reinforced go-arounds as the safety solution in all pilot communications, training and checking events. They were:
    (1) Rotate the pitch and hold 7.5°on the PFD
    (2) Move throttles to a maximum power.

    As a result, LOSA data and safety report data indicate that go-arounds in response to bounces have increased.
k. Trains and checks a pilot's "hand flying" skills during every simulator and line-check event.
l. Installed HUDs to airplanes concerned to improve landing safety and conducted

relevant training.

m. Shared information about the operations of the MD-11 with the Boeing Company and other MD-11 airplane operators.
n. Is improving CRM and human factor skills.
o. Implemented fatigue risk management to ensure all pilots are properly rested before flying.
p. Continuous work to ensure the flight crews understand the proper use of medications, including restrictions of the use of all medications and the proper reporting of medications to their Aviation Medical Examiners.
q. Is improving the corporate safety culture.

5.2 Actions to Be Taken for Accident Prevention

5.2.1 Revision of Landing Gear Design Criteria

It is somewhat likely that, if the fuse pin in the MLG support structure had failed and the MLG had been separated in the overload condition in which the vertical load is the primary component, the damage to the fuel tanks would have been reduced to prevent the fire from developing rapidly.

The design criteria applied to the airplane requires that MLG system to be designed so that, if it fails due to overloads during takeoff and landing, assuming the overload to act in the upward and aft direction, the failure is not likely cause the spillage of fuel to constitute the fire hazard. However, the FAA explained, in its response to the NTSB safety recommendation, that “the MD-11 MLG was designed for an overload condition in which the drag load was the primary component. This landing gear was not designed to separate for a purely vertical overload”.

As of April 2013, the FAA initiates rulemaking to revise the relevant airworthiness regulation, however, the proposed regulation does not include the overload condition in which the vertical load is the primary component, and the FAA plans not to revise the airworthiness regulation but to issue advisory material (Advisory Circular) with regard to the present interpretation which is already being applied on all new transport airplane programs including the Boeing 787 and the Airbus 350.

Even if an advisory material is issued, it is neither mandatory nor regulatory in nature and does not constitute a regulation. It describes an acceptable means, but not the only means, for demonstrating compliance with the applicable regulations. Therefore, it is necessary to revise the airworthiness regulation rather than the guidance material and mandate the assumption of the overload condition in which the vertical load is the primary component in order to ensure that this kind of design will not be certified from now on.

5.2.2 Prevention of Overloads with Overwhelming Vertical Element Upon Touchdown

It is highly probable that the left wing was exposed to overload with an overwhelming vertical load due to the followings:

a. The airplane bounced upon first touchdown due to high sink rate and late flare
b. Nose-down elevator input initiated before the first touchdown became effective to continue lowering the nose during the bounce.
c. The second touchdown from the NLG caused the airplane to bounce again with its

nose upward and fall into porpoising.

d. With the absence of bounce recovery by this time, the airplane made the nose-low third touchdown even harder with the fuselage tipping to the left. The left MLG landed following the NLG and the overload with the primary vertical component was transferred to the wing structure.

Therefore it is considered necessary to study the preventive measures as stated below

ⅰ. To develop a means to inform the crew of the bounce after the first touchdown.
ⅱ. To optimize the timing of AGS deployment to prevent the bounce.

5.2.3 Measures to Increase Crew Survivability

It is highly probable that in this accident, the fire reached the inside of the airplane at an early stage after the accident.

Meanwhile, the plastic webbing net and the synthetic rubber curtain separating the flight crew area from the cargo area were almost consumed by the fire.

Therefore, with the effective measures to prevent or minimize fire damage in the flight crew area, crew survivability could be increased.

5.2.4 Appropriate Measures for Medicine Taking Habit by Flight Crew

The substance which is not allowed to be taken on a regular basis was detected in the PIC's urine but not in his blood. It is probable that the medication did not influence the accident. It could not be determined that the PIC took the medication in a manner consistent with the FAA guidance. Flight crews should report medications they are currently using and take medicines in an appropriate manner in accordance with the FAA guidance.

6 SAFETY RECOMENDATIONS

On March 23 (Monday), 2009, about 06:49 JST (Japan Standard Time), a McDonnell Douglas MD-11F, registered N526FE, operated by Federal Express Corporation as the scheduled cargo flight FDX80, bounced repeatedly during landing on Runway 34L at Narita International Airport. During the course of bouncing, its left wing was broken and the airplane caught fire. The airplane rolled over to the left being engulfed in flames, swerved off the runway to the left and came to rest inverted in a grass area on the west side of the runway.

The airplane approached with a high sink rate, with its autothrottle "on" amid strong gusty winds and with unstable airspeed and attitudes. The late flare caused hard landing and the airplane bounced. Large nose-down elevator input just before and during the touchdown caused the second touchdown on the NLG with negative pitch attitude developing into porpoising. Upon the third touchdown, the left wing structure fractured because it surrendered to an overload transferred from the left MLG.

As a result of the investigation of this accident, the JTSB makes the following recommendations to the Federal Aviation Administration of the United States of America to take the following measures to prevent the recurrence of similar accidents.

6.1 Actions to Be Taken by the Federal Aviation Administration

a. Although the MD-11 airplane was certified to the requirement 14 CFR 25.721(a) under the interpretation at the time of certification, its design would not meet the present interpretation of the requirement since the design allows the possibilities of causing severe damage to the airplane structure in the failure mode under an overload condition where the vertical load is the primary component, resulting in the fire due to fuel spillage. As this kind of design should not be certified from now on, the airworthiness regulation rather than the guidance material should be revised to mandate the assumption of the overload condition in which the vertical load is the primary component.

b. Heat and smoke from the fire reached the cockpit at an early stage after the accident, making it difficult to initiate quick rescue activities from outside. In order to increase the crew survivability, studies about ways to separate the flight crew compartment from heat, smoke and toxic gas should be made, and if there are any effective solutions, the FAA should consider their application to in-service airplanes.

6.2 Measures to Be Taken to Supervise the Boeing Company as the Airplane Manufacturer

Past MD-11 accident investigation reports pointed out that in case of the primarily vertical overload transferred from MLG to wing structures, the gear design allows the fire hazard as a result of the destruction of wing structure followed by fuel spillage. The Boeing Company has so far focused its efforts on improving flight control programs which are effective in lessening overloads and these efforts are positively appraised to some extent; however, it's not a fundamental solution. As the occurrences of vertical overload have been reported after this accident, the measures taken so far are not considered to be satisfactory.

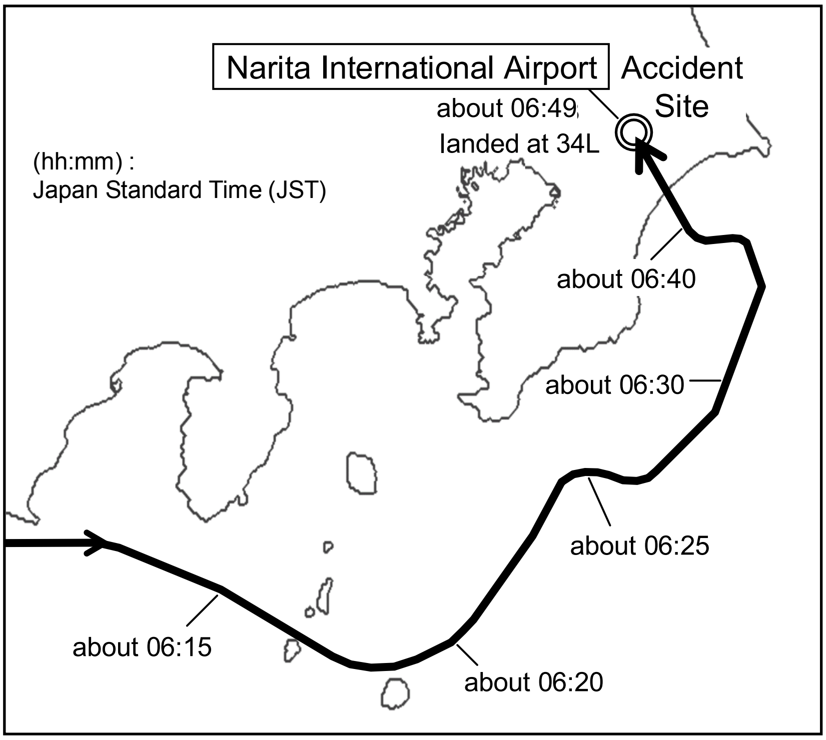
The JTSB recommends that the Federal Aviation Administration require the Boeing Company to study the possibility of design change for the MLG support structure and matters mentioned below in order to prevent the recurrence of similar accidents and minimize damage to be caused by such accidents.

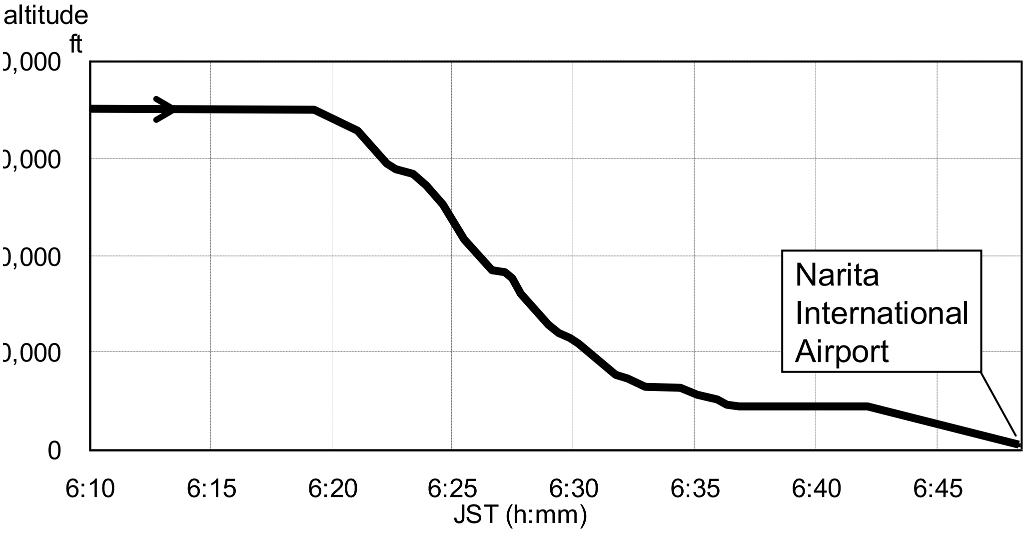
c. In order to reduce the occurrence of MD-11 series airplanes' severe hard landing and bounce in which an overload is transferred to the MLGs and their supporting structure, the Boeing Company should improve the controllability and maneuver characteristics by improving the LSAS functions, reducing the AGS deployment delay time and other possible means.

   Possible improvement on LSAS functions may include: a function to limit large nose-down elevator input during touchdown phase, which is a common phenomenon in severe hard landing cases accompanied by structural destruction for MD-11; and a function to assist bounce recovery and go-around in case of bounce.

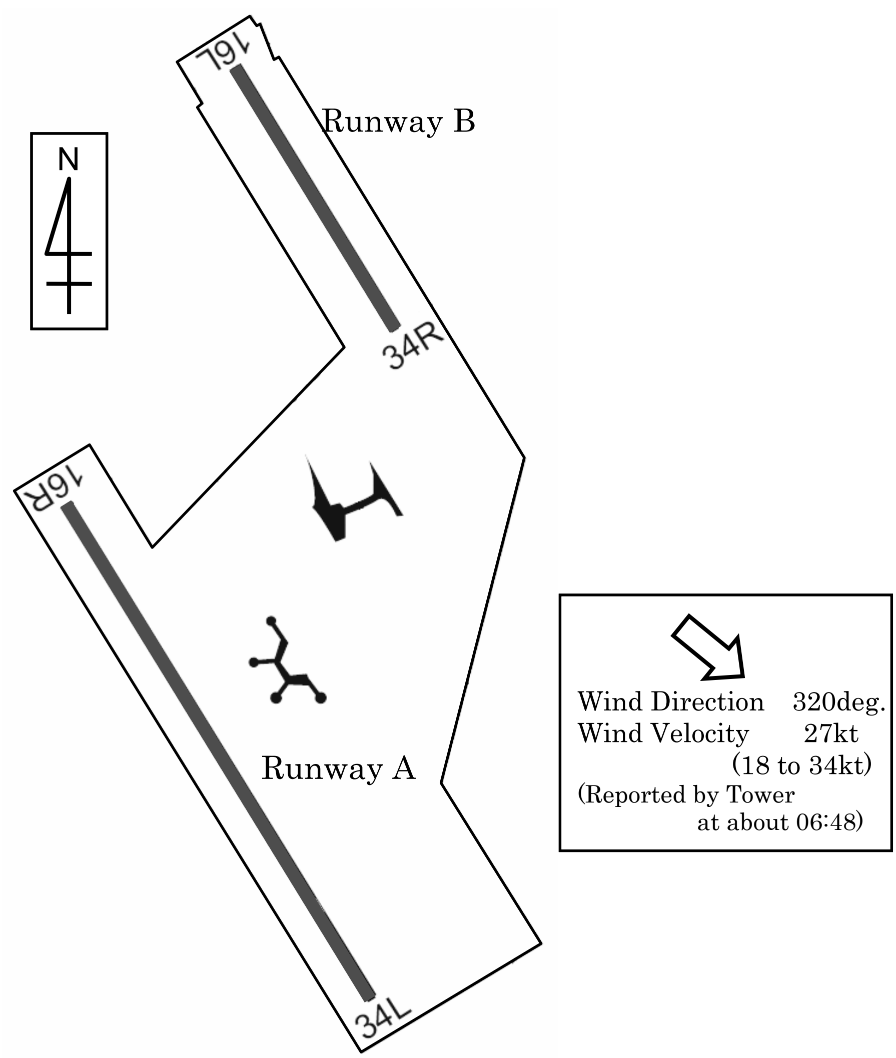
d. In order to help pilots to conduct recovery operation from large bounces and judge the necessity of go-around, studies should be made to install a visual display and an aural warning system which show gear touchdown status on MD-11 series airplanes.

Appendix 1 Estimated Flight Route

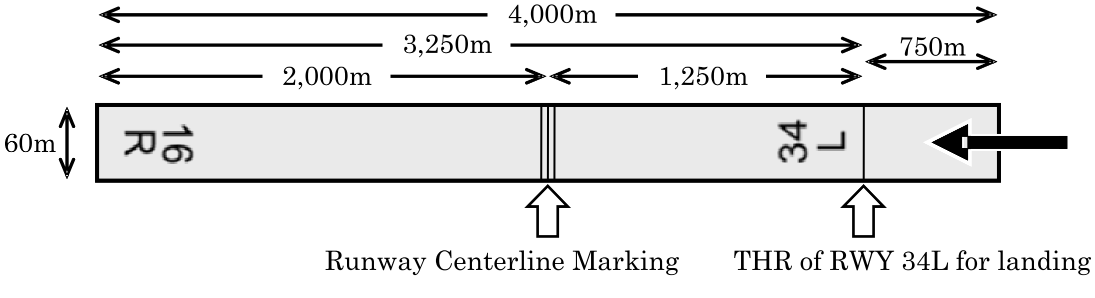




Appendix 2 Overview of the Runways for Narita International Airport

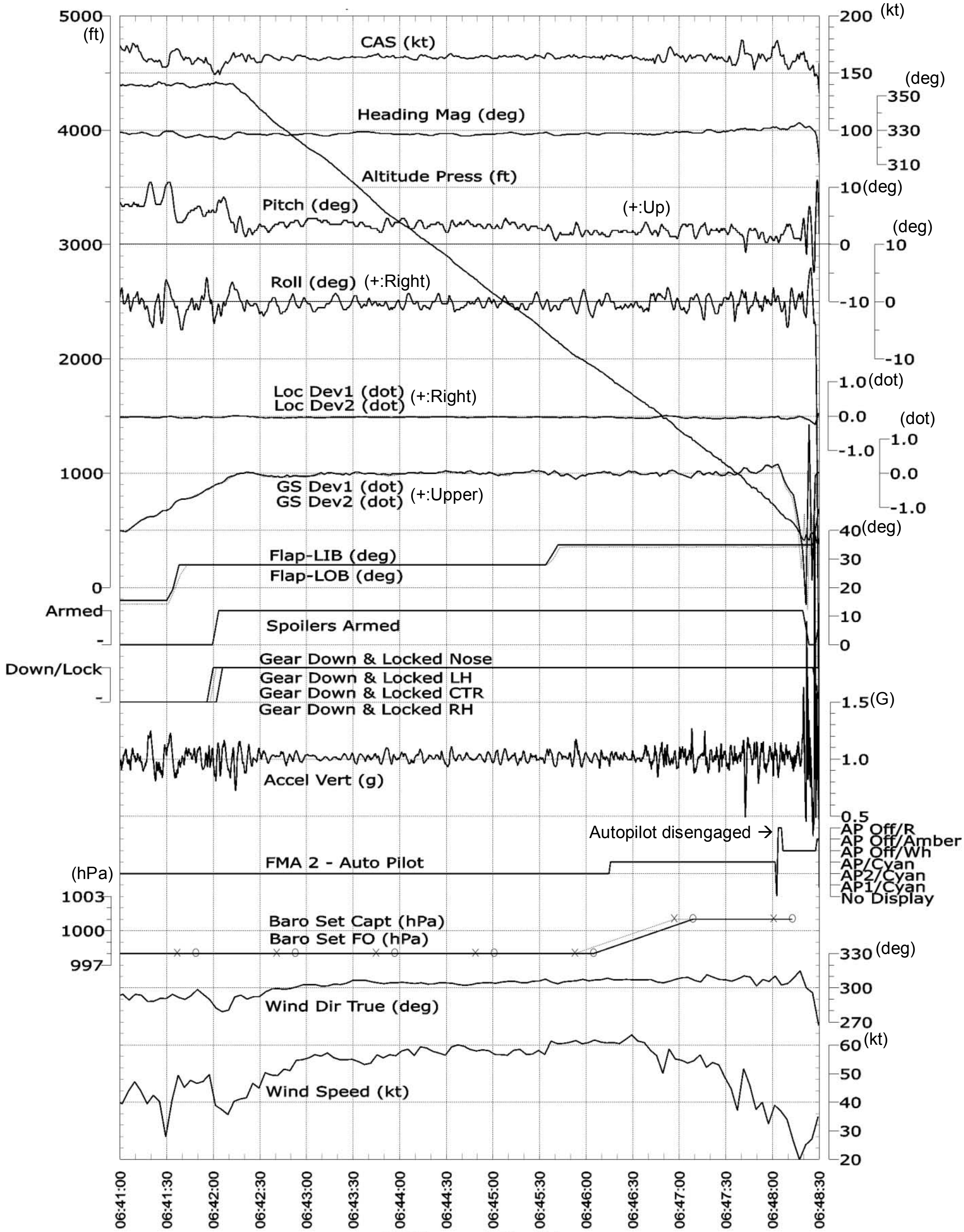


Runway 34L, Narita International Airport

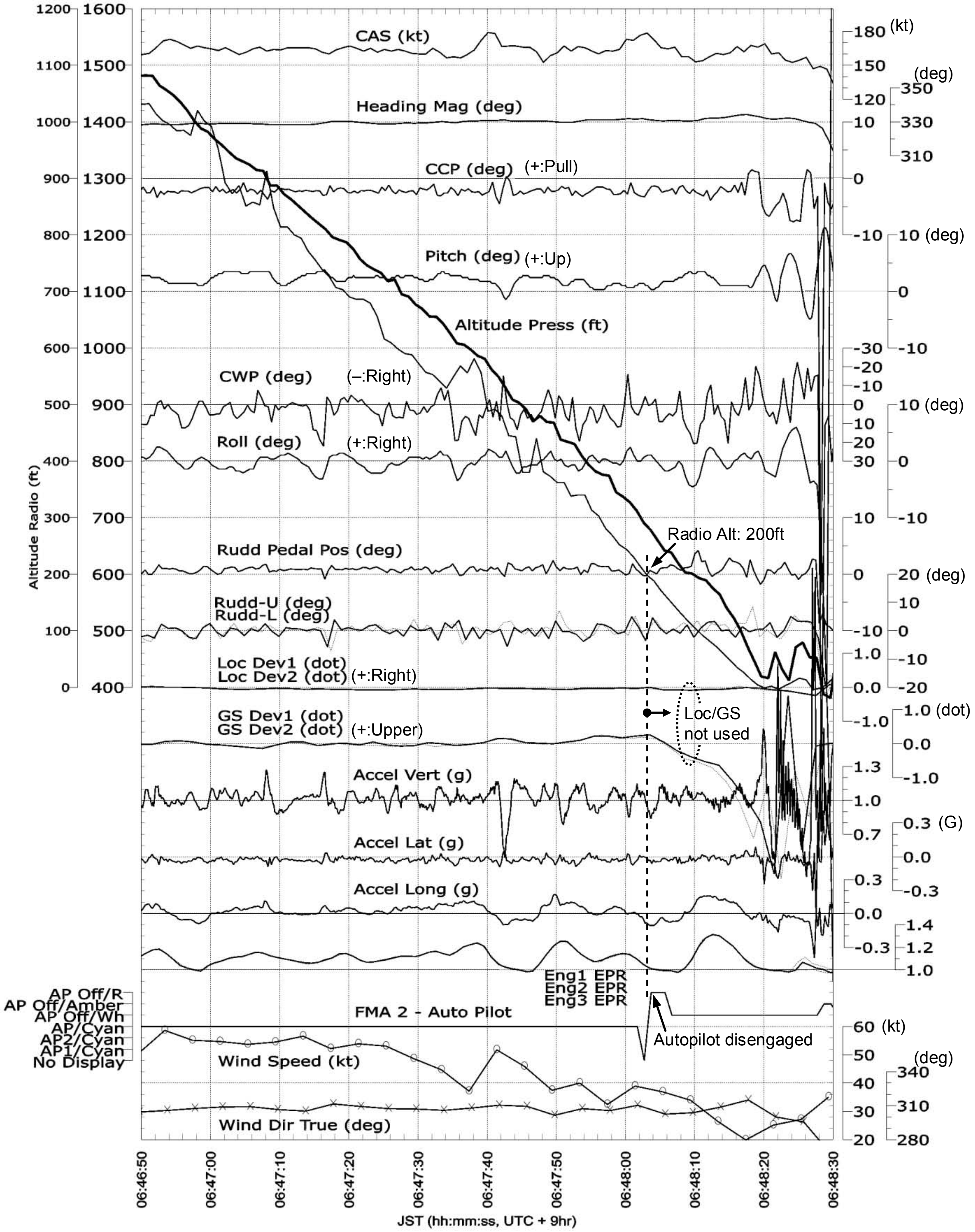


Note: The usable length of RWY 34L for take-off and of RWY 16R for both landing and take-off is 4,000m.

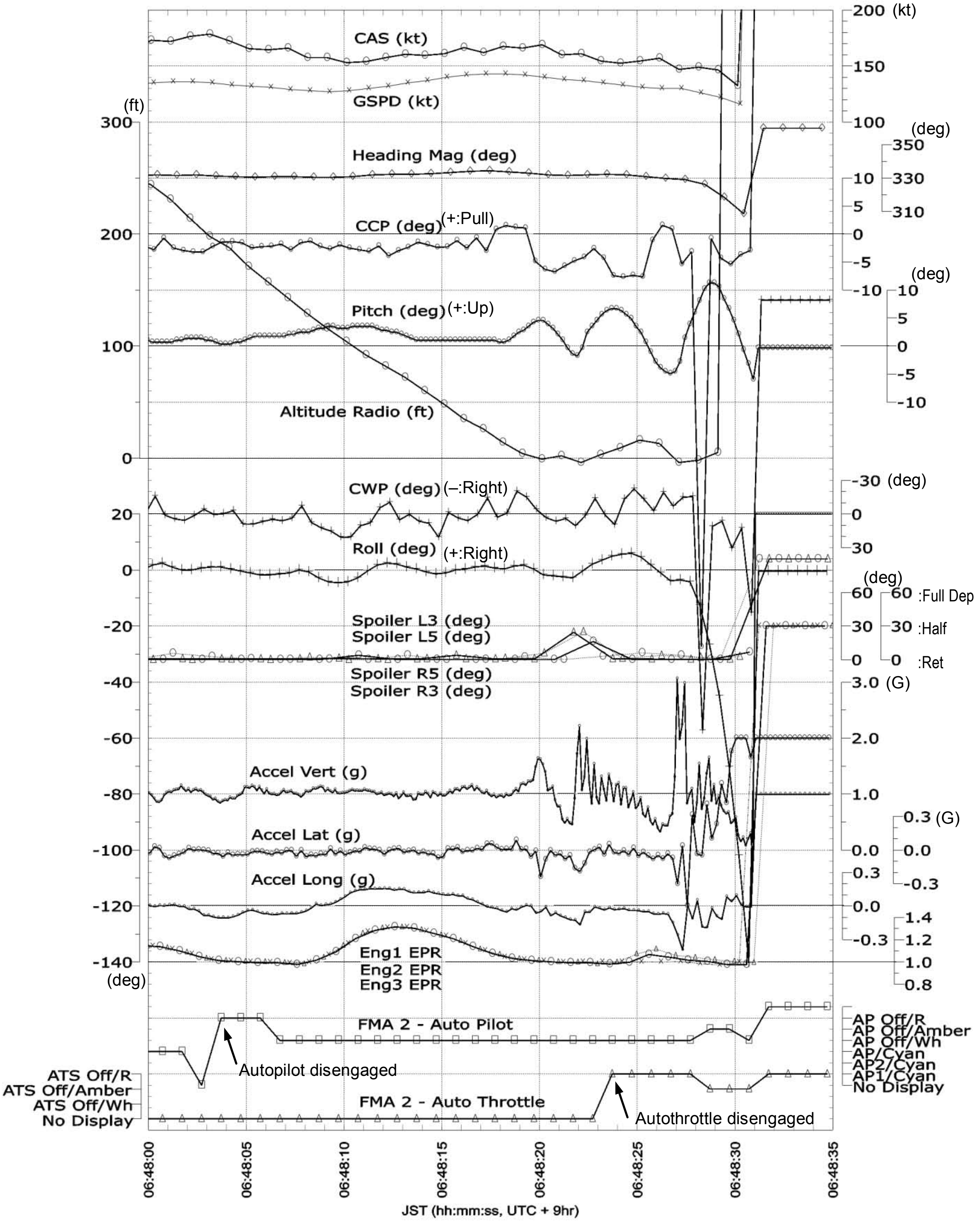
Appendix 3 – 1 DFDR Records



Appendix 3 – 2　　DFDR Records

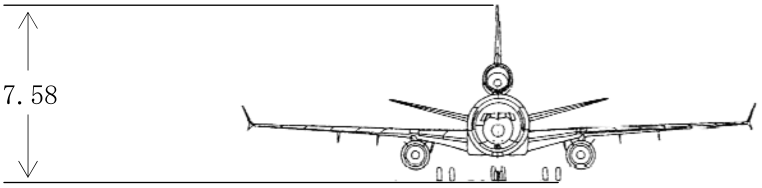


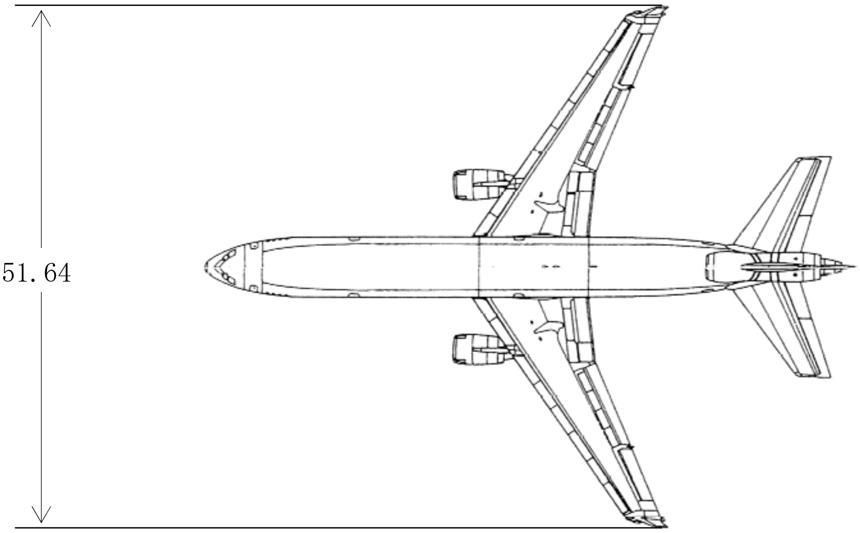
Appendix 3 – 3 DFDR Records

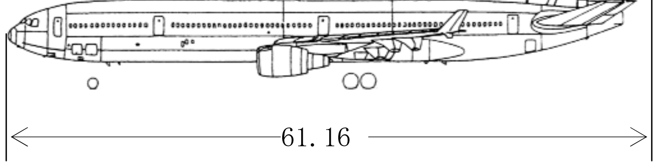


Appendix 4 Three Angle View of McDonnell Douglas MD-11

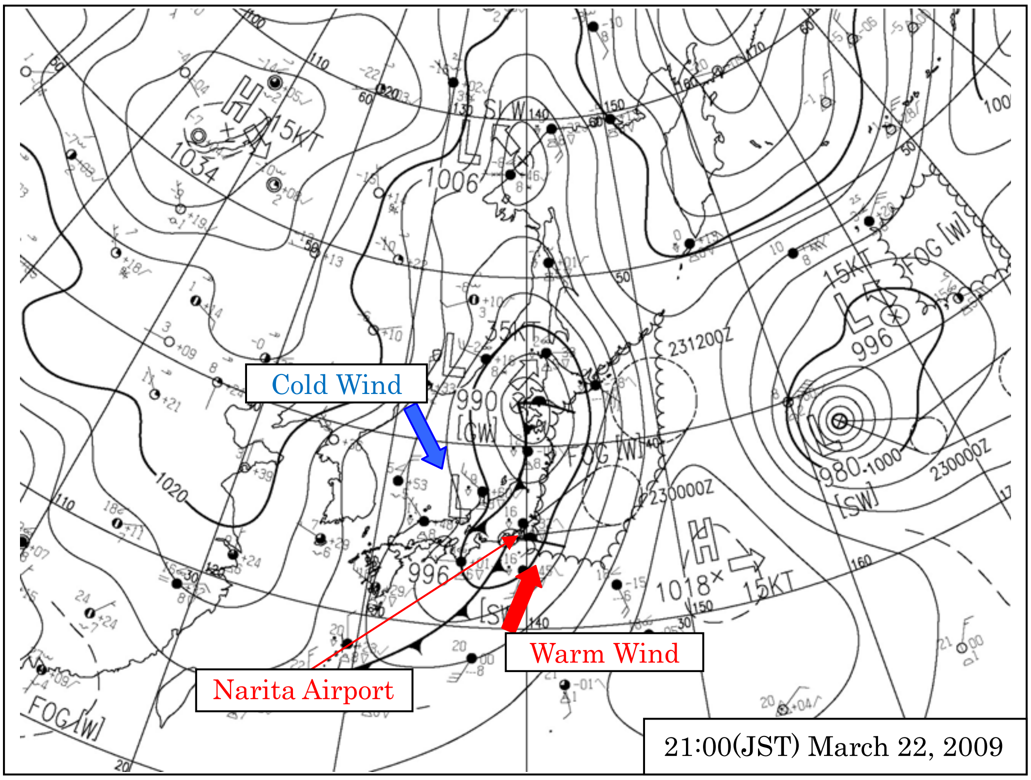
Unit: m



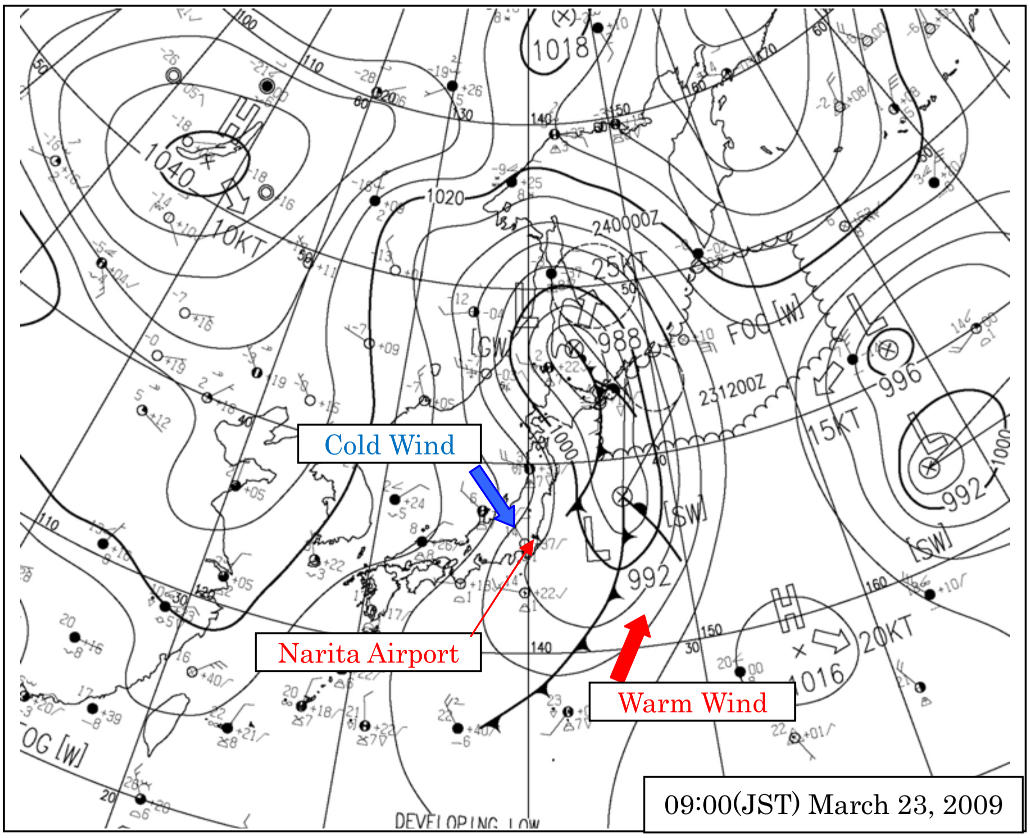




Appendix 5　Asia-Pacific Surface Analysis Chart



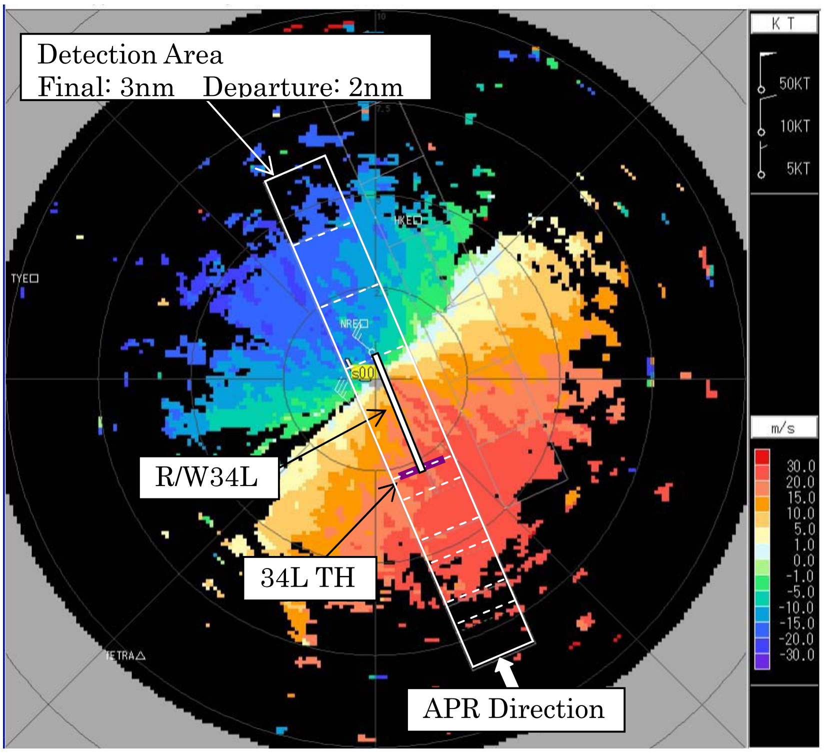
21:00(JST) March 22, 2009



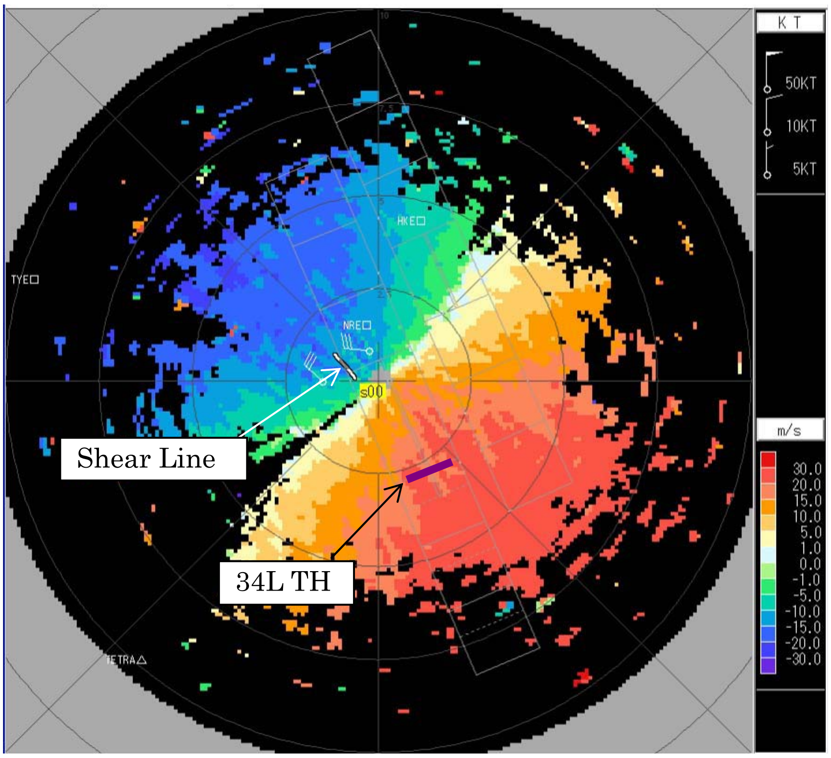
09:00(JST) March 23, 2009

Appendix 6-1 Doppler Velocity and Shear Line (Elevation Angle 2°)

06:40:45(JST)

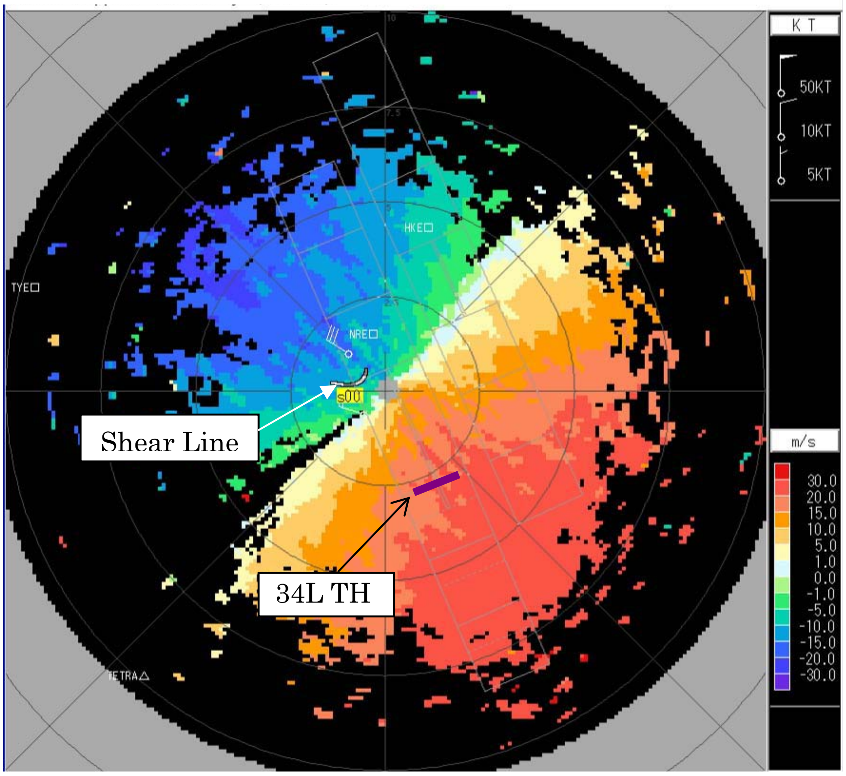


06:43:13(JST)

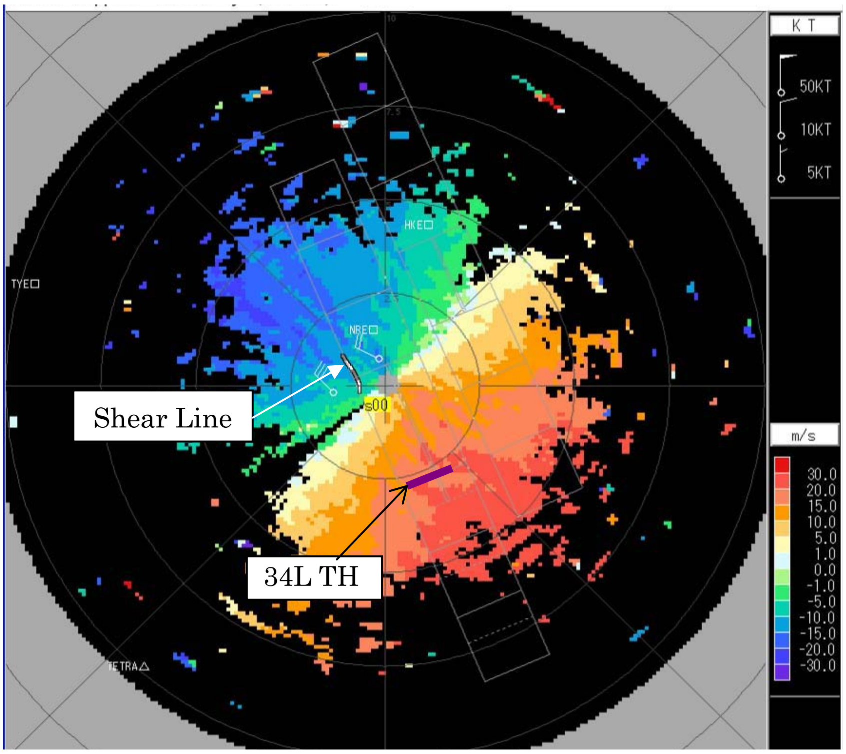


Appendix 6-2 Doppler Velocity and Shear Line (Elevation Angle 2°)

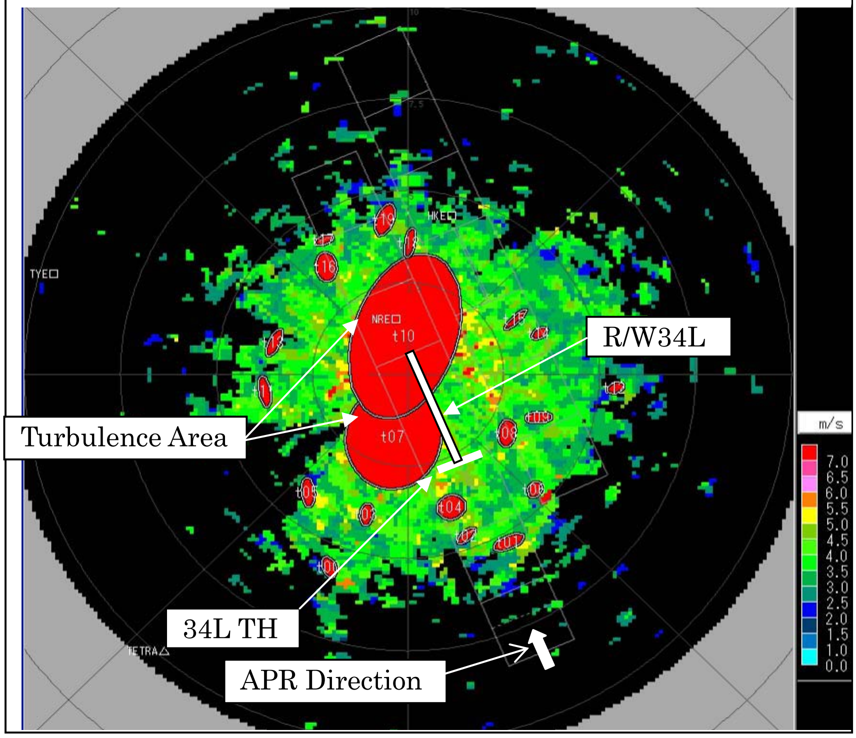
06:45:40(JST)

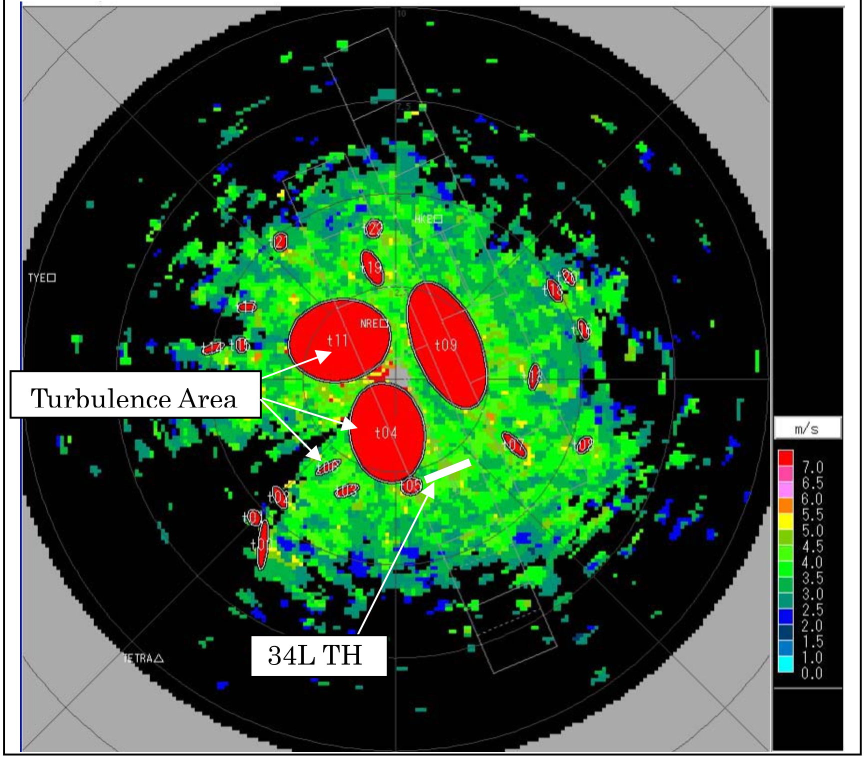


06:48:08(JST)



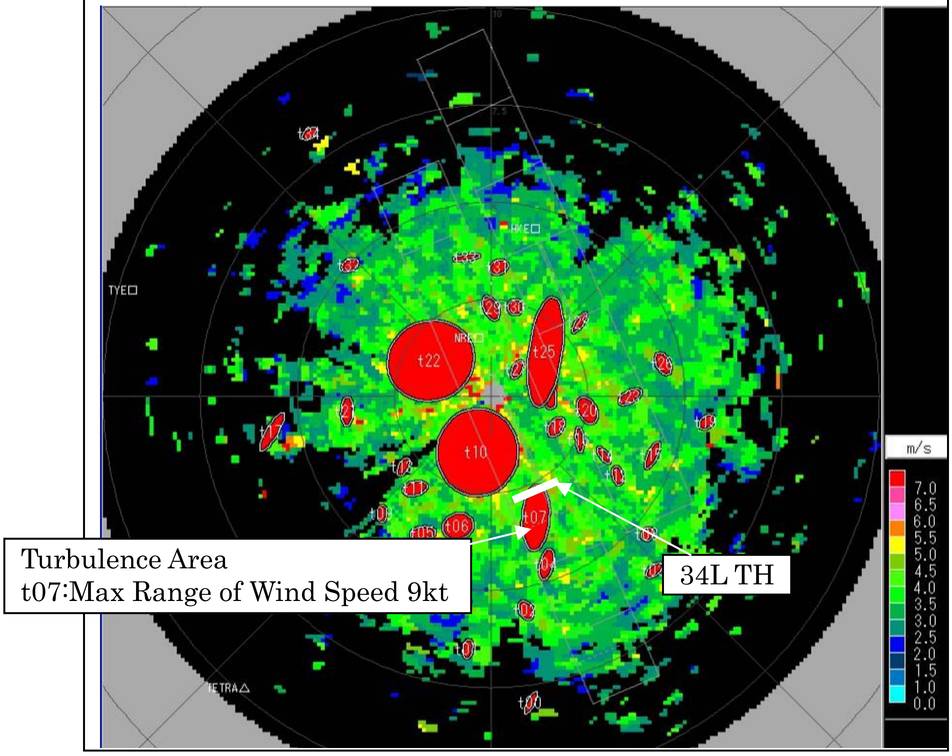
Appendix 7-1　TURB（Turbulence）（Elevation Angle 2°　）


06:40:45(JST)


06:43:13(JST)

Appendix 7-2　TURB（Turbulence）
（Elevation Angle 2°）

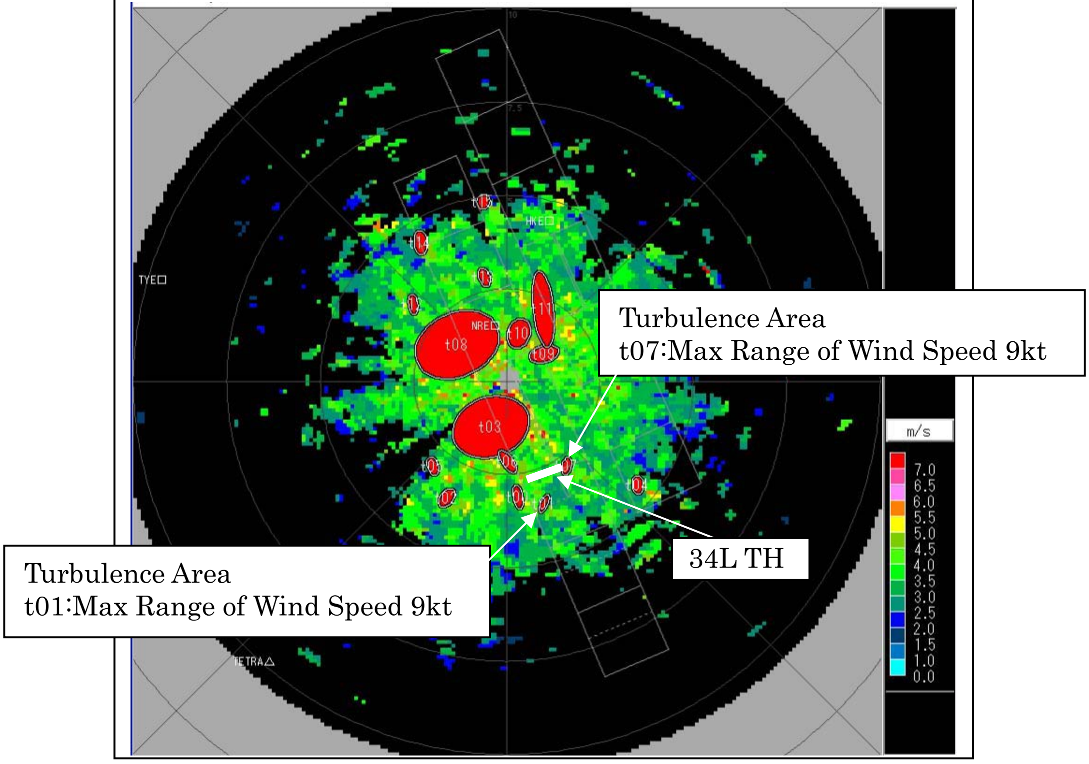
06:45:40(JST)



Turbulence Area
t07:Max Range of Wind Speed 9kt

34L TH

06:48:08(JST)



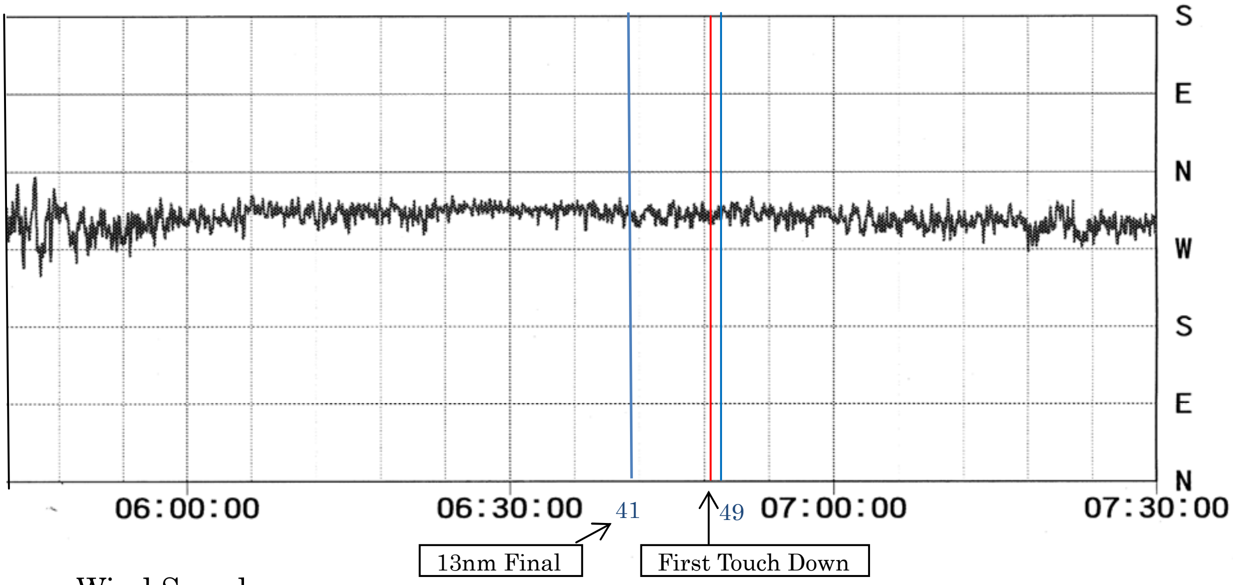
Turbulence Area
t07:Max Range of Wind Speed 9kt

Turbulence Area
t01:Max Range of Wind Speed 9kt

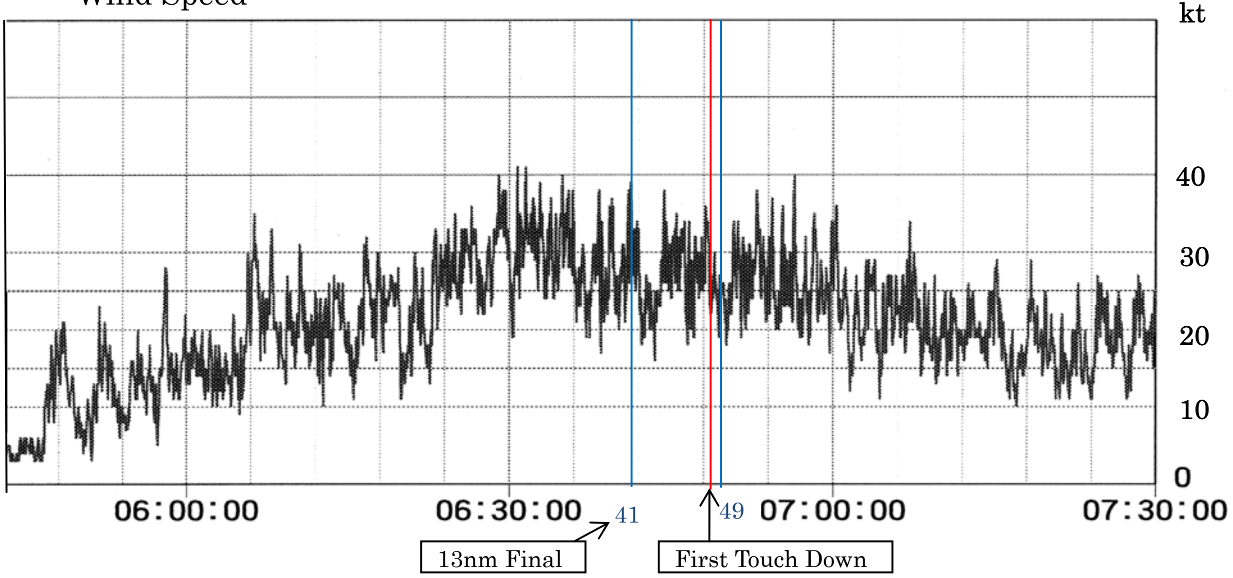
34L TH

Appendix 8 Instantaneous Wind Direction and Wind Velocity over Runway 34L Area

Wind Direction



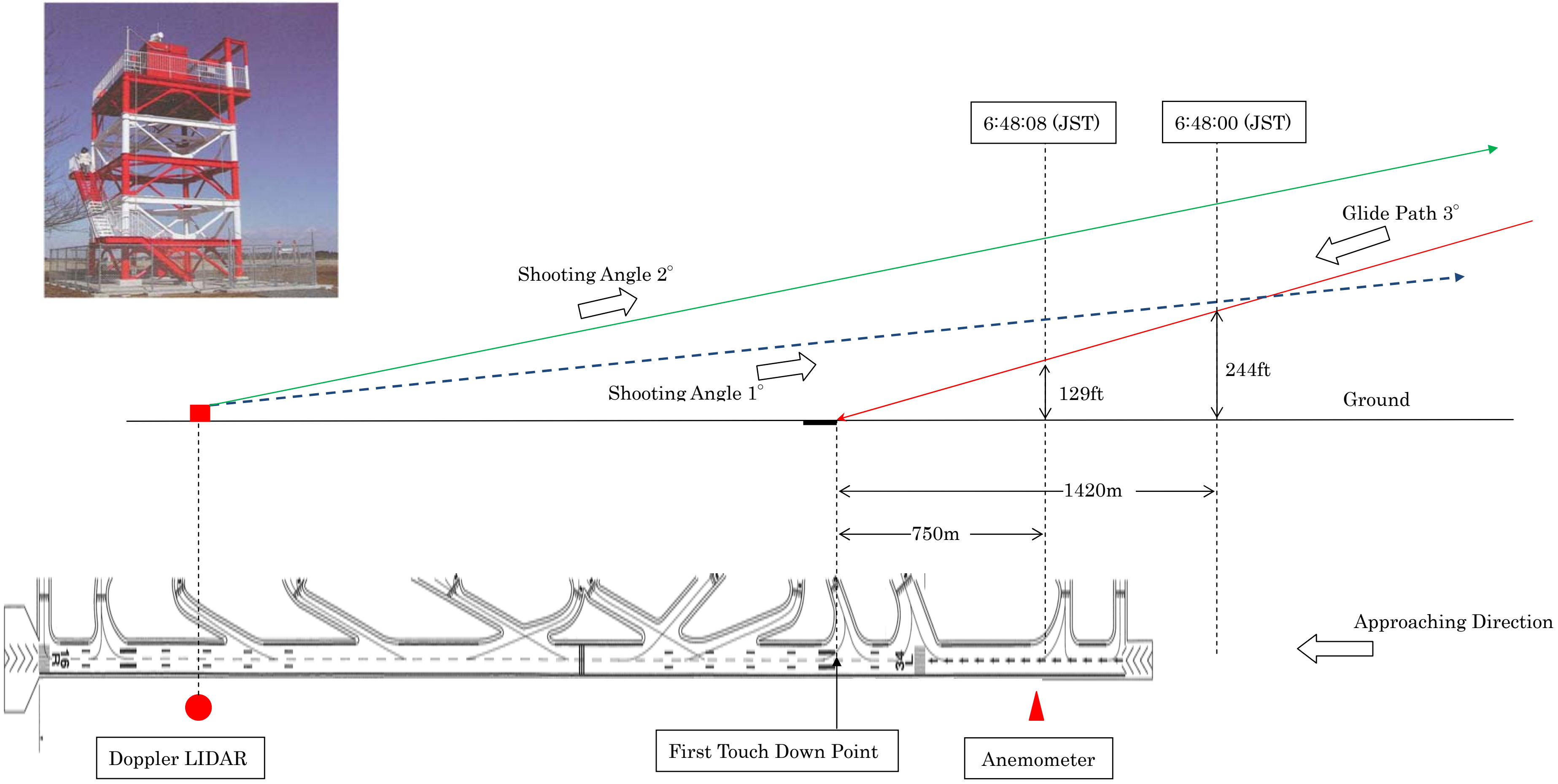
Wind Speed



(JST)	W/D(°)	W/S(kt)
06:48:00	325	25
06:48:03	322	28
06:48:06	312	29
06:48:09	310	26
06:48:12	317	36
06:48:15	318	34
06:48:18	318	33
06:48:21	321	34

Appendix 9　The Glide Path of the Airplane and the Shooting Angle of the Doppler LIDAR Laser

Doppler LIDAR



Attachment 1 CVR Records

TIME	Origin	Contents
06:46:29	TWR	FedEx80, cleared to land, runway 34L, wind 320 at 29, maximum 36, minimum 17, QNH 2956.
06:46:39	FDX80	Okay, cleared to land 34L, copy that, 2956.
06:46:42	TWR	Roger.
06:46:44	PIC	Five six.
06:46:45	FO	Got it.
06:46:45	TWR	Tower broadcast, Narita QNH change 2956, Narita QNH changed 2956, broadcast out.
06:46:53	CAWS	One thousand.
06:47:10	PIC	Yee haw.. ride em cowboy.
06:47:17	RAAS	Approaching 34L.
06:47:40	CAWS	Five hundred.
06:47:42	PIC	Cleared to land 34L..... stable. ［sound of laughter］
06:47:46	FO	Sheee.
06:48:03	CAWS	［sound similar to autopilot disconnect tone］ Autopilot. ［sound similar to autopilot disconnect tone］ Autopilot.
06:48:08	TWR	Wind 320 at 27, maximum 34, minimum 18.
06:48:11	CAWS	One hundred.
06:48:15	CAWS	Fifty.
06:48:16	CAWS	Forty.
06:48:17	CAWS	Thirty.
06:48:18	CAWS	Twenty.
06:48:19	CAWS	Ten.
06:48:20	CAM	［sound similar to touchdown］
06:48:22	CAM	［sound of loud bang］
06:48:27	CAM	［sound of loud bang］
06:48:28	CAWS	［sound of level 3 tri-tone warning］ ［master warning］
06:48:28	CAM	fire * oh ####
06:48:30	EGPWS	Bank angle, bank angle.
06:48:32		［End of Recording］

Legend		
	TWR	Narita Tower (118.2MHz)
	FDX80	Radio transmission from FedEx eight-zero
	PIC	Captain
	FO	First Officer
	CAM	Cockpit Area Microphone
	CAWS	Automated callout from Central Aural Warning System
	RAAS	Automated callout from Runway Awareness Advisory System
	EGPWS	Automated callout from Enhanced Ground Proximity Warning System
	*	Unintelligible word
	####	Expletive deleted
	［ ］	Editorial insertion

TIME was corrected from Japan Standard Time recorded on ATC Communication Records.

Attachment 2　ATC Communications Records

TIME	Origin	Contents
06:41:35	**FDX80**	Narita Tower, FedEx 80, thirteen miles for 34L.
06:41:39	TWR	FedEx 80, Narita Tower, runway 34L, number two, continue approach, wind 320 at 28, maximum 40, minimum 20.
06:41:51	**FDX80**	Uh.. continue FedEx..uh..80, roger.
06:41:54	TWR	Nippon Cargo 037, Tower.
06:42:15	NCA037	Tower, Nippon Cargo 037, uh.. six miles on final, runway 34L.
06:42:20	TWR	Good morning, Nippon Cargo 037, Narita Tower, runway 34L, cleared to land, wind 320 at 29, maximum 40, minimum 20. Also PIREP windshear below 2000, plus minus 15 knots, reported Boeing 747.
06:42:35	NCA037	Thank you, Nippon Cargo 037, cleared to land runway 34L.
06:42:40	TWR	Roger.
06:43:57	TWR	Tower broadcast, PIREP, windshear on final, runway 34L, below 2000, plus minus 15 knots. Now surface winds 320 at 23 knots, maximum 34, minimum 15. Out.
06:44:21	FDX38	Narita Tower, FedEx 38, * 34L.
06:44:25	TWR	Good morning, FedEx 38, Narita Tower, you are number three, landing runway 34L, continue approach, wind 320 at 24, maximum 38, minimum 15. Also PIREP windshear 2000 feet, plus minus 15 knots.
06:44:41	FDX38	Continue approach, FedEx 38.
06:45:16	TWR	Wind 320 at 26 knots, maximum 38, minimum 16.
06:46:08	TWR	Nippon Cargo 037, taxi A-3 then W-3.
06:46:12	NCA037	A-3 W-3, Nippon Cargo 037.
06:46:16	TWR	How about final conditions?
06:46:18	NCA037	Ah, really rough, plus minus 15 knots below 1000.
06:46:22	TWR	Below 1000, plus minus 15 knots, thank you. Contact Narita Ramp 121 decimal 6.
06:46:28	NCA037	One-two-one-six.
06:46:29	TWR	FedEx 80, cleared to land runway 34L, wind 320 at 29, maximum 36, minimum 17, QNH 2956.
06:46:39	**FDX80**	Okay, cleared to land 34L, copy that, 2956.
06:46:42	TWR	Roger.
06:46:45	TWR	Tower broadcast, Narita QNH change 2956, Narita QNH changed 2956, broadcast out.
06:48:08	TWR	Wind 320 at 27, maximum 34, minimum 18.
06:48:20		[First touchdown]

Legend		
	FDX80	FedEx eight-zero
	TWR	Narita Tower (118.2MHz)
	NCA037	Nippon Cargo zero-three-seven
	FDX38	FedEx three-eight
	*	Unintelligible word
	[　]	Editorial insertion

TIME was corrected from Japan Standard Time recorded on ATC Communication Records.

Attachment 3-1　Camera Images from about 50ftRA to Stoppage of Airplane

15 frames/ 4 sec


1　Passing through 50ftRA
6:48:15.6


2　6:48:15.9


3　6:48:16.2


4　6:48:16.4


5　6:48:16.7


6　Passing through 30ftRA
6:48:17.0


7　6:48:17.2


8　6:48:17.5


9　6:48:17.8


10　Passing through 20ftRA
6:48:18.0

Attachment 3-2　Camera Images from about 50ftRA to Stoppage of Airplane


11　6:48:18.3


12　6:48:18.6


13　6:48:18.8


14　6:48:19.1


15　6:48:19.4


16　6:48:19.6


17　1st touchdown　6:48:19.9


18　6:48:20.2


19　6: 48:20.4


20　6:48:20.7

Attachment 3-3 Camera Images from about 50ftRA to Stoppage of Airplane


21 AGS deployed 6:48:21.0


22 1st bounce 6:48:21.2


23 6:48:21.5


24 2nd touchdown on NLG 6:48:21.8


25 2nd touchdown on MLGs 6:48:22.0


26 6:48:22.3


27 2nd bounce 6:48:22.6


28 6:48:22.8


29 6:48:23.1


30 6:48:23.4

Attachment 3-4 Camera Images from about 50ftRA to Stoppage of Airplane


31 Pitch angle: at about6.7° 6:48:23.6


32 6:48:23.9


33 6:48:24.2


34 6:48:24.4


35 6:48:24.7


36 6:48:25.0


37 Highest bouncing point 6:48:25.2


38 6:48:25.5


39 Start of nose down 6:48:25.8


40 6:48:26.0

Attachment 3-5 Camera Images from about 50ftRA to Stoppage of Airplane


41 6:48:26.3


42 6:48:26.6


43 3rd touch down on NLG 6:48:26.8


44 Just after 3rd touch down (MLGs) 6:48:27.1


45 Fuselage twists to the right 6:48:27.4


46 6:48:27.6


47 6:48:27.9


48 Roll to the left 6:48:28.2


49 6:48:28.4


50 6:48:28.7

Attachment 3-6 Camera Images from about 50ftRA to Stoppage of Airplane


51 Fire break out 6:48:29.0


52 6:48:29.2


53 6:48:29.5


54 6:48:29.8


55 6:48:30.0


56 6:48:30.3


57 6:48:30.6

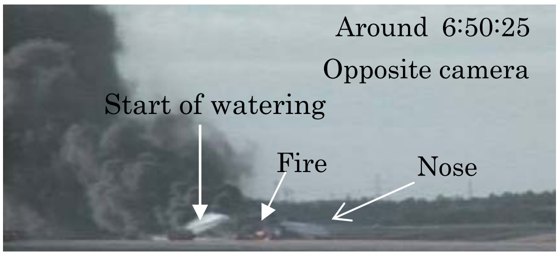

58 6:48:30.8

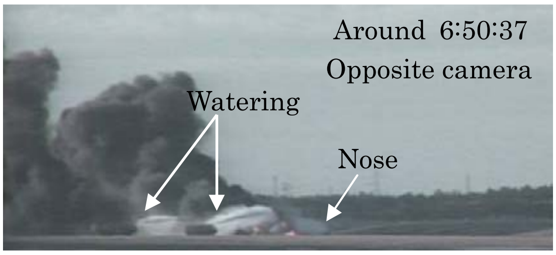

59 The Airplane completely inverted 6:48:31.1

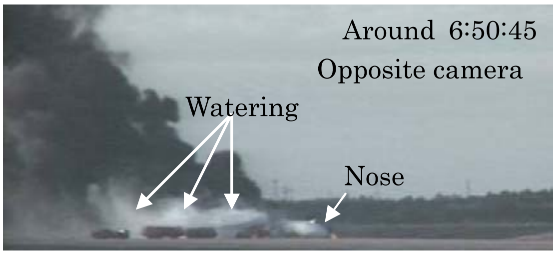

60 6:48:31.4


61 6:48:31.6

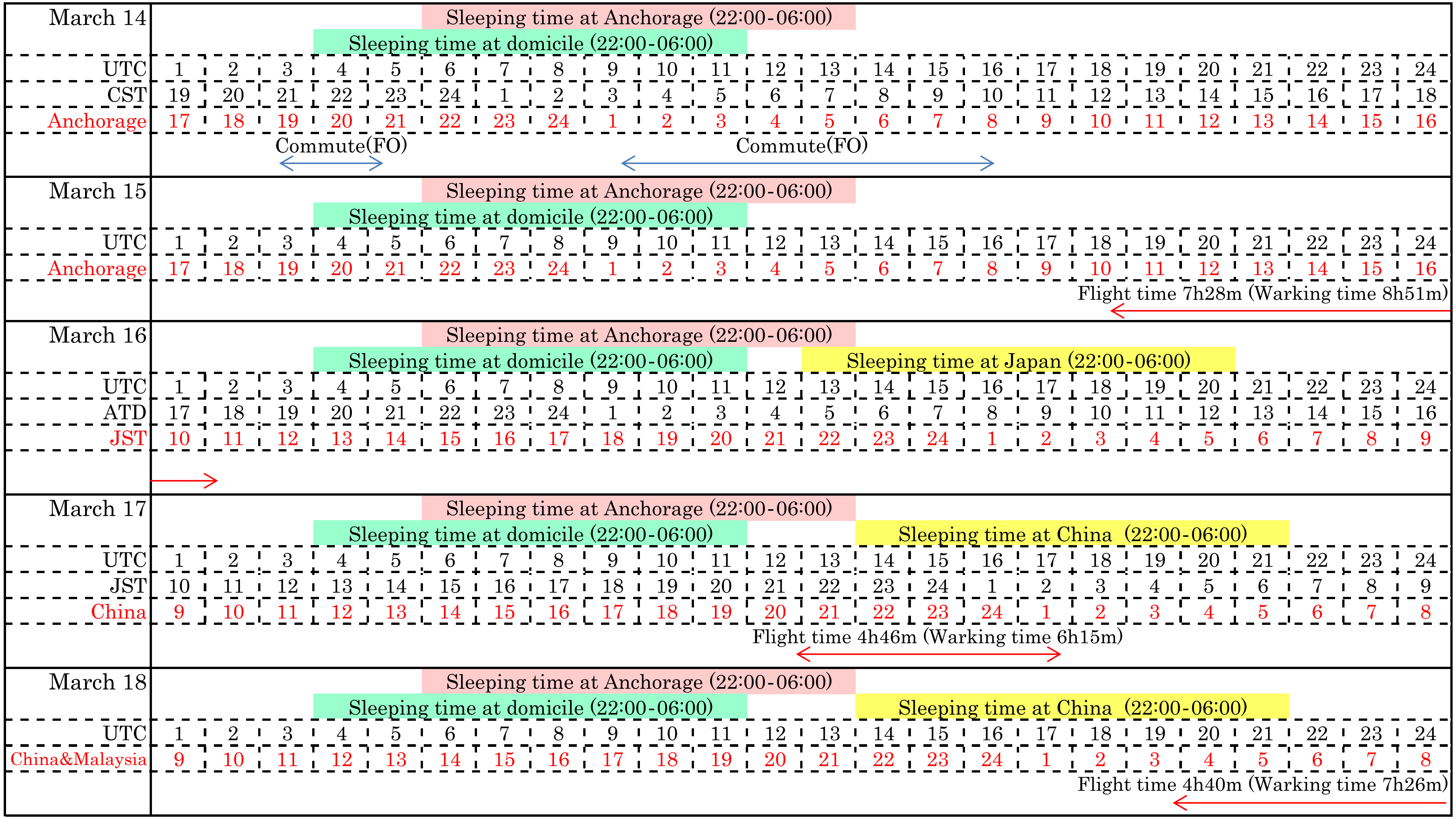
Attachment 4 Fire Fighting







Attachment 5-1 Working Conditions of the PIC and the FO



March 14

Sleeping time at Anchorage (22:00-06:00)

Sleeping time at domicile (22:00-06:00)

UTC	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24
CST	19	20	21	22	23	24	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18
Anchorage	17	18	19	20	21	22	23	24	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16

Commute(FO)

Commute(FO)

March 15

Sleeping time at Anchorage (22:00-06:00)

Sleeping time at domicile (22:00-06:00)

UTC	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24
Anchorage	17	18	19	20	21	22	23	24	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16

Flight time 7h28m (Warking time 8h51m)

March 16

Sleeping time at Anchorage (22:00-06:00)

Sleeping time at domicile (22:00-06:00)

Sleeping time at Japan (22:00-06:00)

UTC	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24
ATD	17	18	19	20	21	22	23	24	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
JST	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	1	2	3	4	5	6	7	8	9

March 17

Sleeping time at Anchorage (22:00-06:00)

Sleeping time at domicile (22:00-06:00)

Sleeping time at China (22:00-06:00)

UTC	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24
JST	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	1	2	3	4	5	6	7	8	9
China	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	1	2	3	4	5	6	7	8

Flight time 4h46m (Warking time 6h15m)

March 18

Sleeping time at Anchorage (22:00-06:00)

Sleeping time at domicile (22:00-06:00)

Sleeping time at China (22:00-06:00)

UTC	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24
China&Malaysia	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	1	2	3	4	5	6	7	8

Flight time 4h40m (Warking time 7h26m)

Attachment 5-2　Working Conditions of the PIC and the FO