

The investigation for this report was conducted by Aircraft and Railway Accidents Investigation Commission about the aircraft accident of Japan Airlines Boeing 747-400D (an approach to JA8546 of the same airline) in accordance with Aircraft and Railway Accident Investigation Commission Establishment Law and Annex 13 to the Convention of International Civil Aviation for the purpose of determining cause of the aircraft accident and contributing to the prevention of accidents and not for the purpose of blaming responsibility of the accident.

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

Junzo Sato,
Chairman,
Aircraft and Railway Accidents Investigation Commission

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Abbreviated words

Abbreviated words used in this report are as follows:

A C	: Advisory Circular
A C A R S	: Aircraft Communication Addressing and Reporting System
A C A S	: Airborne Collision Avoidance System
A C C	: Area Control Center
A C M S	: Aircraft Condition Monitoring System
A F M	: Airplane Flight Manual
A I C	: Aeronautical Information Circular
A I D S	: Aircraft Integrated Data System
A I P	: Aeronautical Information Publication
A N O	: Air Navigation Order
A O M	: Aircraft Operating Manual
A / P	: Auto Pilot
A T C	: Air Traffic Control
A V T	: Audio Visual Tutor
B K N	: Broken
C A	: Cabin Attendant
C A P	: Civil Aviation Authority Publication
C A S	: Computed Airspeed
C B T	: Computer Based Training
C L R C F T	: Clear of Conflict
C N F	: Conflict Alert
C P	: Chief Purser
C P A	: The Closest Point of Approach
C R M	: Crew Resource Management
C V R	: Cockpit Voice Recorder
D F D R	: Digital Flight Data Recorder
E E C	: Electronic Engine Control
E N G	: Engine
F A A	: Federal Aviation Administration
F A R	: Federal Aviation Regulations
F L	: Flight Level
F O	: First Officer
I C A O	: International Civil Aviation Organization
J A A	: Joint Aviation Authorities
J A R	: Joint Aviation Requirements
J A R - O P S	: Joint Aviation Requirements - Operations
L O F T	: Line Oriented Flight Training

MAC : Mean Aerodynamic Chord
MCT : Maximum Continuous Thrust
ND : Navigation Display
NDB : Non-Directional Radio Beacon
OJT : On the Job Training
OM : OPERATIONS MANUAL
OVC : Overcast
PANS – ATM: Procedures for Air Navigation Services
Air Traffic Management
PANS – OPS: Procedures for Air Navigation Services
Aircraft Operations
PANS – RAC: Procedures for Air Navigation Services
Rules of the Air and Air Traffic Services
PF : Pilot Flying
PFD : Primary Flight Display
PIC : Pilot in Command
PNF : Pilot Not Flying
QM : QUALIFICATIONS MANUAL
RA : Resolution Advisories
RDP : Radar Data Processing System
RPM : Revolutions Per Minute
SCT : Scattered
TA : Traffic Advisories
TCAS : Traffic Alert and Collision Avoidance System
THR REF : Thrust Reference
TRM : Team Resource Management
UTC : Coordinated Universal Time
VHF : Very High Frequency
VNAV : Vertical Navigation
VOR : VHF Omni-Directional Radio Range
VORTAC : VOR and TACAN (UHF Tactical Air Navigation aid)
combination
VSI : Vertical Speed Indicator

Remarks for usage of terms

- (1) Directions are expressed by magnetic directions, except for relative directions.
- (2) "Course" is used in the same meaning with "magnetic course".
- (3) "Heading" is used in the same meaning with "magnetic course", "course" or "magnetic heading".
- (4) As for "bank angle", "roll angle" is used in case that the value is cited from "roll angle" of DFDR.
- (5) "TCAS" is an abbreviation of Traffic Alert and Collision Avoidance System. "ACAS" is an abbreviation of Airborne Collision Avoidance System. Both expressions mean an aircraft collision avoidance system. The term "ACAS" is used in ICAO regulations, AIC issued by Civil Aviation Bureau and the regulations of European authorities. The term "TCAS" is used in the regulations of air traffic control facilities and aircraft operators, etc. and the regulations of the authority of the United States.

In this report, the term "TCAS" is used in principle. The term "ACAS" is used in sentences cited from ICAO regulations, AIC issued by Civil Aviation Bureau or the regulations of European authorities

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AIRCRAFT ACCIDENT INVESTIGATION REPORT

JAPAN AIRLINES FLIGHT 907

BOEING 747-400D, JA8904

JAPAN AIRLINES FLIGHT 958

DOUGLAS DC-10-40

A NEAR MIDAIR COLLISION OVER THE SEA OFF

YAIZU CITY, SHIZUOKA PREFECTURE, JAPAN

AT ABOUT 15:55 JST, JANUARY 31, 2001

July 12, 2002

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

Chairman Junzo Sato

Member Ryouhei Katsuno

Member Susumu Kato

Member Sumio Matsuura

Member Yukiko Kakimoto

Member Kozaburo Yamane

1. PROCESS AND PROGRESS OF THE ACCIDENT INVESTIGATION

1.1 Summary of the Accident

On Wednesday January 31, 2001, a Boeing 747-400D of Japan Airlines, registration JA8904, departed Tokyo International Airport as scheduled passenger flight 907 to Naha Airport. The aircraft was climbing through an altitude of approximately 37,000 ft as the result of a climb instruction from Tokyo Area Control Center (ACC) when it commenced descending to an altitude of 35,000 ft in response to an instruction from Tokyo ACC.

On the same day, a Douglas DC-10-40 of Japan Airlines, registration JA8546, departed Pusan International Airport in South Korea as scheduled passenger flight 958 to New Tokyo International Airport. In accordance with its flight plan, the aircraft was cruising at an altitude of 37,000 ft over the Shima peninsula, Aichi prefecture, heading toward the Oshima VORTAC navigational fix having crossed the Kowa VORTAC navigational fix.

At around 15:55, the two aircraft experienced a near midair collision and took evasive actions at an altitude between approximately 35,500 ft and 35,700 ft over the sea about 7 nautical miles (about 13 kilometers) south of Yaizu NDB, Shizuoka prefecture. Passengers and flight attendants on board Flight 907 sustained injuries as the result of the evasive maneuvers.

Of the 427 persons aboard Flight 907 — 411 passengers, the captain and 15 other crewmembers — seven passengers and two cabin attendants were seriously injured, and 81 passengers and 10 cabin attendants sustained minor injuries. The interior of the passenger cabin of Flight 907 was slightly damaged due to the upset, but no fire occurred.

There were 250 persons on board Flight 958 — 237 passengers, the captain and 12 other crewmembers — but there were no injuries. There was no damage to Flight 958.

1.2 Outline of the Accident Investigation

1.2.1 The Organization of the Investigation

- 1.2.1.1 On January 31, 2001, the Aircraft Accident Investigation Commission (AAIC) assigned an investigator-in-charge and six investigators.

On July 1, 2001, a further two investigators were assigned.

Subsequently, in accordance with personnel transfers, an investigator-in-charge was newly assigned on October 1, 2001, and two investigators were replaced, one on January 1, 2002 and one on April 1, 2002.

- 1.2.1.2 The AAIC conducted analyses of activations of the traffic alert and collision avoidance system (TCAS) and the recordings of Air Traffic Control (ATC) radar tracking in collaboration with the Equipment Study Group of the Electronic Navigation Development Division, Electronic Navigation Research Institute (ENRI), Independent Administrative Institution.

1.2.2 The Implementation of the Investigation

The investigation proceeded as follows.

January 31–August 7, 2001	On-site investigation
February 1–August 27, 2001	Interviews with flight crews of Flight 907 and Flight 958
February 2, 2001–February 4, 2002	Interviews with Air Traffic Controllers
February 1–June 15, 2001	Investigation into the injured
February 19	Bench-test of the aircrafts' avionics
February 1–August 31, 2001	Analysis of DFDR recordings
February 1–September 20, 2001	Investigation and analysis of RDP and TCAS recordings
March 6, 2001–February 5, 2002	Flight tests using flight simulator
April 17–May 9, 2001	Functional test of TCAS by actual flight

1.2.3 Interim Report and Proposals

On June 22, 2001, based upon the factual investigation up to that date, the AAIC submitted an interim report on this accident to the Minister for Land, Infrastructure and Transport with “Proposals” on safety issues that should be improved. These were also made public on the same day.

1.2.4 Public Hearing

The AAIC published a draft of the Factual Investigation Report on December 14, 2001, and a public hearing was held on January 17, 2002 to hear the accounts of nine witnesses.

- (1) Date: 10:00–16:15 January 17, 2002
- (2) Venue: Assembly Hall, Ministry of Land, Infrastructure and Transport, Building No.3, 2-1-3 Kasumigaseki, Chiyoda Ward, Tokyo, Japan
- (3) Hearing Chairman: Mr. Yasuyuki Chino, Director General of the Aircraft Railway Accident Investigation Commission
- (4) Witnesses (in order of speaking)
 - Mr. Isao Kuroda Chief of the Japan Institute of Human Factors
 - Mr. Moriyuki Mizumachi Professor of Tokyo Shibaura Industry College
 - Mr. Eimei Suzuki Japan Aircraft Pilot Association
 - Mr. Hideo Nakano Air Traffic Control Association, Japan
 - Mr. Ryutaro Kawano Senior researcher of the Human Factors Group, Nuclear Power Research and Development Center, Engineering Research and Development Division, Tokyo Electric Power Company
 - Mr. Hiroyuki Kobayashi (Captain of Boeing 747-400)
 - Mr. Noriyuki Ono
 - Mr. Mikio Hayashida President, Airline Pilot Association of Japan
 - Mr. Osamu Takeda
- (5) Summary of Statements and Attendees
 - Refer to “MINUTES OF HEARING ON AIRCRAFT ACCIDENT” issued in January 2002. in Japanese only

1.2.5 Hearings from Persons relevant to the Cause of the Accident

Hearings were held.

2. FACTUAL INFORMATION

2.1 Flight History

2.1.1 Flight History based on the Recordings of the Onboard Recorders and ATC Recorder, etc.

On 31 Jan 2001, a Boeing 747-400D, registration JA8904 (Aircraft-A) operating as Japan Air Lines scheduled flight 907 took off from Tokyo International Airport for Naha Airport at 1536 Japan Standard Time¹, and was flying under Instrument Flight Rules (IFR) in accordance with its flight plan.

A total of four flight crewmembers were in the cockpit of Aircraft-A; namely the Captain sitting on the left forward seat, a pilot training for first officer sitting on the right forward seat, the First Officer sitting behind the Captain on the left observer's seat (jump seat), and a pilot training for First Officer sitting on the right observer's seat.

The flight plan of Aircraft-A, which had been filed with the Tokyo Airport Office, was as follows:

Flight rules: IFR, Aerodrome of departure: Tokyo International Airport, Planned block out time: 1525, Cruising speed: 497kt, Level: 390, Route: KZE URAGA OCEAN YZ CELLO SAKAK W28 TAPOP G581 ONC NHC, Destination Aerodrome: Naha Airport, Total estimated en-route time: 2 hours and 22 minutes, Fuel load in terms of flight time: 3 hours 52 minutes, Number of persons on board: 415.

The flight history near the location of the accident occurrence, shown by DFDR records, Air Traffic Control Communication records, Air Traffic Control radar records and TCAS data recorded by ACMS and AIDS, was as follows:

When the accident occurred, three air traffic controllers were on duty at Kanto South C sector of Tokyo ACC, namely an air traffic controller undergoing on-the-job (OJT) familiarization training on the sector (trainee controller) seated at the radar controller's console, an air traffic controller supervisor (ATC watch supervisor), and a coordinator at the coordinator's console.

At 1541:16, Aircraft-A informed Tokyo ACC that it was passing 11,000 ft climbing to FL390. The ATC trainee responded to this information.

At 1542:12 and 1544:33, the ATC trainee instructed Aircraft-A to fly direct to Yaizu NDB. Aircraft-A responded that it was complying with this instruction.

At 1545:25, trainee controller instructed Aircraft-A to maintain FL350 until further notice. Aircraft-A read back this instruction. Meanwhile, an aircraft operating as

1 Unless stated otherwise, all times in this report are Japan Standard Time.

American Airlines scheduled flight 157 (Aircraft-C) was cruising at FL390 above the vicinity of Izu Oshima towards Kushimoto, Wakayama prefecture.

At 1546:38, Aircraft-A, which was climbing near FL216, was instructed to climb to FL390 by the ATC trainee. At 1546:41, Aircraft-A replied to Tokyo ACC that it was climbing to FL390.

At 1546:51, as a result of an adjacent sector handing over control of Aircraft-B to Kanto South C sector, the letters "HND" appeared in Aircraft-B's data block on the radar display of Kanto South C sector, and flashed on and off.

At 1547:02, the ATC trainee instructed Aircraft-C to descend to FL350, because it was occupying the planned flight level of Aircraft-A, but Aircraft-C did not respond.

At 1547:14, an aircraft operating as Japan Airlines scheduled flight 952 (Aircraft-D) requested Tokyo ACC to fly directly to a fix in the vicinity of New Tokyo International Airport, and the ATC trainee instructed it to stand by.

At 1547:47, an air traffic controller of Kanto South C sector input a command into the Radar Data Processing System (RDP) to receive the hand over of control of Aircraft-B from an adjacent sector.

At 1547:56, the ATC trainee called up Aircraft-C again, but Aircraft-C still did not respond.

At 1548:08, the ATC trainee instructed Aircraft-D to contact New Tokyo International Airport. Aircraft-D responded at 1548:12 that it would comply with this instruction.

At 1548:14, Aircraft-B, which was cruising at FL370 to the west of Aircraft-A towards New Tokyo International Airport, contacted Tokyo ACC, stating that it was at FL370. Three flight crewmembers were in the cockpit of Aircraft-B, namely the Captain sitting in the right forward seat, the first officer for upgrade to captain sitting on the left forward seat, and the Flight Engineer.

At 1548:18, the ATC trainee responded to acknowledge this information. The ATC trainee subsequently continued to communicate with other aircraft.

At 1548:22, an air traffic controller of Kanto South B sector, who had controlled Aircraft-C up to that time, instructed Aircraft-C to change its radio frequency to Kanto South C sector.

At 1548:37, Aircraft-C contacted Kanto South C sector, stating that it was at FL390. The ATC trainee instructed it to descend to FL350, because another aircraft was cruising at the same flight level as Aircraft-C. Aircraft-C read back this instruction, and responded that it was leaving FL390.

During a nine minute period from 1543:00 to 1552:00, the ATC trainee was handling at most 14 aircraft, and made a total of 37 radio transmissions under the

guidance of the ATC watch supervisor. Of these transmissions, 18 comprised air traffic instructions. During this 9 minute period, there were three intervals with no communication that lasted longer than 15 seconds, and 4 or 5 transmissions were being made each minute. During the period from 1552:00 to 1554:22, when the series of communications related to this accident started, the ATC trainee made four transmissions to three aircraft, giving one instruction.

At 1553:50, Aircraft-A which had been climbing on a heading of 270°, began a left turn and then continued climbing while maintaining a bank angle of approximately 25°.

At 1554:00, Aircraft-B was to the west of the location of the near-midair collision cruising at FL370 at a heading of 095° and a ground speed of 567kt. At that time, its TCAS display showed a symbol corresponding to Aircraft-A with an upward arrow next to it indicating that Aircraft-A was climbing.

At 1554:15, a CNF conflict alert was indicated on the radar display of the Kanto South C sector at Tokyo ACC. At that time, the radar screen showed that the altitude of Aircraft-A was FL367 and the altitude of Aircraft-B was FL370.

At 1554:18, Aircraft-B's TCAS issued a Traffic Advisory (TA), which showed that another aircraft was approaching.

At 1554:19, Aircraft-A TCAS issued a TA. At that time, Aircraft-A was in a climbing left turn at FL369, and the ATC radar display also showed its altitude as FL369.

(Note: When a TA is issued, the symbol of the approaching aircraft on the TCAS display is shown in yellow, and a synthetic voice annunciation of "TRAFFIC, TRAFFIC" sounds in the cockpit.)

Between 1554:26 and 1554:29, the autothrottle of Aircraft-B, which had been engaged up to that time, was disengaged.

Between 1554:27 and 1554:32, the ATC trainee instructed Aircraft-A to descend to FL350 and to start descent due to traffic.

At 1554:32, the autopilot of Aircraft-A, which had been engaged up to that time, was disengaged.

At 1554:33, fuel flow rate to the engines of Aircraft-A began to decrease.

Between 1554:33 and 1554:38, Aircraft-A, which was climbing near FL371, replied to the ATC instruction to descend to FL350 and acquired the traffic visually. Also, a voice "CLIMB, CLIMB, CLIMB" was recorded on the ATC communications recorder with Aircraft-A's reply to the instruction from 1554:35 to 1554:38.

At 1554:34, the pitch angle of Aircraft-A began to decrease.

At 1554:34, Aircraft-B's TCAS issued a Resolution Advisory (RA) directing a 1,500ft/min descent.

At 1554:35, Aircraft-A's TCAS also issued an RA that directed a 1,500ft/min climb.

At that time, Aircraft-A was in a climbing turn at around FL371, and Aircraft-B was cruising at FL370 on a heading of 095°.

(Note: When a TA changes to an RA, the symbol of the other aircraft on the TCAS display changes from yellow to red, and an instruction is issued to avoid the other aircraft. In the case of an instruction to climb, the commanded rate of climb is indicated on the TCAS display while a synthetic voice “CLIMB, CLIMB, CLIMB” sounds in the cockpit. In the case of an instruction to descend, the commanded rate of descent is indicated on the TCAS display while a synthetic voice “DESCEND, DESCEND, DESCEND” sounds in the cockpit.)

At 1554:37 the pitch angle of Aircraft-A, which had been decreased up to that time, momentarily increased, but subsequently continued to decrease.

At 1554:38, Aircraft-A's auto-throttle was disengaged.

Between 1554:38 and 1554:41, the ATC trainee instructed Aircraft-B to turn to heading 130° to establish separation. Aircraft-B did not respond to this instruction.

Between 1554:39 and 1554:43, the fuel flow rate of Aircraft-A momentarily increased, but subsequently continued to decrease.

At 1554:39, Aircraft-B's autopilot, which had been engaged up to that time, was disengaged.

At 1554:43, Aircraft-A reached the top of its climb (FL372) while making a left turn, and subsequently its altitude began to decrease.

At 1554:43, Aircraft-B's altitude began to decrease.

At 1554:46, the bank angle of Aircraft-A momentarily increased to more than 30° left, but subsequently began to decrease. Then, Aircraft-A began to roll out slowly on a heading of 207°.

At 1554:49, Aircraft-B's TCAS issued an increase descent RA, commanding descent at 2,500ft/min. At that time, Aircraft-B was at FL369 and descending, Aircraft-A was at FL370 and descending, and Aircraft-A's TCAS RA was commanding a 1,500ft/min climb.

(Note: when an increase descent RA is issued, the commanded descent rate indicated on the TCAS display increases and a synthetic voice “INCREASE DESCENT, INCREASE DESCENT” sounds in the cockpit.)

Between 1554:49 and 1554:52, the ATC trainee instructed Aircraft-B to turn to heading 140° to establish separation.

Aircraft-B did not replied to this instruction. At that time, Aircraft-B was descending at around FL369, and Aircraft-A was descending through FL370–FL369.

Between 1554:51 and 1555:12, the altitudes of Aircraft-A and Aircraft-B changed as follows.(Note: the following data includes some error.)

Time (15:xx:xx) (15:xx:xx)	Altitude of Aircraft-A (Flight Level)	Altitude of Aircraft-B (Flight Level)
54:51	369	369
:52	369	369
:53	368	368
:54	368	368
:55	367	368
:56	367	367
:57	366	367
:58	366	366
:59	366	366
55:00	365	365
:01	365	365
:02	365	364
:03	364	363
:04	363	363
:05	363	362
:06	362	361
:07	362	360
:08	360	359
:09	358	358
:10	357	358
:11	355	357
:12	354	357

At 1554:54, Aircraft-A's TCAS display indicated that Aircraft-B was descending, by a downward arrow by the side of the symbol corresponding to Aircraft-B on the display.

Between 1554:55 and 1554:57, the ATC watch supervisor overrode the ATC trainee, and instructed JAL957 to start descent, but there was no aircraft with a corresponding callsign in the neighborhood.

Between 1555:02 and 1555:05, the ATC watch supervisor instructed Aircraft-A to climb to FL390, but Aircraft-A did not respond to this instruction. At that time, the RA issued by Aircraft-A's TCAS was commanding a 1,500ft/min climb, while the RA issued by Aircraft-B's TCAS was commanding a 2,500ft/min descent .

At 1555:05, the nose-down pitch angle of Aircraft-A began to increase in the nose-down sense. Aircraft-B was descending at around FL362, and the angle of its control columns changed from pitch down to pitch up. The RA issued by Aircraft-B's

TCAS was commanding a 2,500ft/min descend.

At 1555:06, at which time Aircraft-A was descending at FL362, Aircraft-A's TCAS issued an increase climb RA, commanding a 2,500ft/min climb. The CAS (Computed Air Speed) of Aircraft-A was 284kt had been stable during Aircraft-A's descent until that point, but subsequently it began to increase.

(Note: when an increase climb RA is issued, the commanded climb rate indicated on the TCAS display increases while a synthetic voice "INCREASE CLIMB, INCREASE CLIMB" sounds in the cockpit.)

At 1555:07, the nose-down pitch angle of Aircraft-A reached its maximum value of 10.8°. Subsequently, the pitch angle gradually began to return to nose-up.

At around 1555:08, the fuel flow rate of Aircraft-A decreased to around the rate corresponding to engine idling. At that time, Aircraft-A was descending at around FL360.

The recorded TCAS data of Aircraft-B show that the increase descent RA changed to a TA at 1555:09. This was because Aircraft-B's TCAS had not received information from Aircraft-A in a continuous period. As a result a track drop occurred, which meant that data were deleted in the TCAS equipment, Aircraft-A's symbol on the TCAS display Aircraft-B disappeared, and TA was not indicated.

At 1555:10, Aircraft-B's TCAS received information from Aircraft-A again, and Aircraft-A's symbol reappeared, but a maneuver command was not displayed because the TCAS had only just started receiving information from Aircraft-A.

At around 1555:11, Aircraft-A and Aircraft-B passed by each other.

At 1555:13, when Aircraft-A was descending at around FL353, the CAS of Aircraft-A increased to 299kt, which was the maximum speed attained in the descent. At that time, the fuel flow rate of Aircraft-A corresponded to near engine idle, and the nose-down pitch angle had returned to 5.5°. At that time, Aircraft-B was descending at around FL356.

At 1555:15, the RA on Aircraft-A, which was commanding a 2,500ft/min climb, changed to a TA, and indicated CLR CNF (clear of conflict).

At 1555:18, Aircraft-A was descending through FL348, and its pitch angle become positive.

At 1555:20, Aircraft-A was at around FL348, and it began to climb from 1555:21.

Between 1555:21 and 1555:27, Tokyo ACC received a notification from an aircraft that an RA had been issued, that the aircraft was currently descending, and would climb again. Although this notification did not include a callsign, as a result of investigation, this aircraft was identified as Aircraft-B. At that time, Aircraft-B was descending near FL353, but, at around 1555:26, it began to climb.

At 1555:29, the ATC watch supervisor of Tokyo ACC replied “Japan air niner zero ...eight, roger.”, but there was no aircraft with a corresponding callsign in the neighborhood.

Between 1555:32 and 1555:34, Aircraft-A notified Tokyo ACC that it was clear of traffic to, and the ATC watch supervisor responded “Roger”.

Between around 1555:00, when Aircraft-A was descending, and around 1555:21, when it began to climb again, the vertical acceleration of Aircraft-A varied remarkably. At 1555:06, it became -0.55G, and at 1555:17, it became +1.59G. (Note: vertical acceleration indicated is in the neighborhood of the aircraft’s center of gravity.)

The autopilot and autothrottle of Aircraft-A were reengaged, and Aircraft-A notified Tokyo ACC that a near-midair collision with a DC-10 had occurred. After that, it requested to return to Tokyo International Airport since there were injured persons, this clearance was received from Tokyo ACC.

Aircraft-A landed at Tokyo International airport at 1644.

Aircraft-B, after passing by Aircraft-A, reengaged autopilot and autothrottle and continued its flight. At 1632, Aircraft-B landed at New Tokyo International Airport.

2.1.2 Statements of Flight Crew with respect to Flight History

2.1.2.1 Statements of the Captain of Aircraft-A

The following are outlines of the statements made by the Captain of Aircraft-A on the progress of the flight.

“Our aircraft departed from Tokyo International Airport’s runway 34R at 15:35. The aircraft and engines were normal. I engaged the autopilot (AP) when we had accelerated to 250 knots at an altitude of about 5,000 ft. Before crossing MIURA point, we were instructed to turn right and were cleared ‘Direct YAIZU’.

“While climbing to FL 390 toward the YAIZU point, I visually identified traffic with a contrail at about 11 o’clock. It was at a higher altitude and approximately 40 nautical miles (nm) from our position. I talked with the trainee pilot about how close the traffic would come before being displayed on the Navigation Display (ND). The traffic was displayed on the ND as a TCAS symbol when it reached 25 nm. The TCAS-indicated altitude was FL 370. The cockpit crew discussed that we should keep an eye on the traffic.

“Our aircraft began to turn left onto course 207° around YAIZU. After the left turn, as our aircraft was approaching FL370, we were instructed by Tokyo ACC to ‘DESCEND FL350’. I understood that this was to maintain separation from the traffic, and thought that the controller intended to have our aircraft

pass below the traffic because the situation was not yet critical. Since the controller handles multiple aircraft with a grasp of the whole traffic situation, we followed the instruction to descend.

“Since we had been instructed to descend during a climb, I disengaged the AP and autothrottles and reduced the power to idle while commencing the descent. In the event, our aircraft ascended to around FL371 due to inertia.

“Just as the aircraft had begun to descend, the TCAS traffic advisory (TA) “TRAFFIC, TRAFFIC” sounded.

“Immediately thereafter, the TCAS resolution advisory (RA) “CLIMB, CLIMB, CLIMB” sounded.

“At that time, I observed the other aircraft approaching from the forward right at about the same altitude, but I had already initiated a descent and judging that the best way to avoid a collision at that altitude would be to continue descending contrary to the TCAS command, I continued descending to FL350. Further, I also considered the risk of stalling if we pitched up given the insufficient thrust, leading to an even more dangerous situation.

“The other aircraft appeared to be about in level flight at FL370.

“As a relative distance to the other aircraft remained unchanged, I thought that without further action we would collide and pitched down even further. After that I saw the other aircraft appear to pass from right to left at about eye level.

“I indicated in the Captain’s Report that the closest vertical separation from the other aircraft was approximately 10 meters. While we were maneuvering to pass just below the DC-10, it appeared to fill the forward right window but we were able to avoid a midair collision. I recalled writing that the altitude at the time of occurrence was FL368–FL368.5.

“I leveled off at an altitude of FL350 and, after stabilizing the pitch and thrust levers, I engaged the AP. After leveling off, we reported the occurrence of the near midair collision to Tokyo ACC.

“We received a report from the chief purser (CP) via interphone that several passengers and cabin attendants (CA) had been injured. I therefore decided to divert back to Haneda Airport (Tokyo International Airport) and, having received clearance, we landed at Haneda Airport at 16:44 JST.”

Note: Regarding the First Officer advising “Captain, the DC-10 is descending!”, which the First Officer submitted as a statement in the final stage of the investigation as described in the note in section 2.1.2.3 of this report, the Captain

stated that he was not aware of the advice.

2.1.2.2 Statements of the Pilot Under Training (Trainee Pilot) of Aircraft-A

The following are the summarized statements of the trainee pilot who was sitting in the right seat of the cockpit regarding progress of the flight of Aircraft-A.

“Our aircraft departed from Tokyo International Airport’s runway 34R at 15:35. After takeoff, soon after contacting Tokyo Departure, we were instructed ‘VECTOR TO MIURA’ and to climb to FL390.

“Subsequently, we were again instructed ‘VECTOR TO YAIZU’ and then ‘DIRECT YAIZU’.

“There were no problems with the weather, which was extremely fine with good visibility and smooth air.

“I saw a contrail, which turned out to be Aircraft-B, far away at 10–11 o’clock. There was a common awareness among the flight crew about the contrail as traffic.

“Subsequently, the traffic was displayed on the ND. It was indicated as at an altitude of FL370 and a distance of 30–40 nm.

“At the time we had turned left over the Yaizu NDB to head south, I recognized that the traffic was quite close.

“During the climb, when we were at about FL365–FL370, we were told by ATC ‘JAL907 DESCEND AND MAINTAIN FL350’. Judging that the ATC instruction was made taking into account the traffic which we had already sighted, the Captain disengaged the AP and autothrottles and commenced descending manually. As a result of inertia we ascended to approximately FL372, and began descent after that.

“During the operation to descend, the TCAS gave a TA ‘TRAFFIC, TRAFFIC’.

“Thereafter, although the RA ‘CLIMB, CLIMB, CLIMB’ sounded, the captain, probably considering we have been instructed by ATC to descend, stated ‘I will continue to descend’, and continued descending. Our aircraft pitched nose down but did not bank. (See Note below.)

“I felt that Aircraft-B would pass in front of or just above my eyes, and I thought that if we continued as we were, we would collide. The captain applied further pitch-down, at which time I felt as if I were being lifted.

“Subsequently, we were instructed by ATC to ‘CLIMB AND MAINTAIN FL390’. In response, we started to climb and during the climb, engaged the AP

when the aircraft had stabilized.

“The First Officer (FO), who had been sitting in the jump seat, confirmed the situation in the passenger cabin and the damage to the aircraft, and said that several people sustained injuries, so we decided to return to Haneda Airport.

“While en-route back, the two pilots sitting in the aft seats communicated with the company and confirmed the situation in the passenger cabin.

“We landed on runway 34L of Tokyo International Airport at 16:44.”

Note: In the final stage of the investigation, the Trainee Pilot submitted his opinions that “the First Officer looked outside and said ‘Captain, the other aircraft is descending too’.

2.1.2.3 Statements of the First Officer of Aircraft-A

The statements of the FO, who was sitting in the left jump seat, regarding Aircraft-A’s flight history are summarized as follows.

“I did not think that the ‘DESCEND FL350’ instruction was smart but I considered it plausible. We had already made visual contact with the other aircraft, so I thought that the instruction would have to avoid it. After the TA alert, the RA ‘CLIMB, CLIMB, CLIMB’ sounded, but I don’t exactly remember the time interval between them. At that point in time, however, as the descent had already been initiated following the ‘DESCEND FL350’, with the thrust levers closed and aircraft already at descent pitch, the captain continued maneuvering to descend while stating ‘we’re already descending, so we’ll descend’. At that time, following the TCAS RA, reapplying maximum power and pitching up to comply with the RA command, at an altitude of what I thought was around 37,000 ft, would have been extremely dangerous.

“During those few tens of seconds, I could not see the instruments from the aft seat. However, to maintain visual contact with the other aircraft at forward right at 1–2 o’clock, I kept my eyes on it while listening to the TCAS aural annunciations. I myself think that actions taken by the captain during that time were timely without any sense of irregularity. (Refer to Note below)

“I did not hear a TCAS “increase” RA command. ATC was communicating something but I was too imminent to understand the communications. I felt that the distance from the other aircraft at the closest point was around 10 meters.

“Subsequently, as some people were injured, with the captain’s permission I walked around the cabin to administer first aid treatment.”

Note: In the final stage of the investigation, the First Officer submitted his opinion that “around the time of the RA, when we were already descending in accordance with the ATC instruction, I advised the Captain with words to the effect of ‘Captain, the DC-10 is descending!’ ”

2.1.2.4 Statements of the Captain of Aircraft-B

The statements of the Captain of Aircraft-B’s regarding its flight history are summarized as follows.

“On the day of the accident, we had a round-trip flight, Narita to Pusan and back to Narita on the same day. The First Officer has been training for upgrade to Captain, and was the Pilot Flying (PF) during the round-trip. I was the Pilot-in-Command (PIC). Until the occurrence of the accident, we had been conducting ATC radio frequency changes as usual.

“After crossing XMC (Kowa VORTAC), at some point before the midpoint between XMC and XAC (Oshima VORTAC), the PF said ‘Traffic at 10–11 o’clock’, and I picked it up because of its contrail. The traffic was also displayed on the TCAS screen beyond the 10 nm arc at between 12–13 nm.

“As we saw the other aircraft turning over YAIJU, a TCAS ‘TRAFFIC, TRAFFIC’ TA sounded while we were about 10 nm distant at FL370. The other aircraft’s altitude was also displayed as FL370. The PF disengaged the autothrottles in anticipation of an RA.

“Before long, the TCAS ‘DESCEND, DESCEND, DESCEND’ RA activated and the PF disengaged the AP, set power to idle and lowered the nose little by little. Since the descent rate at this time was less than 1,000 ft/min, I exerted forward pressure on the control wheel while advising ‘Lower it further’.

“Immediately thereafter, the TCAS ‘INCREASE DESCENT, INCREASE DESCENT’ sounded. Judging that we had to descend rapidly, I called ‘I’m pulling speed brakes’ while pulling the speed brakes to full. The PF lowered the nose further. I switched on the seat belt sign. Glancing outside at that time, I saw the other aircraft approaching from the forward right. Finally it appeared to be approaching rapidly. It appeared to be descending in the same way as us, I could visually see the top of the fuselage, and I judged that it was increasing its descent rate, so I felt that the situation was extremely dangerous. I think the PF felt the same, but we had no time to communicate and we both pulled back on the yokes almost simultaneously.

“The PF increased power. After that, I made evasive maneuvers while

looking outside. Buffeting occurred because the speed brakes remained fully extended. As I continued pulling the control wheel without relaxing pressure although I felt buffeting, a big aircraft passed below our aircraft in an instant.

“At the time of crossing, I felt that the oncoming aircraft passed parallel to rather than in front of our aircraft and in the direction of 10 o’clock rather than ten-thirty. I knew that it was nose down, because I could see the top of its fuselage. I had the impression that the other aircraft was descending at the same altitude as us and was considerably nose down. Seeing that situation, I judged there was nothing that could be done but to pull.

“I do not recall receiving any instruction from ATC.

“I heard the TCAS warning of ‘INCREASE DESCENT, INCREASE DESCENT’ coming from above my head, but there was nothing from ATC. I myself did not hear anything. Subsequently, while returning to FL370, I informed ATC that ‘We have descended following a TCAS alert. We are now climbing through 35,500 ft for FL370’. This was the first radio communication we made after the two aircraft crossed. ATC replied only ‘Roger’.

“When we reached FL370, we heard Flight 907 informing ATC in Japanese that ‘We had a near miss...’. and so we recognized that the other aircraft had been Flight 907.

“After that, we landed safely at Narita Airport.”

2.1.2.5 Statements of the First Officer of Aircraft-B

According to the statement of the left seated First Officer training for upgrade to Captain, the outlines of Aircraft-B’s flight history were as follows.

“We departed Pusan International Airport and continued at FL370 to New Tokyo International Airport. Because we had twice been kept lower by altitude restrictions, I think we finally reached FL370 before JEC (Miho VORTAC).

“Subsequently, at around XMC we changed radio frequency to Tokyo ACC, 124.55 MHz, I think, and established contact.

“While we were flying from XMC to XAC, around about the time an RA went off, I couldn’t make out whether it was for “907” or “957” but I heard a ‘Descend’ command in a fairly faint voice.

“It was after that, I believe, that I became aware of the TCAS display showing traffic at 12–13 nm at FL370 without an arrow pointing upward or downward. At the same time I sighted the traffic at 10–11 o’clock. I wondered why the traffic was at the same altitude as us.

“Meanwhile, the TCAS TA of ‘TRAFFIC, TRAFFIC’ sounded. I disengaged

the autothrottles in anticipation of an RA command.

“Subsequently, the RA ‘DESCEND, DESCEND, DESCEND’ sounded. I disengaged the AP, closed the throttles and put us in a descent attitude, but the captain pointed out that the descent rate was low. While we were descending, I glanced the traffic in a slanting upward direction at 10–11 o’clock.

“Thereafter, an RA ‘INCREASE DESCENT, INCREASE DESCENT’ sounded. The captain selected full speed brakes and switched on the seat belt sign.

“There was no time to look at the instruments. It felt as if the other aircraft was rapidly rushing toward us, and I wondered why since our aircraft was following the TCAS descent command. Subsequently, I saw the other aircraft become larger and lower its nose when it was just off the tip of our left wing or a little bit inward of that. At that point in time, judging that the attitude of the other aircraft was around 10–15° nose down, at the same altitude as us, and descending, I quickly applied power and pulled the control wheel. The other aircraft was so close that I thought its tail would snag our aircraft. After losing sight of the aircraft for a while, I considered it had passed.

“After a short while the captain informed Tokyo ACC of that we had descended following a TCAS alert and were now returning to our original altitude’. The controller replied only ‘Roger’ and I think it was a male voice.

“The CP came in to the cockpit and reported that things in the cabin were normal.

“After that, we landed at New Tokyo International Airport as scheduled.”

2.1.3 Statements of Air Traffic Controllers

2.1.3.1 Statements of the Controller Under Training (ATC Trainee)

The following is the outline of statements made by the trainee air traffic controller who was controlling Aircraft-A and Aircraft-B while seated at the Radar AG console of Kanto South C sector.

“I arrived at work at 12:30 and for an hour from about 12:35, I received simulator training for the Kanto South C sector from the controller who was supervising me at the time of the accident.

“At 14:30, I entered the IFR room for the shift change and from 14:40 received on-the-job training at the Radar AG console of the Kanto South C sector. I think my current proficiency is about four out of ten. The traffic volume at the time of the on-the-job training was at about the level I could handle.

“Since there was an arrival aircraft bound for New Tokyo International Airport, I instructed Aircraft-A to fly heading 240° and then to proceed direct to YAIZU. In addition, I instructed Aircraft-A to maintain FL350 until further advised. That was because there was a possibility of it converging over the Pacific Ocean with Aircraft-C which was at FL390.

“Subsequently, since Aircraft-C had started descending from FL390 to FL350 as instructed, I instructed Aircraft-A to climb to its desired altitude of FL390.

“I don’t recall at what time I received the hand-off of Aircraft-B from the adjacent sector and established the radio contact with it.

I first became aware of Aircraft-B’s presence when CNF operated and the letters ‘CNF’ flashed in the data blocks of Aircraft-A and Aircraft-B. Judging that it was appropriate to descend Aircraft-B, I commanded it to descend to FL350, but I was not aware of issuing a command to Aircraft-A.

“Although I had experienced CNF alerts before, I was surprised by the ‘CNF’ alert on this occasion because I hadn’t been aware of Aircraft-B.

“Since Aircraft-B did not start descending, I instructed it to fly heading 130°.

“Aircraft-B did not reply, so I instructed it to fly heading 140°.

“Immediately thereafter, the training supervisor took over my radio communications.”

2.1.3.2 Statements of the ATC Watch Supervisor

The following is the outline of the statements made by the training supervisor who was supervising the ATC trainee handling Aircraft-A and Aircraft-B at the Radar AG console of the Kanto South C sector.

“I arrived at work at 12:30 and for about an hour from 12:35, I gave the trainee training for the Kanto South C sector using a simulator. The training exercise was the same as one he had carried out previously, so I thought he had no trouble handling it. At 15:15, I took over from the controller who had been supervising the radar console, and began supervising the same trainee.

Aircraft-C, which had a possibility of conflicting with Aircraft-A over the Pacific Ocean, was flying at FL390. I guided the trainee to order Aircraft-A to maintain FL350 until further advised.

“As a result of coordinating with the adjacent sector, the trainee instructed Aircraft-A to climb to its desired altitude of FL390. As the traffic was flowing smoothly, I showed him the point where both aircraft would cross, the

instructions given to both aircraft, and other ways of dealing with them. Regarding other aircraft, I also explained the traffic situation up to that point, the instructions the trainee had given, and how to handle the other traffic.

“At around the end of my explanation, the ‘CNF’ alert was flashing in the data blocks of Aircraft-A and Aircraft-B. I was in a flurry because I had forgotten about the presence of Aircraft-B.

“At that point in time, I deemed that the best decision was to descend Aircraft-B, and so even though the trainee actually made Aircraft-A descend, I was convinced that he had issued the instruction to Aircraft-B. When the trainee had issued the descent instruction — which I later realized had been for Aircraft-A — when Aircraft-A read back the instruction, I heard something like the sound of an alert in the background.

“Aircraft-B’s altitude did not change so the trainee instructed it to fly heading 130°, but this was his own decision. Although I thought that the first thing was to provide vertical separation, I did not think it necessary to dare to correct his instruction.

“Since Aircraft-B’s altitude and heading did not change, the trainee again instructed it to fly heading 140°. Thereafter, I took over radio communications from him.”

2.1.3.3 Statements of the Coordinator

The outline summary of the statements made by the coordinator who was on duty at the Radar Coordinator console of the Kanto South C sector is as follows.

“I got down to work at the Radar Coordinator Console at around 15:15. I confirmed Aircraft-A’s altitude around the time it was instructed to fly heading 240° and then to proceed direct to YAIJU. Although I don’t remember the altitude, I thought that it was possible for Aircraft-A to climb from it to the assigned altitude of FL390 before it crossed YAIJU.

“I confirmed the presence of Aircraft-B on the radar screen and judging by the relative positions, I thought that at that point in time it would be better to instruct Aircraft-A to proceed direct to SAKAK. However, I thought that Aircraft-A had been instructed to fly via YAIJU because its relation to Aircraft-C.

“Subsequently, Aircraft-A was instructed to maintain FL350 until further advised in view of its relation to Aircraft-C, but I coordinated a climb to FL390 with the Kanto South B sector, and I informed the radar [controller] of this.

“I, too, noticed when the ‘CNF’ alert was displayed in the data blocks of Aircraft-A and Aircraft-B. Given the relationship between the aircraft it would have been usual to descend Aircraft-B, but I thought that descending Aircraft-A would also be able to provide vertical separation. I was not able to confirm the altitude of Aircraft-A immediately before the closest point, but FL369 was shown in the data block of Aircraft-B.

“At around 16:00 after the two aircraft crossed, I recommended the supervisor sitting at the Radar AG console to go off shift, and after finishing briefing about the shift change, my Radar Coordinator duty was also taken over.”

2.1.4 Situations in the cabin at the time of the accident

2.1.4.1 Statements of the CP and CA of Aircraft-A

According to the statements of the CP and CA, the situation in the passenger cabin of Aircraft-A at the time of the accident were summarized as follow.

“About ten minutes after the aircraft had taken off, after the seat belt sign had been turned off, we started showing the TV news. However, since there was shaking due to normal turbulence, we waited about five minutes while preparing beverages in the galley until things settled down so we could start the cabin service. About five minutes after we started serving, we felt unpleasant sinking sensations several times even though the aircraft was climbing, and immediately after that the aircraft descended abruptly.”

The following is a summary of the situations in the forward and aft cabins and the upper deck at around the time of the aircraft’s abrupt descent.

(1) Forward Cabin (Compartments A–C)

“Just after experiencing ‘motions which caused us to feel as if we were pulled towards the front of the aircraft’ or ‘about two normal up-down motions’, the aircraft suddenly dropped and we floated upwards in slow motion (around 2–3 seconds). Although we gripped and pressed down on the galley carts, they floated up and then fell together with us.”

Although the motions were to the extent that the CAs’ backs or heads struck the ceiling and galley carts toppled over after they fell, two of the five galley carts fell back to their original upright positions.

(2) Aft Cabin (Compartments D–E)

After experiencing ‘a two or three up-down motions, which we thought were

strange’ or ‘motions that weren’t sufficient to lift us from the floor, which we thought was turbulence’, the next moment the aircraft descended abruptly. Although almost all the CAs tried to grab onto something, they floated while pressing down on the galley carts as hard as possible, struck the ceiling panels almost hard enough to break them, then fell hard against the floor. The situation was expressed as a momentary occurrence like ‘I found myself turning over sideways in the darkness above the ceiling’ or ‘I floated up together with the other CA in the same aisle.’

One galley cart jumped up above the ceiling and toppled over there. The other galley carts dropped into the aisle; some toppled over and sustained damage.

(3) Upper Deck

“Immediately after ‘two drops’, the galley cart floated up so I desperately pressed it down but my feet left the floor and I floated to about the height of the passengers’ heads.

“Subsequently, I fell back to the upright position together with the galley cart.”

2.1.4.2 Statements of the passengers of Aircraft-A

Statements from the passengers of Aircraft-A regarding the situation in the cabin at the time of the accident were obtained through interviews, telephone conversations and written statements. These are summarized below.

Regarding the time of the aircraft’s sudden descent, there were statements such as ‘it happened about five minutes after the CAs started the drinks service just after the seat belt sign went off’, ‘it occurred around the time I was starting to relax. looking at Mt. Fuji from the right side window’ and ‘it happened just after I felt a couple of sideways motions’.

The following are summaries of the situation in the forward and aft cabins and the upper deck around the time of the aircraft’s sudden descent.

(1) Forward Cabin

The passengers experienced the sudden descent in various ways, such as ‘we suddenly entered an air pocket’, ‘I felt as if I had ridden on a roller coaster’, ‘I felt the impact just like a free-fall landing’, ‘the aircraft dropped suddenly and my cup floated’, and ‘the nose suddenly dropped’. Passengers who did not have their seat belt fastened floated up, struck the ceiling and dropped down.

(2) Aft Cabin

Although similarly to the passengers in the forward cabin, many passengers experienced the aircraft's sudden descent as 'an air pocket', 'free-fall' or 'a roller coaster', some passengers expressed 'it felt as if the nose would end up pointing straight down' and 'it was a vertical dive which lasted as long as counting to slowly to ten'. Some passengers floated upwards despite their seat belts being fastened, and some unbuckled passengers suddenly struck the ceiling.

(3) Upper Deck

There were the statements such as "I felt as if I had ridden on a roller coaster", 'the nose dropped as if we were suddenly diving forward and we plummeted', and 'after a drop, sideways motions and another slight drop, we suddenly dived'.

Regarding the overall situation in the passenger cabin, there were expressions such as 'pamphlets, shoes and bags flew towards the back', 'the CA floated up like walking in space', 'drinks were dripping down on us from the ceiling' and 'I heard screams'.

The passengers heard a public announcement (PA) about 10 minutes after the sudden descent giving various explanations such as 'changes in the air flow', 'an ATC instruction', 'evasive maneuvers to avoid aircraft' and so on. There was also a call for medical assistance 'is there doctor or nurse on board', and then after a while, 'we are turning back because there are some injured persons and we expect to land at around 16:45', and various other announcements.

In addition, a male seated in the forward cabin stated that "from the left window, I saw an aircraft 500–600 meters away in left-upward and aft direction".

2.2 Injuries to Persons

Combining the results of investigations by Japan Airlines Company, relevant organizations and the AAIC, the number of persons who sustained injuries on board Aircraft-A as a result of the accident are as follows. (The number of persons that sustained minor injuries includes those who reported being injured in telephoned or written statements.)

Serious injuries:	7 passengers,	2 CAs	total: 9 persons
Minor injuries:	81 passengers,	10 CAs	total: 91 persons
Total injured:	88 passengers,	12 CAs	total: 100 persons

No persons on board Aircraft-B received injuries as a result of the accident.
(Refer to Attached Figure 14)

2.3 Damage to the Aircraft

Post-accident investigations of Aircraft-A and Aircraft-B revealed no damage to the exterior of either aircraft. However, parts of Aircraft-A's interior sustained damage. Details of the damage are as follows.

(1) Seats

The following is a list of seats that were replaced due to damage sustained. The numbers in parentheses indicate positions in the passenger cabin shown in Attached Figure 15.

- Seat 19G due to damage to its right armrest (①)
- Seat 31H due to damage to its left armrest (②)
- Seat 32H due to damage to its left armrest (③)
- Seat 33G due to damage to its right armrest (④)
- Seat 35H due to damage to its left armrest (⑤)
- Seat 41G due to damage to its right armrest (⑥)
- Seat 44C due to damage to its right armrest (⑦)
- Seat 45C due to damage to its right armrest (⑧)
- Seat 32B&C due to damage to their attached tables (⑨)

(2) Ceiling Panels

In the vicinity of the left aisle.

Dents and bends were noted on part of the panel in the vicinity of seat 32

Cracks were noted on part of the panel in the vicinity of seat 33

The panel in the vicinity of seat 41 was fractured and had dropped onto the cabin floor.

Cracks were noted on part of the panel in the vicinity of seat 42

Cracks were noted on part of the panel in the vicinity of seat 48

Dents were noted on part of the panel in the vicinity of seat 51

In the vicinity of the right aisle.

Cracks were noted on part of the panel in the vicinity of seat 26

Cracks were noted on part of the panel in the vicinity of seats 32–33

Dents were noted on part of the panel in the vicinity of seats 45–48

(3) Floor

Dents and bends were noted on the right aisle floor between seats 34G and 34H.

Dents and bends were noted on the right aisle floor between seats 46G and 46H.

(4) Galley carts

Five of the passenger service galley carts sustained damage. One of these was found resting on top of a ceiling panel in the vicinity of seats 47E and 47F.

(5) Ducts

Holes were noted in the air-conditioning duct piped to the ceiling in the vicinity of seats 32–34C.

Holes were noted in the air-conditioning duct piped to the ceiling in the vicinity of seats 32–34H.

Cracks were noted in part of the air-conditioning duct piped to the ceiling in the vicinity of seats 45–47H.

The galley cart mentioned in the (4) above was found resting on an air-conditioning duct behind the ceiling in the vicinity of the seat 46–48EF, and the portion of the duct concerned was slightly crushed.

(6) Other damage

In the Passenger cabin, there were stains and soiling from beverages and so on found near the right aisle in the forward cabin, the left aisle in the center cabin and the right and left aisles in the aft cabin.

In the upper deck, stains and soiling from beverages and so on were found near the aisles in the forward and aft sections.

The forward galley's left curtain had been soiled by beverages and so on.

Damage was found to part of a public announcement speaker and a light.

(Refer to attached Figure 15 and attached Photographs 1–8.)

2.4 Information on the Crew and Air Traffic Controllers

2.4.1 Flight Crew

2.4.1.1 Flight Crew of JAL Flight 907

1. Captain: Male, aged 40

Airline Transport Pilot License

No.4602, issued December 7, 1994

Type Ratings

Airplane multiengine (land)

Issued January 27, 1982

Boeing 747-400

Issued November 7, 1991

Class 1 Airman Medical Certificate	No.11714167
Term of Validity	Until April 17, 2001
Total flight time	7,446 hours 30 minutes
Flight time during the previous 30 days	45 hours 10minutes
Total flight time on B747-400	3,758 hours 25 minutes
Flight time during the previous 30 days	45 hours 10minutes
Issuance of Captain Certificate on Boeing 747-400	January 27, 1997
Right-seat Approved Captain Certificate	November 17, 1997

2. First Officer: Male, aged 28

Commercial Pilot License	No.A316357, issued April 9, 1998
Type Rating	
Airplane multiengine (land)	Issued September 16, 1998
Boeing 747-400	Issued December 24, 1999
Instrument Rating	No.7978
	Issued December 25, 1998
Class 1 Airman Medical Certificate	No.11721667
Term of Validity	Until August 1, 2001
Total flight time	569 hours 53 minutes
Flight time during the previous 30 days	30 hours 32 minutes
Total flight time on Boeing 747-400	288 hours 55 minutes
Flight time during the previous 30 days	30 hours 32 minutes
Issuance of First Officer Certificate on Boeing 747-400	June 19, 2000

3. Trainee pilot seated on the right forward seat: Male, aged 26

Commercial Pilot License	No. A316824, issued December 25, 1998
Type Rating	
Airplane multiengine (land)	Issued August 5, 1999
Boeing 747-400	Issued November 2, 2000
Instrument Rating	No.8179
	Issued November 2, 1999
Class 1 Airman Medical Certificate	No.11721425
Term of Validity	Until May 7, 2001
Total flight time	303 hours 21 minutes

Flight time during the previous 30 days	11 hours 46 minutes
Total flight time on Boeing 747-400	29 hours 36 minutes
Flight time during the previous 30 days	11 hours 46 minutes

2.4.1.2 Flight Crew of JAL Flight 958

1. Captain: Male, aged 45

Airline Transport Pilot License	No.4392, issued January 18, 1994
Type Rating	
Airplane multiengine land	Issued January 25, 1978
Douglas DC-10	Issued July 22, 1985
Class 1 Airman Medical Certificate	No.11722338
Term of Validity	Until June 19, 2001
Total flight time	6,584 hours 18 minutes
Flight time during the previous 30 days	41 hours 44 minutes
Total flight time on DC-10	5,689 hours 50 minutes
Flight time during the previous 30 days	41 hours 44 minutes
Issuance of Captain Certificate on DC-10	March 14, 1996
Left-seat Approved Captain Certificate	September 25, 2000

2. First Officer: Male, aged 49

Commercial Pilot License	No.A105371, issued October 26, 1998
Type Rating	
Airplane multiengine (land)	Issued August 21, 1991
Douglas DC-10	Issued October 30, 1992
Class 1 Airman Medical Certificate	No.11714845
Term of Validity	Until August 15, 2001
Total flight time	4,333 hours 20 minutes
Flight time during the previous 30 days	39 hours 56 minutes
Total flight time on Douglas DC-10	3,873 hours 59 minutes
Flight time during the previous 30 days	39 hours 56 minutes
Issuance of First Officer Certificate	January 1, 1993

3. Flight Engineer: Male, aged 43

Flight Engineer Competence License	No.2292, issued April 11, 1983
Type Rating	
Airplane multiengine (land)	
Douglas DC-10	Issued April 11, 1983

Class 1 Airman Medical Certificate	No. 11712814
Term of Validity	Until March 22, 2001
Total flight time	8,336 hours 33 minutes
Flight time during the previous 30 days	33 hours 23 minutes
Total flight time on Douglas DC-10	8,336 hours 33 minutes
Flight time during the previous 30 days	33 hours 23 minutes
Issuance of Flight Engineer Certificate	May 9, 1983

2.4.2 Flight Attendants of JAL Flight 907

1. Chief Purser (Female, aged 57)

Position at the time of accident	Compartment A, L1 door
Date of occupation	May 14, 1963
Total flight time	14,520 hours

2. Flight Attendant (Female, aged 42)

Position at the time of accident	Upper deck, LU door
Date of occupation	November 11, 1982
Total flight time	12,238 hours

3. Flight Attendant (Female, aged 35)

Position at the time of accident	Compartment D, L4 door
Date of occupation	April 1, 1987
Total flight time	10,127 hours

4. Flight Attendant (Female, aged 35)

Position at the time of accident	Compartment B, L2 door
Date of occupation	July 1, 1988
Total flight time	5,298 hours

5. Flight Attendant (Female, aged 24)

Position at the time of accident	Compartment E, L5 door
Date of occupation	May 28, 1999
Total flight time	1,014 hours

6. Flight Attendant (Female, aged 24)

Position at the time of accident	Compartment B, R1 door
Date of occupation	May 28, 1999
Total flight time	1,021 hours

7. Flight Attendant (Female, aged 24)

Position at the time of accident	Compartment E, R5 door
Date of occupation	May 28, 1999
Total flight time	982 hours
8. Flight Attendant (Female, aged 24)	
Position at the time of accident	Compartment E, R4 door
Date of occupation	May 28, 1999
Total flight time	1,011 hours
9. Flight Attendant (Female, aged 24)	
Position at the time of accident	Upper-deck, RU door
Date of occupation	June 4, 1999
Total flight time	984 hours
10. Flight Attendant (Female, aged 24)	
Position at the time of accident	Compartment C, L3 door
Date of occupation	June 14, 1999
Total flight time	974 hours
11. Flight Attendant (Female, aged 24)	
Position at the time of accident	Compartment D, R3 door
Date of occupation	June 14, 1999
Total flight time	983 hours
12. Flight Attendant (Female, aged 24)	
Position at the time of accident	Compartment C, R2 door
Date of occupation	June 22, 1999
Total flight time	942 hours

2.4.3 Air Traffic Controllers

1. Controller on duty as a trainee: Male, aged 26	
Air Traffic Control Basic Examination Certificate	No.2282
Air Traffic Control Certificate	No.3125
Limitation	
Air Route Traffic Control Service	No.1581 Issued April 1, 1997
Approach Control Service	No.1581 Issued April 1, 1997
Radar Area Control Service	No.1491

West Kanto Sector	Issued May 2, 2000
Medical Certificate	No.1770
Term of validity	Until June 30, 2001
Duty period until the occurrence of the accident on the day	1 hours and 15 minutes
Duty period until the occurrence of the accident after the latest rest on the day	1 hours and 15 minutes

2. Controller on duty as supervising the trainee: Female, aged 32

Air Traffic Control Basic Examination Certificate	No. 1826
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Air Traffic Control Certificate	No.2936
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Limitation

Air Route Traffic Control Service	No.1286
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Issued October 1, 1991

Approach Control Service	No.1283
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Issued October 1, 1991

Radar Area Control Service	No.1200
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Kanto West Sector

Issued November 1, 1993

Kanto South Sector

Issued October 30, 1994

Medical Certificate	No.1441
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Term of validity	Until June 30, 2001
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Duty period until the occurrence of the accident on the day	40 minutes
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40 minutes

Duty period until the occurrence of the accident after the latest rest on the day	40 minutes
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40 minutes

3. Controller on duty as coordinator: Male, aged 46

Air Traffic Control Basic Examination Certificate	No. 1191
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Air Traffic Control Certificate	No.693
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Limitation

Air Route Traffic Control Service	No.693
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Issued October 1, 1976

Approach Control Service	No.693
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Issued October 1, 1976

Radar Area Control Service	No.556
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All Sector in the Tokyo ACC

Issued September 1, 1979

Kanto West Sector (approved based on experience)

Issued November 2, 2000
Kanto South Sector (approved based on experience)

Issued November 2, 2000
Medical Certificate No.586
Term of validity Until June 30, 2001
Duty period until the occurrence of the accident on the day
1 hours and 25 minutes
Duty period until the occurrence of the accident after the latest rest on the day
1 hours and 25 minutes

2.5 Aircraft Information

2.5.1 Aircraft-A

(1) The Aircraft

Type	Boeing 747-400D
Serial No.	26348
Date of manufacture	September 22, 1992
Certificate of Airworthiness	10-851
Term of validity	Until valid data of JAL's Maintenance Manual from January 20, 1999
Total flight time	18,563 hours 02 minutes
Flight time since scheduled maintenance	
"C" check on November 20, 1999	2,746 hours 50 minutes

(2) The Engines

Type : General Electric model CF6-80C2B1F

	<u>Serial No.</u>	<u>Date of manufacture</u>	<u>Total time in service</u>
No. 1	702554	July 18, 1990	24,055 hours 58 minutes
No.2	704533	May 16, 1996	7,376 hours 16 minutes
No.3	703117	February 7, 1990	21,875 hours 32 minutes
No. 4	703119	February 7, 1990	33,163 hours 29 minutes

(Refer to Attached Figure 5)

2.5.2 Aircraft-B

(1) The Aircraft

Type	Douglas DC-10-40
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Serial No .	47855
Date of manufacture	January 15, 1981
Certificate of Airworthiness	99-104
Term of validity	Until valid data of JAL's Maintenance Manual from May 13, 1999
Total flight time	42,985 hours 59 minutes
Flight time since scheduled maintenance	
"C" check on May 29, 2000	951 hours 24 minutes

(2) The Engines

Type: Pratt & Whitney model JT9D-59A

	<u>Serial No.</u>	<u>Date of manufacture</u>	<u>Total time in service</u>
No.1	P688888	December 30, 1978	48,457 hours 30 minutes
No.2	P688906	July 1, 1985	45,956 hours 30 minutes
No.3	P688909	July 29, 1985	44,066 hours 12 minutes

(Refer to Attached Figure 7)

2.5.3 Weight and Center of Gravity

(1) Aircraft-A

The weight of the aircraft at the time of the accident is estimated to have been approximately 550,360 lbs, with the center of gravity at 19.1% MAC. Both these parameters are within allowable limits (maximum takeoff weight being 595,000 lbs, with the allowable range of center of gravity corresponding to the estimated weight at the time of accident between 11.0% and 33.0% MAC).

(2) Aircraft-B

The weight of the aircraft at the time of the accident is estimated to have been approximately 376,000 lbs, with the center of gravity at 15.1% MAC. Both these parameters are within allowable limits (maximum takeoff weight being 434,000 lbs, with the allowable range of center of gravity corresponding to the estimated weight at the time of accident between 6.3% and 29.0% MAC).

2.5.4 Fuel and Lubricating Oils

(1) Aircraft-A

The fuel on board was JET-A-1. The lubricating oil was MJO-II.

(2) Aircraft-B

The fuel on board was JET-A-1. The lubricating oil was MJO-II.

2.6 Meteorological Information

2.6.1 Weather Synoptic

The weather synoptic in the Tokai region announced by the Shizuoka Local Weather Service Center of the Tokyo District Meteorological observatory at 17:00 JST on the day of the accident was as follows:

A high pressure system has moved over the ocean to the east of Japan and a trough is approaching the west of Japan. The weather is therefore cloudy in the Tokai region except in coastal areas where it is fine.

Tonight it will be cloudy throughout Shizuoka prefecture due to the approach of the trough.

2.6.2 Satellite Cloud Information Chart over the Asia Pacific Region

According to the Satellite Cloud Information Chart issued at 15:00 JST on January 31, 2001, high-level clouds mostly covered Pacific coast of the Japanese archipelago.

In addition, weather radar observed echoes of a few towering cumulus clouds above the Izu peninsular and in the vicinity of the Ooi river.

(Refer to Attached Figure 16)

2.6.3 Aerological Observation Data

The Aerological Observation Data issued at 15:00 JST on January 31, 2001 relevant to the altitude of the encounter between Aircraft-A and Aircraft-B at the time of the accident were as follows.

(1) Tateno Aerological Observatory

Atmospheric Pressure: 175hpa, Altitude: 12.404ft, Wind Direction: 269°, Wind Speed: 49m/s

(2) Hachijojima Weather Station

Atmospheric Pressure: 200hpa, Altitude: 11.693ft, Wind Direction: 272°, Wind Speed: 71m/s

(3) Wajima Weather Station

Atmospheric Pressure: 175hpa, Altitude: 12.316ft, Wind Direction: 268°, Wind Speed: 52m/s

(4) Shionomisaki Weather Station

Atmospheric Pressure: 175hpa, Altitude: 12.542ft, Wind Direction: 267°, Wind Speed: 65m/s

2.6.4 Shizuhamu Airport Aviation Weather Observations

The aviation weather observations provided by Shizuhamu Airport located approximately 13 km north-north-east of the accident occurrence point were as follows:

Time of Observation (Clock:Minute)	15:00 JST	16:00 JST
Wind Direction (degrees)	240	240
Wind Speed (kt)	12	13
Visibility	more than 10 km	more than 10 km
Cloud amount	1/8	1/8
Cloud form	cumulus	cumulus
Height of cloud base (ft)	2,500	2,500
Cloud amount	6/8	6/8
Cloud form	cirrus	cirrus
Height of cloud base (ft)	23,000	23,000
Temperature (Celcius)	11	10
Dew point (Celsius)	-7	-4
Atmospheric pressure (inHg)	30.06	30.09

2.7 Air Navigation Facilities

Air Navigation Radio Aids, the ATC radar system and Remote Controlled Air Ground Radio Communication system (RCAG) relevant to the operations of Aircraft-A and Aircraft-B were operating normally at the time of accident.

2.8 Communications

2.8.1 Operational Condition of RCAG

It is estimated that all communications between Tokyo ACC (124.55 MHz) and Aircraft-A and Aircraft-B during the periods before and after the occurrence of the

accident were satisfactory.

2.8.2 ATC Recorder Background Noise Level

ATC communications had been recorded continuously by the ATC recorder installed at Tokyo ACC.

Detailed investigation of the ATC communications by replaying the recorded tape revealed that the levels of recorded voice communications and background noise within permissible limits and that the recording was continuous. It was therefore concluded that communications between the aircraft and Tokyo ACC had been satisfactory.

In addition, the investigation found no malfunction in the transmission line between Tokyo ACC and the RCAG facilities.

2.9 Information on the Aircraft Recorders

Aircraft-A was equipped with a Fairchild (Loral) CVR (Serial No. 93-A100-80) and an AlliedSignal DFDR (Serial No. 980-4700-003).

Aircraft-B was equipped with a Collins CVR (Serial No. 522-4057-010) and a Sundstrand DFDR (Serial No. 980-4100-BXUS).

These recorders were removed from the aircraft after they had landed.

2.9.1 CVR Recording

The CVRs installed in Aircraft-A and Aircraft-B record voices and sounds picked up by microphones in the cockpit on a 30-minute magnetic tape loop until the CVR stops. Recordings older than 30 minutes are overwritten. Both CVR tapes contained recordings of the 30 minutes up to the times that the aircraft blocked-in at the respective airports, but since more than 30 minutes had elapsed since the accident had occurred in both cases, no useful information relevant to the accident remained on the tapes.

2.9.2 Recordings of the DFDR, ACM and AIDS

Aircraft-A's DFDR recorded data on 306 parameters from the time the aircraft departed the ramp at Tokyo International Airport until it returned and blocked-in at the same airport.

Aircraft-B's DFDR recorded on 129 parameters from the time the aircraft departed the ramp at Pusan International Airport until it landed and blocked-in at New Tokyo International Airport.

The parameters used for analysis in this accident investigation report include TCAS information such as alerts and the relative lateral/vertical separation between the aircraft. As TCAS information are not among the parameters recorded by either aircrafts' DFDR, the data were obtained from the ACMS installed in Aircraft-A and from the AIDS installed in Aircraft-B.

Additionally, Aircraft-B's DFDR records pressure altitude data derived from the altimeter on the co-pilot's side, but does not record pressure altitude data from the altimeter on the captain's side, which provides altitude data in response to TCAS Mode-S and ATC Mode-C interrogations. Therefore, the AIDS data, which records data from the captain's-side altimeter, was used as the source of pressure altitude data for Aircraft-B in the analysis.

2.9.3 Time Correction of Recordings

The difference between the time recorded on the DFDRs installed in Aircraft-A and Aircraft-B and actual time can be determined by matching discrete VHF keying data (ON/OFF) from the DFDRs with the radio voice transmissions and other information simultaneously recorded on the ATC recorder. This process was made relatively easy by the fact that radio transmissions from both aircraft had characteristics that are not normally found — for example, both aircraft made comparatively long transmissions of around 20 seconds after the near mid-air collision to report it. However, because the VHF keying ON/OFF data recorded on the DFDR are sampled only once per second, while the voice recording on the ATC tapes are analog, there is uncertainty regarding the times from the radio being keyed and the start of voice transmission, and from the end of the voice transmission to the radio key being released. This results in a maximum error of about ± 1.5 seconds when determining the relationship between time recorded on the DFDRs and real time by using the VHF ON/OFF data. It was finally determined to be appropriate to compensate the times recorded on the DFDRs by approximately 22 seconds for Aircraft-A and by approximately two seconds for Aircraft-B.

In the case of Aircraft-B, because the same time data is distributed to the DFDR and AIDS, it was not necessary to correct the time between these recorders. However, in the case of Aircraft-A, because the Flight Data Acquisition Units (FDAUs) for the DFDR and ACMS function independently and use different methods for recording time, it was necessary to apply time compensation between these recorders.

To compensate the time difference between the DFDR and ACMS of Aircraft-A

and the time uncertainty of VHF ON/OFF data recorded on the two aircrafts' DFDRs, the altitude data recorded on the DFDR, ACMS and AIDS of Aircraft-A and Aircraft-B and their times were precisely correlated with the altitude data derived from secondary surveillance radar transponder returns in recorded ATC radar data.

However, it was found that there was a time skew between the TCAS-related data and the other data recorded on the AIDS of Aircraft-B. The time skew was attributed to a difference between the methods of recording TCAS data and other data on the AIDS, since the equipage of TCAS had been made mandatory after Aircraft-B had been manufactured and it had been installed later. It was therefore also necessary to compensate the recorded times of the TCAS data and the other data on the AIDS of Aircraft-B. The correction for the time skew attributed to the difference in recording methods was made by the following process.

Firstly, by using a TCAS tester to generate data while Aircraft-B's AIDS unit was set to record on the bench, it was found that TCAS-related data were recorded two seconds earlier than the other data. Then, the time skew with the AIDS unit installed in an aircraft was examined, using the same type of aircraft as Aircraft-B. Tests were carried out simulating parameters corresponding to various flight conditions, using a TCAS tester and an air data tester to effect changes in altitude, the TCAS activation state, the state of the aircraft's clock, the VHF key state and other discrete states, the state of the control system, and so on. The test conditions were recorded on videotape. After the test, detailed analysis of the AIDS recordings determined that a time skew of approximately 2.5–3.5 seconds (including the time lag of two seconds of the AIDS device alone) arose due to the difference in conditions between the AIDS on a bench and installed in an actual aircraft, and subtle differences probably caused by the timing of power application and the length of time each unit took to come up. However, it was not determined what extent of the time lag was included in the recordings of Aircraft-B at the time of the accident.

With the assistance of the Electronic Navigation Research Institute (ENRI), the AAIC compared the TCAS range data recorded on Aircraft-B's AIDS with the TCAS-to-TCAS range calculated by a computer incorporating the same algorithm as that of the Aircraft-B's TCAS. As a result, it was determined that the time skew associated with the recorded TCAS data was approximately 3 seconds.

As a precaution, the same examinations using the TCAS tester etc. were carried out for Aircraft-A's recorders. As a result, analysis revealed that there was no time skew in the TCAS data recorded on the ACMS, and there was negligible

difference between the time when TAs and RAs were recorded on the ACMS and when TAs and RAs were displayed on the TCAS display and audibly annunciated.

In addition to the above, the times of each parameter recorded on the two aircraft were finally further adjusted by matching the TCAS RA data recorded on Aircraft-A's ACMS with the time that Aircraft-A's TCAS audible "CLIMB, CLIMB, CLIMB" alert was recorded on the ATC recorder

In this accident report, except where detailed analysis was required, corrected times omitting fractions of a second were used: 24 seconds for Aircraft-A's ACMS, 22 seconds for Aircraft-A's DFDR, 1 second for Aircraft-B's DFDR and AIDS (except for the TCAS data) and 4 seconds for the TCAS data on Aircraft-B's AIDS.

Plots of the major parameters from the DFDR, ACMS (including TCAS data), and AIDS around the time the accident occurred are shown in Attached Figures 11–13.

2.10 Medical Information

2.10.1 The number of Cabin Attendants and Passengers sustained injuries

Of the 427 persons – 411 passengers and 16 crewmembers – aboard Aircraft-A, seven passengers and two cabin attendants were seriously injured, and 81 passengers and 10 cabin attendants received minor injuries.

Following the day of the accident, many consultations regarding sprains and/or bruises were received at a call-center established at the Passengers Division of JAL's Haneda Airport branch from passengers who were not examined on the day of the accident. The AAIC interviewed these passengers and obtained written statements about their injuries over a period of about one and half months. As a result, the total number of the injured was reckoned by adding to the 48 persons were confirmed on the day of the accident an additional 58 persons who were confirmed by interview.

No persons aboard Aircraft-B sustained injury as a result of the accident.

2.10.2 Details of Serious Injuries

Details of the extent and portions of injuries to the seven passengers and two CAs who were seriously injured were obtained from statements by them and other persons concerned. These are summarized below.

(1) Passenger, male, aged 29 (Seat 21H)

Situation at the time of receiving injury: seated. Information on whether seat

belt fastened was not available. (Details are now known because no statements were obtained from the passenger, his acquaintances and so on. The AAIC confirmed with a hospital about his hospitalization and condition.)

Location and degree of injuries: Sprain of the cervix, bruising on the lumber and right thigh.

(2) Passenger, female aged 72 (Seat 23F)

Situation at the time of receiving injury: seated. Seat belt not fastened. (The passenger unbuckled her seat belt to receive a drink. Her head struck the ceiling and her back struck the armrest of the seat.)

Location and degree of injuries: Sprain of the cervical vertebrae, bruising on the lumber and head.

(3) Passenger, female aged 50 (Seat 23G)

Situation at the time of receiving injury: seated. Seat belt not fastened. (The passenger unbuckled her seat belt to receive a drink. Her head struck the ceiling and she dropped to the aisle in the forward cabin.)

Location and degree of injuries: Sprain of the cervix, bruising on the head.

(4) Passenger, female aged 60 (Seat 40G)

Situation at the time of receiving injury: seated. Seat belt fastened. (The passenger floated up, and the left side of her head struck another passenger's face.)

Location and degree of injuries: Bruising on the cervix and the left side of the head.

(5) Passenger, female aged 56 (Seat 41F)

Situation at the time of receiving injury: seated. Seat belt not fastened. (The passenger's head struck the ceiling and the back of the seat in front resulting in suffering a concussion. Her side struck the armrest.)

Location and degree of injuries: Rib fracture.

(6) Passenger, female aged 54 (Seat 42C)

Situation at the time of receiving injury: seated. Seat belt not fastened. (The passenger's body struck a speaker attached to the ceiling and she struck an armrest below her waist as she fell into the aisle.)

Location and degree of injuries: Compression fracture of the first lumbar vertebra, dislocation and fracture of the left ankle joint.

(7) Passenger, male aged 63 (Seat 45D)

Situation at the time of receiving injury: seated. Seat belt fastened. (A CA

dropped onto his left shoulder.)

Location and degree of injuries: Sprain of the cervical vertebrae, bruising on the left shoulder.

(8) CA, female aged 35 (Compartment D)

The CA was working in the aisle near seat 33C. (The CA floated upward while pressing down with her right hand on a galley cart and broke through a ceiling panel. She thought she momentarily saw the space above the ceiling, but the next moment struck the floor.)

Location and degree of injuries: cervical concussion, traumatic cervical syndrome

(9) CA, female aged 24 (Compartment E)

The CA was working in the aisle near seat 45C. (The CA gripped the nearest armrest but her hand pulled away from it. Then her back struck the ceiling and she dropped into the aisle.)

The extent and portion of injuries: Laceration of the face, bruising on the lumber.

2.10.3 Details of Minor Injuries

The overall summary of the minor injuries to the 81 passengers and ten CAs who sustained them, obtained from their submitted oral statements, is given below. Regarding the sorts of minor injury, according to statements obtained from the injured and doctors in charge of the diagnosis, sprains of the cervical vertebrae and so on were the largest number at 56. (This number accounted for 62% where the total number of the injured was defined as 100%. However, since there were persons who received multiple types of minor injury, the total number of minor injuries exceeds 100%. Hereinafter, the percentage indicated has the definition above). Bruising was the second largest number at 43 (approximately 47%). Other than these, scratches, concussions, burns, psychological damage, unstable blood pressure and abnormality of eyes and ears, etc. accounted for approximately 21% (17 persons).

(1) Passengers

Of the passengers who sustained minor injuries, 51 passengers had fastened their seat belts and 14 passengers had not fastened them; however, no information regarding seat belt use was available from 16 passengers.

Injuries sustained by the unbuckled passengers were attributed to their floating upwards, striking the ceiling and then dropping. Almost all the minor injuries

sustained by unbuckled passengers were diagnosed as bruising of the head and back etc., and sprains of the cervical vertebrae etc. Some passengers suffered lacerations to the face, burns and psychological damage. However, some unbuckled passengers escaped injury by gripping armrests or keeping their balance and using their hands and/or legs to absorb the shock when they lifted or dropped.

Of the 51 buckled passengers, eight stated that they were seated with the seat belt not tightened. Additionally, there were the statements such as "My bottom was lifted from the seat", "I felt as if I were hanging down the seat, resulting in the seat belt scratching the front of my thighs" and "My forehead struck the back of the seat in front seat when I was lifted, and the reaction caused the back of my head to hit the front of my own seat". Judging from these statements, many passengers had fastened their seat belts improperly.

(2) Cabin Attendants

All of the CAs were serving the passengers at the time of Aircraft-A's upset. They rose from the floor together with the galley carts at the time of Aircraft-A's abrupt descent and then dropped to the floor, sustaining injuries.

The extent of injuries sustained by the CAs in the aft cabin (Compartments D, E) were more severe than the injuries sustained in the forward cabin (Compartments A-C and Upper Deck). More precisely, the CAs in the forward cabin rose to the extent that they touched the ceiling, while the CAs in the aft cabin were smashed into the ceiling, causing ceiling panels to sustain damage, and one of the CAs was projected above the ceiling.

Sprains of the cervical vertebrae and bruises to the face, back, breast, shoulders and thighs were the most common types of minor injury sustained by the CAs.

(Refer to Attached Figures 14 and 15)

2.11 Information on Search, Rescue and Evacuation relevant to Survival, Death or Injury

2.11.1 Situation in the cabin of Aircraft-A after the accident

The following are outlines of the statements obtained regarding the situation in the cabin following the accident, from the flight crew starting with the Captain, the cabin crew and the passengers. (Refer to Attached Figure 3.)

(1) Flight crewmembers Statements (Mainly the Captain's statements supplemented

with those of the other flight crewmembers.)

“After completed the avoidance maneuvers, as we were flying 207° from YAIJU at around 10 nm, I reported the near miss to Tokyo ACC, and receiving clearance to our originally planned FL390, we climbed.

“After that, I received the first information from the CP over the interphone that several passengers and CAs had been injured and that part of the cabin interior in aft cabin had been damaged by galley carts hitting the ceiling, and I realized that motions of the aircraft had been sufficient to cause injury.

“After that I announced over the PA in Japanese and English to the effect “This is Captain from the cockpit. We made a descent following an ATC instruction, but because there was a risk of collision with another aircraft, we made evasive maneuvers. As a result, there were some abrupt maneuvers, and several passengers and CAs have been injured.”

The Captain told the First Officer to confirm the situation in the cabin. He reported that there were injuries, beverages had been splashing over ceiling panels and over the passengers, and some passengers had also been burned.”

“Further, when I received the first report, I was considering whether to land at a nearby airport or to return to Haneda, but after confirming the situation, taking overall consideration of our flight position at the time, medical resources available and so on, I elected to return to Haneda.”

“I conducted prepared the information for the return flight, preparations and a briefing, at we received ATC clearance at around 16:10.

“After that, based on the CA’s report on the cabin situation, the fact that that two persons were seriously injured (a passenger and a CA), and that a galley cart had broken through the ceiling panels and remained behind the ceiling, I made the trainee sitting on the aft seat go and confirm.

“The First Officer reported to the Tokyo Airport Branch Office on the company frequency to the effect that injuries had been sustained as the result of a rapid descent due to a near miss south of Yaezu, and requested securing of a parking spot and the dispatch two ambulances

“Considering the injured, I planned to return at high speed. However, due to the risk of the galley cart above the ceiling dropping onto passenger seats on landing, it was necessary to allow time to move the passengers seated near the galley cart.

“After that, I requested a high speed descent to less than 10,000 ft priority landing to Tokyo ACC and received clearance. I informed a CA that the estimate time of arrival at Haneda would be around 16:45, and about

25 minutes before landing informed the passengers by a cabin announcement.

“The landing time was at 16:44, and we blocked in at the assigned No. 8 spot at 16:47.

“I did not see ambulances at the spot, but rescue personnel were there.”

(2) Statement of CAs and Passengers

Just after the accident, the CP made cabin announcements of “please have your seat belts fastened at all times” and “injured or burned persons please make yourselves known”.

Further, after that, a call was made for any medical persons, but there were no doctors or nurses etc. on board.

The CAs on upper deck administered care to persons who had been splashed with hot coffee and the persons with injuries to the nose using compresses, then thinking that the situation in the aft cabin was serious, went to assist.

The CAs in the forward cabin administered care to persons with neck pains, and two passengers who had struck the ceiling due to not having their seat belts fastened, one of whom had fallen on a seat, the other on the floor. After that, they went to aft cabin.

There were several persons in the aft cabin complaining of pains, including one with back pains who had not had their seat belt fastened, had struck a speaker on the ceiling and then fallen into the aisle, and one injured by a CA falling onto their left shoulder.

Also, a CA had been rendered unconscious by impacting the floor having broken through ceiling panels, but she was aided by passengers who nursed her, and was laid down until landing.

A CA who had been in the right aisle in compartment E had been tossed above the ceiling and was lying above the ceiling over the opposite aisle. As she was slightly injured she was brought down with the assistance of nearby passengers.

However, it was realized that the galley cart which had been thrown above the ceiling was above the vicinity of the center seat in row 47, and because of the risk of it falling, passengers who had been seated around there were moved to vacant seats in the forward and upper deck compartments before landing.

Regarding the state of the injuries, many persons had been injured with bruises and sprains, and were treated with items from the medical kit such as medicated compresses and antiseptic wipes. Damp towels were distributed to passengers who had been splashed by hot beverages. Clearing up, starting with

the galley carts, was arduous. The Captain made a cabin announcement three minutes before landing, and the aircraft landed smoothly. The seriously injured were disembarked first, and rescue team and 3 stretchers had been standing by in the boarding bridge.

2.11.2 Correspondence of JAL and Relevant Facility on the Ground

At around 16:19, the Passenger Department of JAL's Haneda Branch office received information from Aircraft-A to the effect that injuries to persons had occurred as the result of maneuvers to avoid a collision with another aircraft, and that the aircraft intended to return to Tokyo International Airport. At that time the Department did not understand the nature of the injuries or the number of injured, and there was no arrival spot reserved for the aircraft, but at 16:20 it called the emergency services on 119, and requested dispatch of one ambulance and arranged to have it wait in front of the West Passenger Terminal building.

According to the Tokyo Fire Fighting Bureau, the above information was received at about 16:24, as based on it, a the Kamata Command Team, the Airport Rescue Team and the Kamata Rescue Team were dispatched and arrived at their assigned places at around 16:40. Received information around that time that there were six injured, that the estimated time of arrival of Aircraft-A was around 16:49 and its parking spot was No. 8, the rescue teams judged that the number of ambulances was insufficient, and requested dispatch of further support.

As Aircraft-A arrived at spot 8 on schedule, the rescue teams led by relevant personnel from JAL entered in the cabin at around 16:50, and commenced rescue activities. They confirmed that there were three injured persons who were unable to walk were (a passenger and two CAs), and three walking injured (two passengers and one CA). The condition of the injured who were unable to walk was confirmed in the cabin and after first-aid treatment, they were carried from the cabin on stretchers and taken to hospital. The rescue team asked airline company personnel to guide the walking injured to ambulances waiting in front of the West Passenger Terminal building, from where they were taken to hospital.

The rescue team also judged that there were more injured in addition to the first six persons, and requested dispatch of further ambulances. The rescue team also judged that a further 28 injured (27 passengers and one CA) had gathered at the on-site rescue facility established at a waiting room on second floor near gate 8 in response to cabin announcements and calls from the fire-fighting team. Three persons out of these injured were treated by doctors and other medical staff at on site rescue facility and then released, but the remaining 25 persons were received

first-aid treatment at on site rescue facility and were then taken to hospital by ambulances.

Including ambulances, a total of 43 vehicles were dispatched to Aircraft-A on the day of the accident, and 115 personnel were mobilized.

The transportation of the injured to hospital started at around 17:20 and ended at around 19:00. During this time, the injured were taken to and accommodated at nine hospitals by 17 ambulances.

Further, eight of the CAs who were among the injured engaged in rescue activities in the cabin and were taken to hospital separately by JAL, including these, the total number of injured admitted to hospital was 39.

2.12 Tests and Research to Find Facts

2.12.1 Investigation of the Aircraft

2.12.1.1 Tests on Aircraft Equipment and Avionics

The following are the findings of post-accident ground tests on the equipment and systems of Aircraft-A and Aircraft-B.

(1) Functional test on equipment and system installed in the two aircraft

Functional testing of the following equipment and systems revealed no malfunction or abnormality that would have been a factor in the accident.

- ① Pitot-Static pressure system associated with the altimeters and airspeed indicators
- ② VHF radio communication equipment
- ③ Air Data Computer (ADC)
- ④ TCAS

(2) Bench Test of equipment

Bench test examination of the following equipment removed from the aircraft revealed no malfunction or abnormality that would have been a factor in the accident.

- ① ATC Transponder
- ② VHF Radio Communication Equipment
- ③ ADC
- ④ TCAS

2.12.1.2 Investigation into Damage to the Interior of Aircraft-A's Passenger Cabin caused by Galley Carts

At around the time of the accident, ten galley carts were being used by the cabin attendants (CAs) for serving passengers. All were lifted at the time of the accident, and of these, five sustained damage and one was emplaced above the ceiling. All of the CAs who were handling the damaged galley carts stated that they rose into the air together with them. Four of the five damaged galley carts sustained damage to their casters, brakes, etc.

Damage to the galley carts and the interior of the passenger cabin are summarized as follows.

The galley cart in use in compartment A of the passenger cabin was lifted and then toppled over on the floor.

The four galley carts in use in compartments B and C of the passenger cabin, after being lifted either dropped to the floor in their original upright positions or toppled over on the floor. One of these sustained damage. Part of a ceiling panel in the vicinity was damaged.

The two galley carts in use in compartment D of the passenger cabin were lifted and then dropped to the floor, sustaining damage. Damage to seats, ceiling and air-conditioning ducts in the vicinity of the galley carts was noted.

Two galley carts were in use in compartment E of the passenger cabin. The galley cart in the left aisle was lifted and dropped to the floor, sustaining damage. Damage to seats and the ceiling in the vicinity of the galley cart were noted. The galley cart in the right aisle was projected through a ceiling panel in the vicinity of seat row 47 and came to rest on a longitudinal frame member and an air-conditioning duct above the ceiling panel adjacent to the center of the fuselage. The top part of the galley cart was pressed to the left and sustained damage. Damage to the floor, ceiling and air-conditioning duct was noted in the vicinity. It was not possible to bring down the galley cart from above the ceiling in flight, so it remained there until the aircraft landed. The galley cart was emplaced at approximately 2.7 meters above the floor. The galley cart was 101 cm in height, 30 cm wide and 43 cm deep, and weighed approximately 39 kg (including approximately 4.5 kg of its load which was scattered around behind the ceiling).

For reference, the weight of the same type of galley cart as used in Aircraft-A with a standard load was measured at approximately 51 kg

The galley cart in use on the upper deck was lifted, and dropped back to its original upright position.

There was no damage to the galley carts stowed in the galley.

Locking devices to secure galley carts to the floor were installed near the L3, R3, L5 and R5 doors, but these were not in use at the time of the accident.

2.12.2 Investigation into the Operation of the TCAS

2.12.2.1 Outline of TCAS

TCAS is designed to detect aircraft that are a collision risk and issues Traffic Advisory (TA) alerts to advise their positions and Resolution Advisory (RA) commands to avoid collision.

The TCAS installed in an aircraft interrogates the transponders of all nearby aircraft and obtains their distances and altitudes from the replies received. Based on relative speed and rate of change of altitude information computed by the TCAS logic from the distance and altitude, the TCAS calculates the time to the Closest Point of Approach (CPA) with the other aircraft and determines whether or not there is a threat of collision. When the TCAS judges another aircraft to be a collision threat, if the other aircraft is also TCAS-equipped the TCAS sends it a coordination signal to resolve the encounter; for example, when TCAS selects an upward sense RA (to instruct the pilot to climb), it will transmit a coordination signal to the TCAS on the other aircraft to restrict its RA selection to the downward sense (to instruct the other aircraft's pilot to descend). The TCAS also issue a synthetic voice warning together with an indication on the TCAS display device to advise the pilot how to maneuver to avoid the encounter. In addition, the TCAS is designed to secure the minimum vertical separation to safely avoid a collision. Moreover, the TCAS has six levels of sensitivity (SL2–SL7) according to flight altitude to allow a trade-off between necessary protection and nuisance advisories. (See note below.)

The TCAS equipment installed in both Aircraft-A and Aircraft-B was the Collins TTR-920 TCAS II, with TCAS software Version 6.04A, which is basically common.

The TCAS system consists of a TCAS computer, an ATC Mode-S transponder, a TCAS/ATC transponder control panel, directional antennas, antenna for the Mode-S transponder, and display devices.

The TCAS displays differed between the two aircraft: the PFD and ND are used in Aircraft-A, while TCAS information in Aircraft-B is displayed on the Traffic/Weather Radar Indicator and TCAS II RA/VSI.

Note: When a TCAS-equipped aircraft is less than 1,000 ft above ground level (AGL), SL2 is selected to reduce the amount of “protected” airspace by minimizing the threshold level so as to reduce nuisance alerts in the vicinity

of congested airports. RAs are inhibited in SL2. When the aircraft is at 1,000 ft AGL or higher, RAs are enabled and sensitivity levels SL3 and higher are automatically selected by the TCAS logic to control the amount of protected airspace based on the ownship's altitude. The higher the altitude, the earlier RAs are issued. This concept is included in the design of the device to allow sufficient time for TCAS-equipped aircraft to maneuver to avoid collision. TCAS II (Version 6.04A) applies SL7 above FL300.

(Refer to Attached Figures 6–8)

2.12.2.2 Analysis of the TCAS Alerts

Information on the operation of the TCAS is recorded on the ACM installed in Aircraft-A and the AIDS installed in Aircraft-B. The AAIC used this information to analyze the proximity situation of the two aircraft. For the analysis, the time data were corrected using data recorded on the aircraft DFDR, ACMS, AIDS, and ATC radar system and communications recordings, as mentioned in section 2.9.3. The analysis was conducted in collaboration with ENRI.

The result of the analysis is as follows.

(1) TCAS Alert Thresholds

The TCAS alert thresholds that were in effect as the aircraft were converging were the SL7 boundaries that are in use above altitudes of FL300. The TCAS alert thresholds of SL7 are shown in the Table below.

TA and RA Alarm Thresholds at SL7

	Radius of Protected Boundary	Altitude Threshold	Closure Time Threshold
TA	Approx. 1.3 nm	1,200 ft	48 seconds
RA	1.1 nm	800 ft	35 seconds
Increase RA	Omitted	200 ft	26 seconds

Note: Thresholds are the designed criteria used by the TCAS logic to evaluate whether an aircraft is a threat or not. If the TCAS logic determines that the CPA between the two aircraft is within the Radius of the Protected Boundary and the Altitude Threshold, the combinations of range and closure rate trigger an alarm at a range time before the Closure Time Threshold (a TA with a 48-second range time and a RA with a 35-second range time).

(2) Outlines of the TCAS Alerts prior to the CPA

The sequence of issue of TCAS alerts prior to the closest approach between Aircraft-A and Aircraft-B was as follows. The slant range (SR) and vertical separation (VS) calculated by the TCAS logic are given in parentheses.

Maneuvers executed by Aircraft-A and Aircraft-B based on the DFDR recorded data also given in square brackets for reference. Additionally, the flight paths of the two aircraft from their convergence to avoidance are shown in Attached Figure 9.

- 15:54:19 Aircraft-B's TCAS issued a TA (SR, VS, Relative Speed (RS) against Aircraft-A: 12.4–12.8 nm, –100 ft (Aircraft-A lower), approx. 910 kt)
- 15:54:19 Aircraft-A's TCAS issued a TA while the aircraft was climbing (SR, VS, RS against Aircraft-B: 12.38–12.63 nm, 0 ft (approx. co-altitude), approx. 910 kt)
- [15:54:33–38 Aircraft-A replied to Tokyo ACC's descent instruction.]
- 15:54:34 Aircraft-B's TCAS issued a Descend RA with a vertical speed of –1,500ft/min (SR, VS, RS against Aircraft-A: 8.5–8.7 nm, 100 ft (Aircraft-A higher), approx. 910 kt)
- 15:54:35 Aircraft-A's TCAS issued a Climb RA with a vertical speed of 1,500ft/min (SR, VS, RS against Aircraft-B: 8.38–8.63 nm, –100 ft (Aircraft-B lower), approx. 910 kt)
- [15:54:36 Aircraft-A reduced its rate of climb.]
- [15:54:40 Aircraft-A reversed the climb to a descent.]
- [15:54:41 Aircraft-B started descending gradually.]
- 15:54:49 Aircraft-B's TCAS issued an Increase Descent RA with a vertical speed of –2,500ft/min (SR, VS, against Aircraft-A: 4.9nm, 100 ft (Aircraft-A higher)
- [15:55:00 Aircraft-A closed while turning, the bank angle momentarily reducing to 2.5 ° left.]
- 15:55:03 Aircraft-B's TCAS began to lose the track of Aircraft-A. Aircraft-A's symbol continued to be displayed on Aircraft-B's TCAS display as the linearly projected position.)
- [15:55:05 Aircraft-A's bank angle was 11.6° left. Aircraft-B's bank angle was 9.4° right.]
- 15:55:06 Aircraft-A's TCAS issued an Increase Climb RA with a vertical speed of 2,500ft/min (SR, VS, against Aircraft-B: 1.25 nm, 0 ft (approx. co-altitude)
- [15:55:00 Aircraft-A's bank angle was 15.6° left.]
- [15:55:06–07 Aircraft-A experienced a negative load factor.]
- [15:55:06–08 Aircraft-B experienced a large positive load factor.]
- [15:55:07 Aircraft-A's pitch angle was –10.9°. (SR, VS, against Aircraft-B:

1.06 nm, -100 ft (Aircraft-B lower))

[15:55:08 Aircraft-A's bank angle was 19.3° left.]

15:55:09 Aircraft-A's symbol disappeared from Aircraft-B's TCAS display.

[15:55:11 The two aircraft reached the CPA. (Distance: less than 0.19 nm, obtained by measuring the time of radio signal propagation between the antennas of the two aircraft). The CPA was in the vicinity of 34°43' North, 138°15' East .]

(3) Explanation of Results of the Analysis of TCAS Operation

Analysis of the operation of the TCAS systems on Aircraft-A and Aircraft-B revealed that the TAs and RAs occurred within the SL7 boundary at an altitude of above FL300, as mentioned in (1) above, and no abnormality was found in the operation of either TCAS system. The result of the analysis of the TCAS operation is explained as follows.

- ① Absolute values of the distance and vertical separation between the two aircraft at the time when TAs were issued were 12.38–12.80 nm and 0–100 ft, respectively. The TAs were triggered 53 seconds (± 1 second) before the CPA.

The triggering of the TAs before the Closure Time Threshold (48 seconds) was the result of the TCAS prediction concept based on the assumption that the ownship and the other aircraft are flying straight. In the case of the accident, the relative speed between the aircraft after the issuance of the TAs decreased compared to that at the time of the issuance of the TAs because while Aircraft-B was flying straight, Aircraft-A was turning and turned out to be crossing Aircraft-B's flight path. This resulted in the time remaining to CPA became greater than the value predicted by the TCAS systems at the time of the issuance of the TAs.

- ② Absolute values of the relative range and vertical separation between the two aircraft at the time when RAs were issued were 8.38–8.80 nm and 100 ft, respectively. The RAs were triggered 36 seconds (± 1 second) before the CPA.
- ③ Aircraft-A's TCAS selected the upward sense RA and Aircraft-B's selected the downward sense RA. Thus, it is considered that the TCAS coordination to avoid a collision between the two aircraft functioned normally.
- ④ It is considered that the reason why Aircraft-B issued the Increase RA 21 seconds before the CPA after passing the Closure Time Threshold (26 seconds) was that Aircraft-B's TCAS calculated that Aircraft-B would not be able to achieve a vertical separation of more than 200 ft against Aircraft-A

at the present descent rate, even though Aircraft-B had followed the RA with a vertical speed of $-1,500\text{ft/min}$.

- ⑤ It is considered that the reason why the issuance of the Increase RA in Aircraft-A lagged far behind the Closure Time Threshold (26 seconds) until 5 seconds before the CPA was that although Aircraft-A descended with a vertical speed of $1,500\text{ft/min}$, contrary to the RA, the situation still held that Aircraft-A could have achieved a vertical separation of more than 200 ft against Aircraft-B if it had followed the RA and climbed.
- ⑥ It was considered that the reason why Aircraft-B's TCAS lost the track of Aircraft-A while the aircraft continued to converge was that for a few seconds Aircraft-B's TCAS receiver antenna could not receive signals transmitted by Aircraft-A because the two aircraft were rolling in opposite directions. Thus, according to the TCAS data recorded by Aircraft-B's AIDS, the Increase RA changed to a TA at the same time as Aircraft-A's track was lost, and so the TA symbol was not indicated on Aircraft-B's TCAS display.

2.12.3 Test Flight using Flight Simulator, etc.

2.12.3.1 Engine Thrust Response to Movement of Thrust Levers

A Boeing manual for the 747-400D (the same type of aircraft as Aircraft-A) states that at an altitude of 37,000 ft, with the engines at flight idle, there is a delay of about five seconds from the thrust levers being advanced until the engine thrust starts to increase, and a further delay of about 20 seconds until the engine thrust reaches MCT.

In order to confirm characteristics of the engine thrust responsiveness when transiting from descent to climb, plots of changes in N1, N2 and positions of the thrust levers before and after the occurrence of the accident recorded on Aircraft-A's ACMS are shown in Attached Figure 19.

(Note) N1 is the speed of rotation in percent of the engine Low Pressure Compressor, and is used as an index to adjust the engine thrust. For the engines of Aircraft-A, 3,280 RPM is defined as 100% N1.

(Note) N2 is the speed of rotation in percent of the engine High Pressure Compressor. For the engines of Aircraft-A, 9,827 RPM is defined as 100% N2.

2.12.3.2 Flight Simulator Tests

Tests were conducted using a full-flight flight simulator to evaluate the possible maneuvers of Aircraft-A following the TCAS advisories before the

occurrence of the accident. The simulator used for the tests was equipped with sophisticated visual and motion systems, and had been approved as a Phase 3 flight simulator (the highest level of simulation fidelity) by the JCAB, Ministry of Infrastructure, Land and Transport.

There was no Boeing 747-400D flight simulator (the same type as Aircraft-A) available, and so a Boeing 747-400 simulator was substituted for the tests. The 747-400D lacks the winglets that are fitted to the 747-400, and the performance difference between the 747-400D and the 747-400 is detailed in the JAL's AOM SUPPLEMENT. However, it is considered that there is no significant difference between the two aircraft types that would adversely affect the results of the post-accident flight simulator tests. Moreover, the purpose of the post-accident flight simulator test flights was not to obtain precise quantitative data regarding flight performance, but to qualitatively grasp the maneuvering possibilities and flight condition of Aircraft-A at around the time of the accident. These tests were therefore conducted with reference to the aircraft manufacturer's flight performance documentation, descriptions in the AFM, etc.

(1) Aircraft-A's climb without the ATC instruction to descend

This test was carried out to evaluate the result assuming that Tokyo ACC had not instructed Aircraft-A to descend to FL350. It showed that Aircraft-A would have reached an altitude of approximately 38,100 ft around the CPA at the time of the accident.

[Test procedure]

The parameters of climb performance, etc. were set to those of Aircraft-A at the time of the accident. The straight climb prior to YAIZU was conducted with a climb rate of 1,000ft/min, and the turn from YAIZU was conducted with a bank of about 25° left. The wind direction and speed were set to approximately the conditions at the time of the accident.

[Result]

While climbing continuously to its cruising altitude of FL390, the aircraft crossed an altitude of approximately 38,100 ft at around the CPA at the time of the accident. Around YAIZU, the rate of climb decreased from 1,000ft/min to 400–800ft/min due to the turn. The results of the test are described in subsection 3.2.3.4 (4).

(Refer to Attached Figure 18)

(2) The time required to recover climb thrust

This test was conducted to investigate the engine thrust response to movement of the thrust levers from their idle positions to climb thrust positions, with the autothrottle engaged.

[Test procedure]

The time to recover from idle thrust to climb thrust (which is the same as MCT at the altitude at which the accident occurred) was measured to evaluate the engine thrust response to movement of the thrust levers. This test was conducted using the auto throttle, as manual operation could introduce variation in the collected data. During the climb phase, the thrust levers were manually moved to their idle stop positions with the autopilot engaged in VNAV SPEED mode, held there for 5 seconds (after which N1 stood at 73%), and then released. The thrust levers then moved to the climb thrust positions under the autothrottle, and the time from the release of the thrust levers from their idle positions to the engine fuel flows recovering to climb thrust values was measured.

[Result]

It took approximately 5 seconds for the thrust levers to advance from the idle positions to the climb thrust positions under the action of the autothrottle, and it took about 10 seconds for the fuel flows to recover to climb thrust values.

It was considered that these time periods were required because the EEC provided a slow fuel supply operation to guard against engine surge etc. The results of the test are described in subsection 3.2.3.7 (1).

(3) Aircraft-A's climb in response to the RA command

This test assumed that Aircraft-A had climbed obeying the climb RA, and showed that it would have reached an altitude of approximately 37,800 ft around the CPA at the time of the accident.

[Test procedure]

After the fuel flow was stable at approximately 7,600 lb/hr when climbing at around FL371, the thrust levers were slowly moved to their idle positions, and then about 5 seconds later (at the time when the fuel flow had decreased to approximately 5,400 lb/hr) were advanced for climb again while making the aircraft pitch nose up. The decrease in altitude, the changes in the rate of descent, the aircraft stability and so on were investigated from that time until a rate of climb of 1,500 ft/min was achieved.

[Result]

Although the rate of climb shown by the vertical speed indicator decreased to -120 ft/min at the time when the thrust was reduced by slowly moving the thrust levers to their idle positions, altitude was maintained at FL372 for about 9 seconds. Subsequently, the aircraft entered to a gradual climb and reached an altitude of 37,800 ft at around the time of the CPA. During this time period, there was no anomaly in the aircraft stability. The results of the test are described in subsections 3.2.3.5 (2) and 3.2.3.7(1), (4).

(Refer to Attached Figure 18)

(4) TCAS display utilization

This test assumed that Aircraft-A reversed its descent to a climb when its flight crew identified Aircraft-B's descent on the TCAS display. The resulting altitude around the CPA at the time of the accident would have been approximately 36,200 ft.

[Test procedure]

During a climb, a descent was initiated with the thrust levers moved to their idle thrust positions. Twenty seconds later, the aircraft was made to climb again with the thrust levers advanced to the climb thrust positions, and the time required for the aircraft to change from descent to climb and the decrease in altitude during this period were investigated.

[Result]

The decrease in altitude was 320 ft during the period from when climb thrust was set to the time when the aircraft descended to its lowest altitude. Around the time of the CPA the aircraft was climbing through 36,200 ft. The time required for the aircraft to recover the original altitude (idle thrust positions) was approximately 36 seconds. The results of the test are described in subsection 3.2.3.8 (2).

(Refer to Attached Figure 18)

(5) Stall margin

This test was conducted to investigate the stall margin in the situation where Aircraft-A's TCAS issued the RA. In the test described in item ① below, moving the thrust levers to their idle stops caused the airspeed to drop and produced buffeting of the aircraft about 105 seconds later. And, in the test described in item ② below, pitching the aircraft nose up at a rate of 1° per second produced buffeting approximately 17 seconds later, during which time, however, the altitude had increased by 1,400 ft.

① [Test procedure]

The test was started with the aircraft in level flight at an altitude of 37,000 ft and airspeed of 280 kt. After slowly moving the thrust levers to their idle stops, while maintaining altitude and aircraft heading, the decrease in airspeed and the time until activation of stall shaker were measured.

[Result]

Buffeting was produced approximately 105 seconds after moving the thrust levers to the idle stops, at which time the indicated air speed (IAS) was 215 kt.

② [Test procedure]

Five seconds after moving slowly the thrust levers to their idle stops, the thrust levers were advanced to positions corresponding to 93%N1 and the aircraft pitched nose up at rates of 1° per second and 2° per second. The altitude gained within 30 seconds and the situation where the buffet is produced leading to the stall shaker activation were confirmed.

[Result]

In the case of pitching up at a rate of 1° per second, buffet was produced about 17 seconds after beginning the pitch up, at which time the airspeed was approximately 230 kt and the pitch angle was approximately +17°. An altitude of approximately 1,400 ft was gained during this time.

In the case of pitching up at a rate of 2° per second, buffet was produced 5–6 seconds after beginning the pitch up, and the altitude gain was not available.

The results of the test are described in subsection 3.2.3.7 (2) and (4).

(6) The acceleration performance of the engines

This test was conducted to investigate the acceleration performance of the engines under the condition that the aircraft is cruising in level flight at high altitude. The time required for N1 to recover from the idle to MCT was approximately 18 seconds at an altitude of 30,000 ft, and approximately 24 seconds at 40,000 ft.

[Test procedures]

The thrust levers were moved to their idle positions while the aircraft was cruising at 280kt at altitudes of 30,000 ft or 40,000 ft. While maintaining level flight, after the engine N1s had completely stabilized at the idling speed, the

engines' acceleration performance was confirmed by advancing the thrust levers to the climb thrust positions.

[Result]

① In the case of 30,000 ft

The N1 began to increase after about 10 seconds from the initiation of moving the thrust levers, and recovered to the MCT value about 18 seconds later, during which time the airspeed increased from a lowest speed of 255 kt.

② In the case of 40,000 ft

The N1 began to increase after about 18 seconds from the initiation of moving the thrust levers, and recovered to the MCT value about 24 seconds later, during which time the airspeed increased from a lowest speed of 230 kt.

The results of the test are described in subsection 3.2.3.7 (1).

(7) Climb performance at around the maximum operation altitude (MOA)

This test was conducted to confirm Aircraft-A's climb performance at around MOA when obeying a climb RA, attempting to achieve the 1,500ft/min rate of climb commanded by the RA. Although it would be rare in common practice for an aircraft of the same type as Aircraft-A to be actually operating at around MOA, this test was attempted in the most rigorous conditions. As a result, there was a slight decrease in airspeed but it was possible for the aircraft to climb at a rate of 1,300ft/min.

[Test procedures]

Given that an aircraft with the weight of 500,000 lbs cruised at an altitude of 45,000 ft and an airspeed of 235 kt, when the TCAS issued the climb RA with a vertical rate of 1,500 ft/min, it was confirmed whether the aircraft was able to climb responding to the vertical rate issued by the TCAS or not.

[Result]

Thirty seconds later, the decrease in the airspeed was approximately 10 kt but the aircraft gained approximately 650 ft of altitude. One minute later, the decrease in the airspeed was approximately 22 kt but the aircraft had gained approximately 1,300 ft of altitude.

The results of the test are described in subsection 3.2.3.7 (2) and (3).

2.12.4 Investigation into ATC Radar System

2.12.4.1 Radar Data Processing (RDP) system

As a result of the post-accident investigation into the RDP system of Tokyo ACC, there found no fault in the hardware and software, and so it is considered that the entire system was operating normally from receiving the radar data to sending information to the radar controller's plan view display (PVD) on the day of the accident.

The following table shows times of update of the track data of Aircraft-A and Aircraft-B together with their Flight Levels (FL) displayed on the PVD installed at Tokyo ACC's Kanto South C sector during the period from just before the issuance of the CNF alarm to immediately after the CPA.

Aircraft-A		Aircraft-B	
Update Time	FL	Update Time	FL
15:54:09	367		
		15:54:14	370
(15:54:15 CNF alarms of the two aircraft were displayed on the PVD)			
15:54:19	369		
		15:54:24	370
15:54:29	370		
		15:54:34	370
15:54:38	372		
		15:54:43	370
15:54:48	371		
		15:54:53	369
15:54:58	367		
		15:55:03	366
15:55:08	362		
		15:54:12	359
15:55:21	[B] (Note)	15:55:21	354
15:55:31	349	15:55:31	353

Note: [B] indicates that a "B" symbol was displayed in the aircraft's data block on the PVD, showing that the altitude information at the time was invalid. The RDP did not process and dropped the data supplied by the radar site which had tracked Aircraft-A and Aircraft-B until the time just before

15:55:21, due to their information being overlapped. Thus, the track data of Aircraft-A on the PVD at 15:55:21 was supplemented by data previously received from another radar site. However, because the radar site used for supplementing the track data was located far from the two aircraft and was at a bearing prone to errors, altitude information were lost and further, the aircraft positions were displayed on the PVD with relatively large errors, although within the allowable level.

This matter is attributed to the limitations of the RDP system, but is not an anomaly of the system.

In addition, 2–3 seconds are needed for RDP to display the track data after receiving the radar returns, including transmission time. Therefore, information on altitude (FL), which are displayed with some delays, are not necessarily consistent with the altitude data recorded on the DFDR. However, the display positions are corrected by the delayed time.

The reason why the updated times of the two aircraft had a time lag of about five seconds was that the RDP was processing data supplied by several radar sites which covered the air space in the vicinity of the occurrence of the accident.

2.12.4.2 CNF (Conflict Alert)

When aircraft are predicted to become abnormally close, a red symbol “CNF” is flashed in the data blocks of the aircraft concerned on the PVD. The conditions of the CNF activation is described in a RDP operation manual established by the Air Traffic Control Data System Office of the Air Traffic Engineering Service Division as follows.

“When two aircraft are predicted to converge within a vertical separation of 700 ft (1,600 ft in the case of aircraft above 29,000 ft) and a lateral distance of 5 nm, a symbol of “CNF” is displayed 3 minutes before the occurrence of the predicted convergence.”

However, since there can be a situation where the vertical and/or lateral distance between two aircraft decreases due to aircraft turning, the “CNF” symbol is not necessarily displayed three minutes before loss of prescribed separation in all situations. In this accident, because Aircraft-A turned left at a location about 7 nm north of the CPA, the CNF was triggered more than two minutes later than the prescribed three-minute warning time, at 15:54:15 when the RDP detected Aircraft-B within a 5 nm-wide air corridor along Aircraft-A’s projected track.

There was no established manual for air traffic controllers about how to deal

with cases when CNF is triggered while performing their duties, neither was there knowledge given to the controllers about the conditions in which the issuance of CNF might be delayed so that it is issued less than the prescribed three minutes before loss of separation. Although controllers do not receive specific training on how to respond to a CNF alert, they could often experience the CNF alert in the usual ATC simulator training.

(Refer to Attached Figure 4)

2.12.4.3 Radar Hand-Off

When an aircraft flying through a sector under the control of an air traffic control facility approaches the boundary of the next sector it is due to enter, one of duties of the air traffic controller handing the aircraft (the “transfer controller”) is to transfer aircraft identification information (hereinafter called as “ID”) and radio communications to the next sector. This process is called as “Radar Hand-Off”, and is usually carried out by the radar controller operating function keys and a track ball installed at the Radar Console.

A symbol “HND” flashes in the data block of the transferred aircraft on the PVD of the controller of the adjacent sector who will receive the “Radar Hand-Off” (the “receiver controller”). The receiver controller receives the “Radar Hand-Off” by operating function keys at his or her own console.

Acknowledgement that the receiver controller received the ID is indicated on the transfer controller’s PVD by the symbol “OVR” flashing in the data block of the transferred aircraft. Subsequently, the transfer controller instructs the transferred aircraft to change to the radio frequency in use by the next sector.

Responding to this instruction, the pilots of the transferred aircraft call the receiver controller by R/T to establish radio contact.

Then, the receiver controller enters a mark on the aircraft’s flight strip (a slip of paper on which information on aircraft operations are entered) to indicate that the ID was transferred and radio communications established. This completes the “Radar Hand-Off” process.

Regarding the “Radar Hand-Off” of Aircraft-B on the day of the incident, a mark indicating the completion was entered in Aircraft-B’s flight strip.

(Refer to Attached Figure 3 and 4)

2.13 Organization and Management information

2.13.1 Flight crew procedures at the time of the accident

2.13.1.1 Standard flight crew complements

The standard flight crew complement of Aircraft-A, a Boeing 747-400D, is two flight crewmembers — the Captain and the First Officer.

In Aircraft-B, a DC-10-40, three flight crewmembers, the Captain, First Officer, and Flight Engineer, form the flight crew complement.

Japan Air Lines' Operations Manual (OM) states the responsibilities and duties of the Captain (Pilot In Command: PIC), the First Officer, and the Flight Engineer as follows:

1. PIC

- (1) The PIC shall be responsible for judging the execution of the flight, and for commanding and directing the whole flight operations.
- (2) The PIC shall be responsible for the safety of the aircraft, passengers and loaded goods during the flight.
- (3) The PIC shall place all flight crewmembers and their duty performance under his or her control, and direct them adequately.

The PIC shall also pay attention to supervising and educating other flight crewmembers.

- (4) The PIC shall clearly instruct task assignment among flight crewmembers, as the need arises, if there is non-stipulated job item.
- (5) The PIC shall be able to delegate a part of his task to other flight crewmembers under his own responsibility.
- (6) The PIC shall, in case of leaving the cockpit, give instructions to his acting crew for possible contingent occurrences, and receive an immediate debriefing after his return.
- (7) The PIC shall, in the event of an emergency, give adequate instructions to other flight crewmembers until the end of the case. The PIC himself shall manage to control the aircraft during the emergency.

2. First officer

The First officer shall assist PIC during the whole flight, and, in case of a contingent happening to the PIC, immediately take over his duties.

3. Flight engineer

The Flight engineer shall assist PIC, and in particular undertake to maintain the function of aircraft, engines and any other systems in normal conditions.

In addition, the Flight Engineer shall monitor ATC radio communications and the flight path (mainly altitude), for providing backup assistance to the PIC and the First Officer.

2.13.1.2 Flight crew disposition and task assignment at the time of the accident

At the time of the accident, two trainee pilots undergoing training for promotion to first officer position were on the flight deck of Aircraft-A in addition to the Captain and First Officer. Aircraft-B was operated by three flight crewmembers — the Captain, the First Officer who was undergoing training for promoting to captain, and the Flight Engineer. Each crew assumed his position and duties as follows.

Aircraft-A.

The Captain occupied the left-front seat while assuming PF duties, and, as a Senior Instructor (Captain), was instructing the right-front seated trainee pilot who undergoing training for upgrade to first officer status and assumed the duties of PNF.

The First Officer was seated in the left-rear jump seat and was, under the direction of the Captain, providing instruction to the trainee pilots.

One of the two trainee pilots, seated in the right-front seat, was undergoing training to finish up his studies in PNF skills and to drill his proficiency in planning and judgment. The other trainee pilot occupied the right-rear jump seat.

Aircraft-B

The Captain occupied the right-front seat while assuming the duties of PNF, and was giving instruction to the left-front seated First Officer who was in upgrade training for promotion to Captain.

The First Officer, seated in the left-front seat, assumed the duties of PF while receiving the training for promoting to Captain.

The Flight Engineer performed his duties from the flight engineer's seat.

2.13.1.3 Qualification requirements of flight crewmembers

In addition to the Airman Competence Certificate which are required for captains, first officers and flight engineers under the Civil Aeronautics Law, qualifications and duty requirements for air transport service are also stipulated under current statutes and related company regulations.

According to Japan Air Lines' OM, one of the duty requirements for the captain and first officer dictates that they shall meet the specific requirements for TCAS procedures. (Ref. 2.14.2.1)

The captains and first officers of both aircraft, and the flight engineer of Aircraft-B, were properly qualified and licensed.

In this regard, according to Japan Air Lines' company regulations, the qualification requirements for a particular job for the flight crewmembers positioned at the time of the accident are summarized as follows:

1. Trainee pilot in initial training for upgrade to first officer

He shall be a flight crew trainee pilot who has completed a basic training for first officer status.

2. First officer in an upgrade training for promoting to the Captain status

With a synthetic judgment, the company shall choose any applicants from among first officers who have built up experience of more than 60 landings/departures as left-seated first officer in their assigned type of aircraft. After evaluation of their personality, the company shall lay the matter before the Flight Crew Qualification Review Committee to screen the candidates. The Committee shall deliberate over the selected candidates' skill and character, so as to select them as trainee pilots for promotion to Captain.

3. Line Training Instructor

In addition to the qualification requirements for flight crew, a Line Training Instructor shall meet following requirements:

- (1) He shall acquire experience, skill and knowledge of exercising training adequately.
- (2) He shall complete the required training for an assignment.
- (3) He shall meet an upper age limit of 65 if he takes duty as a Special Instructor.
- (4) A Flight Instructor and Line Training Instructor shall be qualified as a Left-Seat Approved Captain.

4. Training for a Left-Seat Approved Captain

A captain to be appointed as a Left-Seat Approved Captain (who is eligible for allowing a first officer to take left-seat flying) shall receive Ground Training, Simulator Training and Local Flight Training, as stipulated by the regulations of Training Standards for Left-Seat Approved Captain.

5. Training for a Right-Seat Approved Captain

A captain to be appointed as a Right-Seat Approved Captain (who is eligible for allowing a first officer to take right-seat flying) shall receive Ground Training, Simulator Training and Line Training, as stipulated by the Training Standards

for Right-Seat Approved Captain and Senior Instructor (Captain).

6. A Senior Instructor (Captain)

A Senior Instructor (Captain), who is eligible for allowing trainee pilot to take line flight training, shall complete training for an appointment.

2.13.2 Air route control services at the time of the accident

2.13.2.1 General information of Kanto South-C sector

From the ATC point of view, the accident site is located in the Kanto South-C sector that is under the jurisdiction of Tokyo ACC.

The size of the Kanto South-C sector is about 120 nm (about 220 km) from east to west and about 60 nm (about 110 km) from north to south. The Sector has responsibility for handling traffic flying along the portion of airway between 10 nm (about 18 km) east of Kowa and the vicinity of Onjuku in Chiba prefecture (or 15 nm (about 28km) east of the Izu Island for arriving traffic to Tokyo International Airport).

The airway links Kowa (of Mihama Town in Aichi prefecture, at the southern tip of the Chita peninsula) with Izu Island, and lies on the north side of the route connecting Miyake Island and Kushimoto in Wakayama prefecture. The sector handles up to about 500 aircraft every day. It takes nearly 15 minutes to traverse the sector's airspace for a jet aircraft flying from east to west at cruising altitude.

The sector mainly controls aircraft that depart from the areas of Kyushu, Chugoku and Shikoku and arrive at Tokyo International Airport, and also handles traffic into New Tokyo International Airport, Yokota US Air Force Base, Atsugi Maritime Self-Defense Force Base, Shimofusa base and Shizuhamu Japan Air Self-Defense Force base. Regarding outbound traffic, the sector controls aircraft departing from Shizuhamu Airport and the above-mentioned airfields bound for the south or south-west. Few aircraft traverse the sector at cruising altitude, while the majority of traffic is departure or arrival traffic that requires climb to or descent from cruising altitude.

The destination of Aircraft-B was New Tokyo International Airport, and the starting point of its descent for approach in case of cruising FL370 was nominally at about 20 nm (about 37 km) east of the area where Aircraft-A and Aircraft-B passed each other. About 30 aircraft each day arrive from neighboring countries into New Tokyo International Airport via XMC (Kowa VORTAC), and these normally take the same route as Aircraft-B.

(Ref. Figure 2)

2.13.2.2 Controller Console Positions and Task Assignments

The standard complement of air traffic controllers for the Kanto South-C Sector is two positions, namely, a radar controller operating the Radar R/G console and a Coordinator.

At the time of the accident, a trainee controller was on duty at the Radar R/G console of the Kanto South-C Sector under the guidance of a supervisor controller. The coordinator's console was also staffed by a controller. The "Tokyo ACC, Air Traffic Service Operational Procedures" defines the basic tasks for the controllers at each console, which are summarized as follows:

The radar controller at the Radar R/G console shall communicate with aircraft in the jurisdictional airspace and issue required ATC clearances or instructions so as to secure aircraft IDs and maintain prescribed separations. The radar controller shall manage the Radar Handoff procedures using a keyboard of the computer system.

The Coordinator shall monitor the communications established by the Radar R/G console, assist in keeping up aircraft IDs displayed on the PVD, and verbally coordinate with neighboring sectors and ACCs. In addition, the Coordinator shall exercise control over the Sector activities.

According to the "Tokyo ACC, Air Traffic Service Handling Procedures", which are subordinate to the "Tokyo ACC, Air Traffic Service Operational Procedures", the duties of the Coordinator are roughly as follows:

- ① The Coordinator shall issue clearances to departing aircraft that are bound for west or south from airports/airfields within the Haneda area, New Tokyo International Airport and airfields within the Yokota area; and also to aircraft departing from Shizuhamu airfield.
- ② The Coordinator shall provide information on aircraft arriving to or flying over the Yokota area airfields, and verbally initiate aircraft radar handoffs.
- ③ The Coordinator shall conduct verbally coordination as necessary for aircraft arriving to Haneda area airfields and New Tokyo International Airport.
- ④ The Coordinator shall initiate coordination with other neighboring sectors.

(Ref. Figure 3)

2.13.2.3 Qualification requirements for controllers

To become an ATC controller, it is necessary to pass an employment examination set by the National Personnel Authority and then be enrolled at the

Aeronautical Safety College.

The examination rules and regulations for ATC staff specify that controllers must take fundamental ATC study courses and pass primary examinations in nine subjects including aeronautical rules and ATC procedures prior to their graduation from the college.

After finishing the college, in the case of starting a new post at the Tokyo ACC, it is necessary to attend classroom training on subjects including regional characteristics and the Flight Plan Data Processing system, and to undergo a six-month training program for acquiring the qualification of an assistant controller who is supplementary to an air traffic controller.

Thereafter, qualifications to carry out ATC duties for both radar-aided and non-radar-aided services must be acquired on a per sector basis. Tokyo ACC normally administers oceanic sector training to give controllers a chance to adjust to air route control services without the aid of radar. The qualification of the oceanic sector service emphasizes understanding of the traffic characteristics of jurisdictional airspace during the training for non-radar-aided air route control services in domestic airspace. The training also underlines procedures for issuing ATC clearances to departing aircraft from airports within jurisdictional airspace, and coordinating duties with other units.

Having acquired qualification for their firstly appointed sector of work, controllers receive training on radar-aided air route control services in domestic airspace. From May 1999 onward this was conducted at the Iwanuma Branch of the Aeronautical Safety College (reorganized as the Iwanuma Training Center from April 2002). The ATC trainee at the time of the accident had joined a classroom lecture at the college which included study of TCAS procedures.

The college also teaches basic methods of radar vectoring and speed adjustment for controlled aircraft. Thereafter, each ATC center unit provides classroom lectures on sector-specific characteristics and training with radar simulators tailored to each sector's features.

After that, in parallel with on-the-job training in the use of control panel, an instructor posted to each team will provide radar simulator training conducted during outside of control duty periods. The length of the training differs between sectors according to their traffic characteristics. The period of training for qualification for radar-aided control services in the Kanto South Sector (qualification-wise, the Kanto South-A Sector, -B Sector and -C Sector are all regarded as the undivided Kanto South Sector) in which the accident occurred covers 11 months.

The ATC trainee at the time of the accident had acquired qualification in air route radar control services for the Kanto West sector on May 2000. Thereafter, he acquired the qualification of the (non-radar-aided) air route control service in the Kanto South sector in September 2000 — four months from started training for the radar-aided air route control service. In addition, teams on duty at the Tokyo ACC at the time of the accident had assigned an instructor to each individual trainee controller for the radar simulator training.

(Ref. Figure 20)

2.13.2.4 Requirements for a ATC watch supervisor

At the time of the accident, there were no stipulated requirements of study and qualification for control supervisor duties. Both the Iwanuma Branch of the Aeronautical Safety College and the FAA Academy in the USA have courses for training supervisors, although these were not mandatory. However, the supervisor control in question had not attended the course. Tokyo ACC's "Instructor's Handbook" states the basic points to be followed for supervising OJT, but it does not contain any notes regarding debriefing trainees during duty periods on tasks performed. In regard to training methods, the following is summarized from the "training for persons that have not acquired a Competence Certificate (No. 7-6)", contained in the "Tokyo ACC, Air Traffic Service Handling Procedure":

The following items shall be observed in case of training of persons who have not acquired a Competence Certificate (hereinafter referred to as a "trainee controller") at the controller console:

- ① An associate operations manager shall select supervisors from among controllers who hold a Competence Certificate after evaluating their skills and other relevant abilities.
- ② The supervisor shall be responsible for every aspect of the training of the ATC trainee.
- ③ The supervisor shall conduct training under reasonable traffic conditions and, if the increasing traffic volume seems to exceed trainee controller's ability, immediately discontinue the training.
- ④ The supervisor shall continually give the ATC trainee advice or directions and, if necessary, assume personal command of the controller console.
- ⑤ The supervisor shall ask the ATC trainee to monitor the work for more than 15 minutes and give the ATC trainee points to be followed during the training prior to allowing him to take his position at the controller

console.

- ⑥ The supervisor shall assume leadership and secure the closest coordination with the ATC trainee, especially in the handling of ATC clearances/instructions, ATC handoffs, position report records, and strip removals, in order to ensure the accuracy and adequacy of the handling.

2.14 Other information

2.14.1 Regulations related to TCAS operations

2.14.1.1 Japanese Regulations

(1) Japanese Civil Aeronautics Laws Article 96 section 1

Any aircraft shall, in a control area or control zone, navigate in accordance with instructions which are given by the Minister for Land, Infrastructure and Transport for aircraft safety, with regard to the order, time or methods of take-off or landing, or method of flight.

(2) Japanese Civil Aeronautics Regulations Article 147 (Excerpts)

The equipment necessary for installation in an aircraft used for air transport service under the provisions of Article 60 of the Law shall be as specified each applicable subsection as follows, and the quantity of each item of said equipment shall be not less than the number specified in each subsection:

(Texts from subsection 1 to 4 are omitted)

Subsection 5. Traffic alert and collision avoidance system which indicates Resolution Advisory in vertical direction (limited to aircraft with more than 30 seats excluding those in the cockpit, or turbine-engined aircraft with a maximum take-off weight exceeding 15,000 kilograms).

(This subsection has been taken effect from January 4, 2001.)

(3) AIC(Aeronautical Information Circular)

Civil Aviation Bureau of Japan has issued AIC related to the operation of TCAS, and in AIC, avoidance maneuvers are mentioned as follows (Excerpts):

(See Attachment 3)

4. Procedures to be followed by pilots

(1)b. In the event of a Resolution Advisory (RA) to alter the flight path, the search for the conflicting traffic shall include a visual scan of the airspace into which own ACAS aircraft might maneuver.

(1)c. The alteration of the flight path shall be limited to the minimum

extent necessary to comply with the RA.

(1)d. Pilots who deviate from an ATC clearance in response to an RA shall promptly return to the terms of the previous ATC instruction or clearance when the conflict is resolved and they shall notify the appropriate ATC unit by the use of the following phraseologies as soon as possible on the radio frequency.

Circumstances	Phraseologies
after modifying vertical speed to comply with an ACAS RA	TCAS CLIMB (or DESCENT)
after ACAS “Clear of conflict” is annunciated	RETURNING TO (assigned clearance)
after the response to an ACAS RA is completed	TCAS CLIMB (or DESCENT), RETURNING TO (assigned clearance)
after returning to clearance after responding to an ACAS RA	TCAS CLIMB (or DESCENT) COMPLETED, (assigned clearance) RETURNED
when unable comply with a clearance because of ACAS RA	UNABLE TO COMPLY, TCAS RA

NOTICE: “TCAS” should be used as ATC phraseology instead of “ACAS”.

5. Aircraft operators involvement

(1) Operators shall stipulate detailed ACAS operational procedures in each Aircraft Operations Manual.

6. Pilot responsibility

When an RA is initiated and the pilot deviates from an ATC clearance, the pilot is not considered to violating against the Civil Aeronautics Law, article 96-1.

7. Controller's responsibility during an RA

Once an aircraft departs from an assigned ATC clearance in compliance with an RA, a controller ceases to be responsible for providing ATC

separation between that aircraft and other aircraft affected by the direct consequence of that RA maneuver. The controller's responsibility for providing separation for all affected aircraft resumes when either;

- (1) the aircraft returns to the assigned clearance, or
- (2) the pilot reports a controller ATC that RA maneuver is completed and the controller confirms that separation is established.

2.14.1.2 ICAO Regulations

ICAO regulations related to the operation of TCAS are as follows.

(1) ICAO Annex 6

ICAO Annex 6 Part 1 section 6.18 states as follows (Excerpts):

6.18.1 From 1 January 2003, all turbine-engined aeroplanes of maximum certificated take-off mass in excess of 15,000kg or authorized to carry more than 30 passengers shall be equipped with an airborne collision avoidance system (ACAS?).

6.18.4 An airborne collision avoidance system shall operate in accordance with the relevant provisions of Annex 10, Volume 4.

(2) PANS-OPS

PANS-OPS, as the supplement to Annex 6, Volume 1, Part VIII, Chapter 3 “Operation of ACAS Equipment” states as follows:

3.1 GENERAL

3.1.1 The information provided by airborne collision avoidance system (ACAS) is intended to assist pilots in the safe operation of aircraft.

3.1.2 Nothing in the procedures specified in 3.2 hereunder shall prevent pilots-in-command from exercising their best judgment and full authority in the choice of the best course of action to resolve a traffic conflict.

3.2 USE OF ACAS INDICATIONS

ACAS indications are intended to assist the pilots in the active search for, and visual acquisition of the conflicting traffic, and the avoidance of potential collisions. The indications generated by ACAS shall be used by pilots in conformity with the following safety considerations:

a) pilots shall not maneuver their aircraft in response to traffic advisories only;

Note 1.-- Traffic advisories are intended to assist in visual acquisition of conflicting traffic and to alert the pilot to the possibility of a resolution advisory.

Note 2.-- The above restrictions in the use of traffic advisories is due to the

limited bearing accuracy and to the difficulty in interpreting altitude rate from displayed traffic information.

- b) in the event of a resolution advisory to alter the flight path, the search for the conflicting traffic shall include a visual scan of the airspace into which own ACAS aircraft might manoeuvre;
- c) the alteration of the flight path shall be limited to the minimum extent necessary to comply with the resolution advisories;
- d) pilots who deviate from an air traffic control instruction or clearance in response to a resolution advisory shall promptly return to the terms of that instruction or clearance when the conflict is resolved and shall notify the appropriate ATC unit as soon as practicable, of the deviation, including its direction and when the deviation has ended.

Note.-- The phraseology to be used for the notification of manoeuvres in response to a resolution advisory is contained in the PANS-ATM (Doc 4444), Chapter 12.

(3) ICAO Annex 10

ICAO Annex 10 Volume Chapter 4 “AIRBORNE COLLISION AVOIDANCE SYSTEM” Attachment A “Guidance material related to airborne collision avoidance system (ACAS)” states as follows related to contrary pilot response (Excerpts):

- 3.5.8.10.3 Contrary pilot response. Manoeuvres opposite to the sense of an RA may result in a reduction in vertical separation with the threat aircraft and therefore must be avoided. This is particularly true in the case of an ACAS-ACAS coordinated encounter.

(4) PANS-RAC

PANS-RAC, as the supplement to Annex 2 and Annex 11, Part II states as follows related to the relation TCAS and ATC (Excerpts).

(Note that PANS-RAC have been amended as PANS-ATM from November, 2001, and the text as PANS-RAC Part X section 3.1.2 has been transferred to PANS-ATM Chapter 12 section 12.3.1.2.)

- 19.1 The procedures to be applied for the provision of air traffic services to aircraft equipped with ACAS shall be identical to those applicable to non-ACAS equipped aircraft. In particular, the prevention of collisions, the establishment of appropriate separation and the information which might be provided in relation to conflicting traffic and to possible avoiding action shall conform with the normal ATS procedures and shall exclude consideration of aircraft

capabilities dependent on ACAS equipment.

- 19.2 When a pilot reports a manoeuvre induced by an ACAS resolution advisory, the controller shall not attempt to modify the aircraft flight path until the pilot reports returning to the terms of the current air traffic control instruction or clearance but shall provide traffic information as appropriate.

Note 1.-The ACAS capability of an aircraft will not normally be known to air traffic controllers.

Note 2.-Operating procedures for use of ACAS are contained in PANS-OPS(Doc 8168), Volume 1, Part VIII, Chapter 3.

Note 3.-The phraseology to be used by controllers and pilots is contained in Part X, 3.1.2

2.14.1.3 Aircraft-A's Manuals

(1) OM SUPPLEMENT

The Operations Manual of Japan Air Lines is prepared in accordance with Japanese Aeronautical Laws Article 104. The OM SUPPLEMENT which supplements the Operation Manual states as follows (Excerpts):

(Tentative translation)

1. When a TCAS issues an RA, the pilot shall immediately comply with the RA unless he considers it unsafe to do so. The deviation from the authorized flight level shall be limited to the minimum extent necessary to comply with the RA.

Furthermore, the pilot shall notify the appropriate ATC unit of the compliance with the RA as soon as practicable, when the avoidance maneuver has been completed.

2. When the "Clear of Conflict" Advisory is issued by the TCAS, the pilot shall promptly return to the flight level instructed previously by ATC, unless ATC instructs a different flight level.

When the aircraft has returned to the flight level, he shall notify the appropriate ATC unit that he complied with an RA as soon as practicable.

(2) Operations Order

The Japan Air Lines Operations Order states as follows (Excerpts):

(Tentative translation)

The operation of TCAS

1. When TCAS is operated, TA/RA mode shall be engaged in all airspaces

under the view that TCAS is effective for the prevention of mid-air collisions.

3. The method executed when an RA is issued

In case that an RA is issued, the pilot shall notify the appropriate ATC unit of the compliance with the RA as soon as practicable using prescribed phraseologies when the avoidance maneuver has been completed, and when the flight is ended the pilot shall file the comment sheet in accordance with the Operations Order which is issued for every aircraft type,.

Filing of TCAS operation data

4. Others

- (2) In case that an RA is issued, the pilot shall notify the appropriate ATC unit of the compliance with the RA using the following phraseologies when the avoidance maneuver has been completed. (If necessary, the pilot may supplement using ordinary descriptions.)

As a note, the pilot shall notify the appropriate ATC only when deviating from the authorized flight level, and in principle it is not necessary to notify when a Preventive RA is issued.

Circumstances	Phraseologies
after modifying vertical speed to comply with an ACAS RA	TCAS CLIMB (or DESCENT)
after ACAS "Clear of conflict" is annunciated	RETURNING TO (assigned clearance)
after the response to an ACAS RA is completed	TCAS CLIMB(or DESCENT), RETURNING TO(assigned clearance)
after returning to clearance after responding to an ACAS RA	TCAS CLIMB (or DESCENT) COMPLETED (assigned clearance) RETURNED
when unable comply with a clearance because of ACAS RA	UNABLE TO COMPLY, TCAS RA

(3) AIRPLANE FLIGHT MANUAL

The Airplane Flight Manual (AFM) of Aircraft-A states the following (Excerpts):

CERTIFICATE LIMITATIONS

TRAFFIC ALERT AND COLLISION AVOIDANCE SYSTEM (TCAS) (If installed)

Pilots are authorized to deviate from their current ATC clearance to the extent necessary to comply with a TCAS resolution advisory.

NORMAL PROCEDURES

Compliance with a TCAS resolution advisory (RA) is necessary unless the pilot considers it unsafe to do so, or unless the pilot has better information about the cause of the RA and can maintain safe separation from a nearby aircraft, obvious TCAS system failure, etc.

CAUTION: Once an RA has been issued, safe separation could be compromised if current vertical speed is changed, except as necessary to comply with the RA. This is because TCAS? -to-TCAS coordination may be in progress with the intruder aircraft and any change in vertical speed that does not comply with the RA may negate the effectiveness of the other aircraft's compliance with the RA

NOTE: The consequences of not following an RA may result in additional RAs in which aural alert and visual annunciations may not agree with each other.

The pilot should not initiate evasive maneuvers using information from the traffic display only or on a traffic advisory (TA) only without visually sighting the traffic.

(4) AIRCRAFT OPERATING MANUAL

The Aircraft Operating Manual (AOM) is a supplement to the Operation Manual and is prepared for every aircraft type. It is usually referred to by flight crews. The AOM of Aircraft-A contains the following prescriptions (Excerpts):
(Tentative translation)

① Operating Limitations

Pilots are authorized to deviate from their current ATC clearance to the extent necessary to comply with a TCAS resolution advisory (RA).

② Non-Normal Maneuvers

Pilots shall carry out the following operations when a TCAS issues a Traffic Advisory (TA) or Resolution Advisory (RA).

Note: If “stick shaker” activation or “initial buffet” occur during avoidance maneuvers, pilots shall rapidly effect stall recovery procedures.

Note: If “high speed “ occurs during an avoidance maneuver, pilots shall reduce the pitch force in order to reduce the buffet while continuing the avoidance maneuver.

For RA (except CLIMB RA in Landing Configuration):

PF	PNF
If it is necessary to execute an avoidance maneuver, disengage an autopilot, and adjust control pitch angle and thrust to comply with the RA.	
Try to search for the other traffic visually. When the other traffic is sighted, call out to that effect.	

(5) AOM SUPPLEMENT

The following are excerpts from prescriptions in the AOM SUPPLEMENT Procedures and Techniques under Warning Systems in the section titled “A vertical avoidance maneuver when a TCAS issues an RA”.

(Tentative translation)

- Disengage the autopilot.
- Operate the aircraft in accordance with RA Pitch Guidance Command on the PFD, such that the Airplane Symbol on the PFD should be just outside of the Red Line.
- While an RA is being issued, the PF should firstly concentrate on the RA avoidance maneuver on the PFD, and other crewmembers in the cockpit should search for the other traffic visually comparing with the TCAS display until “Clear of Conflict” is announced (if possible).

However, crewmembers should consider that other traffic sighted may not always be the intruder aircraft, and there may be cases in which more than one intruder is indicated by TCAS.

Further, the section “TCAS Vertical Guidance on PFD” states as follows related to the TCAS function for complementing each other (Excerpts):

(Tentative translation)

In case that the TCAS equipped in the intruder is also engaged, TCAS Vertical Guidance operates coordinating with the intruder's TCAS.

2.14.1.4 Aircraft-B's Manuals

(1) The OM SUPPLEMENT and Operations Order applied to Aircraft-B are omitted here, since these manuals are the same as those of Aircraft-A.

(2) AFM

The AFM of Aircraft-B states as follows (Excerpts):

(Tentative translation)

Chapter I CERTIFICATE LIMITATIONS

Pilots are authorized to deviate from their current ATC cleared altitude to the extent necessary to comply with a TCAS resolution advisory.

Chapter III NORMAL PROCEDURES

Compliance with a TCAS resolution advisory (RA) is necessary unless the pilot considers it unsafe to do so, or unless the pilot has better information about the cause of the RA and can maintain safe separation from a nearby aircraft, obvious TCAS system failure, etc.

CAUTION: Once an RA has been issued, safe separation could be compromised if current vertical speed is changed, except as necessary to comply with the RA. This is because TCAS II-to-TCAS II coordination may be in progress with the intruder aircraft and any change in vertical speed that does not comply with the RA may negate the effectiveness of the other aircraft's compliance with the RA

NOTE: The consequences of not following an RA may result in additional RAs in which aural alert and visual annunciations may not agree with each other.

In addition, Aircraft-B's AFM states as follows as general matters:

It is considered that TCAS is operated as a back-up for the general rule of "SEE-AND-AVOID" and air traffic control with ATC Rader.

(3) AOM

Aircraft-B's AOM states as follows (Excerpts):

(Tentative translation)

When an RA is issued

(1) Execute the avoidance maneuver rapidly and smoothly in accordance with the instruction of RA/VSI.

(2) Try to search other traffic visually comparing with the Traffic Display.

NOTE (1) If an avoidance maneuver is necessary, disengage an autopilot.

And then, do not comply with the Flight Director “Pitch Command”.

(4) AOM SUPPLEMENT

Aircraft B's AOM SUPPLEMENT states as follows (Excerpts):

(Tentative translation)

1. TCAS

(1) GENERAL

If the intruder is equipped with TCAS (except TCAS-I that issues only TAs), the TCAS systems on each aircraft coordinate automatically through the Mode-S Transponder and each issues a RA that is in the opposite direction (descend or climb) to the other.

(2) Supplemental explanation to TCAS Operation

b. when an RA is issued

- The PF informs other crew member that he is carrying out an avoidance maneuver, and executes the necessary avoidance maneuver after disengaging the A/P.
- The PNF visually searches for the traffic comparing with Traffic Display, and checks that the vertical rate is kept within the RA instruction.

2.14.1.5 Regulations applied to air traffic control

“Air Navigation Regulations Work Chapter 5 Air Traffic Control Regulations I Air Traffic Control Procedures” describes the methods, limitations, phraseologies, etc. on which the performance of ATC duties by air traffic controllers is based.

Descriptions related to TCAS added by KU-SEI No.412 (which was amended on December 27, 1995.) are as follows (Excerpts):

(Tentative translation)

Actions in accordance with Resolution Advisory

When a pilot informs that the aircraft is complying with an RA, air traffic controllers should advise air traffic information to the aircraft concerned and to other related aircraft to the extent possible. Air traffic controllers can issue ATC instructions after confirming some of the following.

- a The aircraft has returned to its clearance after executing the avoidance maneuver

- b The aircraft informs that the avoidance maneuver has ended, and safe separation between the aircraft and the other traffic is ensured

In addition to the above, the “Supplemental works”, which is defined to be executed within feasible purview with considering the operation of instruments, the volume of traffic and the volume of communication, states as follows regarding the response of air traffic controllers to close approach between aircraft (Excerpts): (Tentative translation)

- (1) The response in case that there is a potential danger of mid-air collision

If there is a concern that an aircraft (except for aircraft holding) on radar display may collide with another target traffic information of the latter shall be notified to the former unless it is obvious that the vertical separation between this aircraft and the other aircraft is greater than the minimum safe separation.

- (2) The avoidance maneuver

If an aircraft which has received radar traffic information requests a maneuver to avoid the other aircraft, instruct this aircraft so as not to collide with the other aircraft, but if this request can not be accepted, notify the aircraft to that effect.

2.14.1.6 U.S.A. Regulations

The U.S.A., took the lead in the world by mandating installation of TCAS by Federal Aviation Regulations (FAR) from December 31, 1993. The Federal Aviation Administration (FAA) issued Advisory Circular 120-55A “AIR CARRIER OPERATIONAL APPROVAL AND USE OF TCASII” (referred to as “AC” below) related to TCAS operations at the occasion of introduction of TCAS, and subsequently amended the AC with reference to later experiences.

The AC specifies a wide range of matters related to TCAS in detail, for example, authorization of TCAS operation, method of TCAS operation, education and training for flight crew about TCAS, preparation of TCAS, RA report, etc.

AC section 11 “TCAS OPERATIONAL USE” subsection c “The Potential Consequences of Improperly Maneuvering the Aircraft in Response to an RA Include:” states as follows (Excerpts):

- (3) ATC may not know when TCAS issues RA's. It is possible for ATC to unknowingly issue instructions that are contrary (opposite) to the TCAS RA indications. Safe vertical separation may be lost during TCAS coordination when one aircraft maneuvers opposite the vertical direction indicated by TCAS and the other aircraft maneuvers as indicated by TCAS.

As a result, both aircraft may experience excessive altitude excursions in

"vertical chase" scenarios due to the aircraft maneuvering in the same vertical direction.

Accordingly, during an RA, do not maneuver contrary to the RA based on ATC instructions.

And AC section 11 "TCAS OPERATIONAL USE" subsection b "Pilot Responsibilities" states as follows related to the PNF's responses when an RA is issued and notification to air traffic control facilities during an avoidance maneuver in accordance with an RA:

- (5) The non flying pilot should advise the pilot flying when there is a deviation from the vertical flight path indicated by TCAS. The non flying pilot, and any onboard observers, also, will assist in the visual search for the intruder, and continue to cross-check the TCAS displayed information with other available traffic information to ensure the RA response is being flown correctly.
- (10) In responding to a TCAS RA that directs a deviation from assigned altitude, communicate with ATC as soon as practicable after responding to the RA.

2.14.1.7 European Regulations

(1) Joint Aviation Authorities (JAA) Regulations

The JAA, which has been established cooperatively by European Nations, has enacted Joint Aviation Requirements (JAR).

Every member nation of JAA takes standards and procedures prescribed in JAR into their domestic regulations, and maintains and operates aircraft in accordance with these standards and procedures.

In JAR, JAR-OPS are the regulations for aircraft operations

JAR prescribe that all turbine-engined airplanes of maximum certificated take-off mass in excess of 15,000kg or authorized to carry more than 30 passengers shall be equipped with a TCAS from January 1, 2000. And JAR-OPS section 1.398 "Use of ACAS" states as follows related to TCAS.

An operator shall establish procedures to ensure that:

- (a) When ACAS is installed and serviceable, it shall be used in flight in a mode that enables Resolution Advisories (RA) to be produced unless to do so would not be appropriate for conditions existing at the time.
- (b) When undue proximity to another aircraft (RA) is detected by ACAS, the commander or the pilot to whom conduct of the flight has been delegated shall ensure that corrective action is initiated immediately to establish safe

separation unless the intruder has been visually identified and has been determined not to be a threat.

(2) U.K. Regulations

As mentioned above, every member nation of JAA enacts its aviation regulations based on JAR.

In the U.K., a member nation of JAA, the obligation to install TCAS on an aircraft is prescribed in the Air Navigation Order (ANO) in the same terms as the JAR.

The publication CAP 579 is issued as a guidance material of ANO concerning TCAS operations. CAP 579 sections 6.2.2 and 6.2.4 state as follows:

6.2.2 Pilots are to initiate the required manoeuvre immediately, adjusting flight path, aircraft power and trim accordingly. Crewmembers not involved in executing this manoeuvre should confirm that the sky ahead is clear of other traffic and continue the visual search for the established threat. They are to inform ATC as soon as possible of any deviation from an air traffic control clearance.

6.2.4 Manoeuvres should never be made in a direction opposite to that given in an RA; this is because the sense may have been determined following an exchange of data with the established threat. For this reason;

- (a) RAs may be disregarded only when pilots visually identify the potentially conflicting traffic and decide that no deviation from the current flight path is needed.
- (b) If pilots receive simultaneously an instruction to manoeuvre from ATC and an RA, and both conflict, the advice given by ACAS should be followed.

2.14.2 Training for TCAS procedure

2.14.2.1 Training for flight crewmembers

Japan Air Lines's Operations Manual (OM), "Operational procedures (bylaws) 5-7, TCAS operational requirements for a captain and a first officer" states that both captains and first officers shall complete the prescribed training prior to their TCAS operations.

In addition, the same company's Qualification Manual (QM), "9-7, Training of TCAS operations" requires captains and first officers to receive qualifying training and recurrent training.

(1) Details of qualification training and its implementation

① Training details

According to the QM, the training details are roughly as follows:

- a System explanation (system components, application methods, displayed contents, indication of audio warnings, operating limitations, relationships with the other systems)
- b Actions in response to TCAS advisories
- c Related information (relationships between TCAS “RA” advisory and pilot’s judgment formed by visual contact, limitations described in the Airplane Flight Manual, communications with ATC controllers concurrent with TCAS activation, subsequent return to the terms of the previous ATC clearance, etc)
- d Functioning conditions in the line operations
- e Quiz (knowledge test)

The teaching materials and training periods are:

- a – c — slides and a system study guidebook, for 60 minutes,
- d — CBT or video (*), for 50 minutes,
- e — CBT or AVT(*), for 50 minutes.

(*) only for B767 and B747-400

- ② The flight crews (including trainees, but excluding the flight engineer) of Aircraft-A and Aircraft-B had completed all of the above-mentioned TCAS qualification training.

(2) Details of recurrent training and its implementation

① Recurrent training details

According to the QM, the outlines of the contents of recurrent training are roughly as follows:

- a Briefings on actual occurrences in the line operations
 - b System improvements
 - c Improvements in methods of applications and operational procedures
- Training courses on these subjects are to be completed in recurrent ground training, and a knowledge test is completed in recurrent flight training.

The recurrent training details are summarized below.

In addition, training for an encounter between two TCAS-equipped aircraft had been fulfilled; however, there was no concrete lesson about the risk of pilot’s failure to follow RA advisories.

- a The flight crew of Aircraft-A had completed the training by the use of a flight simulator with a simulated TCAS system. An outline of the training is summarized as follows:

(a) Briefing

- An instructor gives a briefing along with the flight curriculum.
- With regard to the TCAS, the briefing places emphasis on flight maneuvering.

(b) Simulator training

- Simulator training is to be accomplished in keeping with a ridge-shaped flight pattern originated under Pilot Flight Training Guide.
- Evasive maneuvers are to be initiated using the simulator programmed to activate the TCAS with the situation of “conflicting with a nearby aircraft”.
- Either a low altitude flight maneuver or a higher altitude maneuver (5,000ft or 11,000ft) is to be chosen by the instructor at his discretion.

- b The flight crew of Aircraft-B had completed the training by the use of flight simulator that was not equipped with a simulated TCAS system. An outline of the training is summarized as follows:

(a) Briefing

- The teaching materials on a company-produced TCAS video are to be reviewed.

The following are details of other items:

- Verifying the parameters and conditions related to TCAS activation (functioning conditions of TA/RA, reaction time prior to initiating maneuvers, G-values, pitch rate, conditions of inhibiting RA).
- An example of model maneuvering (e.g. while cruising at 8,000ft, a climbing opponent aircraft nears toward a head-on collision course, and thus an RA “Climb” warning ensues, during which escape action is to be taken).

(b) Simulator training

- Simulator training is to be accomplished in keeping with a ridge-shaped flight pattern originated under the Pilot Flight Training Guide.
- With audible TA/RAs, an evasive action is to be taken responding to

the advisories.

- Either low altitude flight maneuver or higher altitude (33,000ft) maneuver is to be chosen by the instructor at his discretion.

② Implementation status

With regard to the recurrent ground training, the captains and the first officers of both Aircraft-A and Aircraft-B had completed training on evasive action involving TCAS advisories.

The trainee pilot of Aircraft-A, who was training for upgrade to first officer, had completed an instruction session by the use of CBT and video materials.

(3) TCAS instruction by the use of video

Japan Air Lines' recurrent training has classes on contemporary study subjects in every year. In 1998, the TCAS-specific class had been held by the use of video demonstrating concrete details on the following items:

- ① Overview, compulsory equipment
- ② Contents of AIC published by the Civil Aviation Bureau
- ③ Function of cross-checked TCAS-to-TCAS coordination
- ④ Risk of maneuvers contrary to an RA advisory based on ATC instructions
- ⑤ Specific past examples of taking evasive actions
- ⑥ Standard maneuvering

The captains of both the aircraft and the first officer of Aircraft-B had taken the chance to attend the class.

2.14.2.2 Training for Air Traffic Controllers

(1) Status of TCAS training for Air Traffic Controllers

With the addition of TCAS procedures to "Standards for Air Traffic Control Procedures", training for controllers on TCAS function, capabilities and involvement with ATC services has been given at the Aeronautical Safety College and at the college's Iwanuma Branch.

The Aeronautical Safety College has provided a classroom lecture and practical training for new members, and given a 1-hour classroom session both in initial training and in a regular course from fiscal 1998 onward.

The Iwanuma Branch of the college has provided a TCAS course for trainees who have obtained the required qualifications at their appointed place of work, and has also given an 1.5-hour classroom session in the specialized training for

both air route radar controllers and terminal radar controllers from fiscal 1995 onward.

(2) Implementation status of TCAS training for controllers

At the time of the accident, the training controller had received air route radar training that included the TCAS lecture (1.5-hour) referring to a general outline of the system using teaching materials on video (Ref. 2.14.2.3) at the Iwanuma Branch.

Although the training supervisor and the coordinator who were also on duty at the Kanto South C sector at the time of the accident had had the opportunity to examine technical magazines which contained accounts of the TCAS, there had been no briefing sessions or the like at their appointed place of work.

(3) Training status in the USA

Regarding the education and training of controllers, the FAA published a booklet of TCAS which states, in part:

Controller Training Programs

While controllers do not use TCAS II, they need to be aware of its presence, capabilities, and limitations while performing their responsibilities. The controller training should be similar to the classroom training provided to pilots, but supplemented with material that demonstrates advisories that have had both positive and negative impacts on the control and traffic situation.

2.14.2.3 Study materials compiled by the aircraft manufacturers

Flight crewmembers were to view teaching materials of TCAS on video (Flight crew briefing: 1993) compiled by the aircraft manufacturers.

In addition, controllers had been given lectures at the Aeronautical Safety College from fiscal 1998 onward, and at the IWANUMA Branch from fiscal 1995 onward using the same TCAS video.

The video presentation is roughly as follows:

- (1) The purpose of the TCAS system and the history of its development
- (2) The operation of the TCAS equipment and associated display units
- (3) Maneuvers in responding to TCAS advisories
- (4) Procedural points to be noted

Moreover, the video visually demonstrates the following that should be regarded as points implicitly related to the accident in question.

- (1) TCAS assists the pilots in visual acquisition of conflicting traffic, and serves as backup to the ATC system for providing traffic separation.

- (2) The TCAS computer communicates with other transponder-equipped aircraft.
- (3) TCAS is capable of providing information on several conflicting aircraft.
TCAS exchanges data with nearby aircraft and, if necessary, issues an RA after mutual coordination.
- (4) If an RA is issued during a circling maneuver, it is not necessary to alter the flight path since TCAS is only able to give guidance on pitch adjustment.

3 ANALYSIS

3.1 General

3.1.1 Aircrew Certificates and Medical Certificates

- (1) The Captains and FOs of both aircraft, the Flight Engineer of Aircraft-B and the pilot-under-training of Aircraft-A had valid aircrew proficiency certificates and valid aircrew medical certificates.
- (2) The ATC trainee under OJT, the ATC watch supervisor and the radar coordinator controller had the requisite ATC certificates and valid medical certificates.

3.1.2 Certificates of Airworthiness

Both aircraft had valid certificates of airworthiness, and had been maintained and inspected as specified by the applicable regulations.

3.1.3 Weather Conditions

It was determined that the weather conditions at the time of accident were visual meteorological conditions with good visibility; therefore the flight crewmembers of both aircraft would have been able to make mutual visual contact.

3.2 Analysis of flight

3.2.1 The history of occurrence of the accident

It is supposed that the history of occurrence of this accident, based on DFDR records, ACMS records, AIDS records, TCAS records, Air Traffic Control communication and radar records, and the statements of the flight crews, cabin crews and air traffic controllers, is as follows:

On 31 January 2001, Aircraft-A took off from Tokyo International Airport for Naha Airport as Japan Airlines scheduled flight 907. After taking off, Aircraft-A continued to YAIZU under IFR, and was climbing to FL390 in accordance with an instruction by Tokyo ACC. Four flight crewmembers were in the cockpit of Aircraft-A: the Captain, the First Officer and two pilots training for first officer.

Aircraft-B, operating as Japan Airlines scheduled flight 958, was cruising at FL370 to the west of Aircraft-A towards New Tokyo International Airport. Three flight crewmembers were in the cockpit, namely the Captain, the First Officer, a pilot training for upgrade to Captain and the Flight engineer.

Three air traffic controllers were on duty at the Kanto South C sector of Tokyo ACC, namely an air traffic controller undergoing on-the-job training (OJT) for familiarization with the sector, the ATC watch supervisor and a coordinator.

At around 1547:47, an air traffic controller of Kanto South C sector input a

command into the Radar Data Processing System (RDP) to receive the hand over of control of Aircraft-B from an adjacent sector. At 1548:14, Aircraft-B called Kanto South C sector to establish a communication with ATC, and the sector responded at 1548:18.

Meanwhile, Aircraft-C was cruising to the west and south of Aircraft-A at FL390, which was the same as the planned flight level assigned to Aircraft-A, and the planned flight path of Aircraft-C crossed that of Aircraft-A. As it was possible that Aircraft-C would approach closely to Aircraft-A if Aircraft-C continued to cruise along its flight path, the ATC trainee at Kanto South C sector called Aircraft-C, which had already completed radar hand-off from an adjacent sector, twice at 1547:02 and at 1547:56. However, Aircraft-C did not respond because the sector had not yet established communication with the aircraft. At 1548:22, an air traffic controller at Kanto South B sector, which had been communicating with Aircraft-C up until that time, instructed Aircraft-C to change radio frequency to Kanto South C sector.

At 1548:37, Aircraft-C contacted Kanto South C sector and informed that its altitude was FL390, and the ATC trainee instructed it to descend to FL350.

At around 1553:50, Aircraft-A began to make a slow left turn above the sea off Yaizu City. At Tokyo ACC, the ATC watch supervisor was giving comments to the ATC trainee about the tasks performed up to that time. It was in this situation that the CNF alert, which warns of close approach between aircraft, appeared on the radar display of Kanto South C sector at Tokyo ACC at 1554:15.

At 1554:18, a traffic advisory (TA) alert, which indicates the proximity of another aircraft, was indicated on the TCAS display of Aircraft-B, advising it of the presence of Aircraft-A.

At 1554:19, a TA advising of the presence of Aircraft-B was indicated on the TCAS display of Aircraft-A.

Between 1554:27 and 1554:32, Tokyo ACC instructed Aircraft-A to descend to FL350 immediately due to traffic. However, the controller had mistaken the flight numbers of Aircraft-A and Aircraft-B, and had actually intended the instruction for Aircraft-B.

Although Aircraft-A read back the instruction and stated its flight number, neither the ATC trainee nor the ATC watch supervisor noticed that the flight number in the read back was that of Aircraft-A, not that of the intended Aircraft-B.

At 1554:34, Aircraft-B's TCAS changed the TA to a resolution advisory (RA) alert, commanding a descent.

At 1554:35, just after the crew of Aircraft-A began operations to make it descend, the TCAS on Aircraft-A changed the TA to an RA commanding a climb.

Between 1554:38 and 1554:41, the ATC trainee instructed Aircraft-B to turn to

130°, but Aircraft-B did not respond to this instruction.

At around 1554:40, Aircraft-A reached to the top its climb, and after around 1554:41, its altitude began to decrease.

At 1554:49, Aircraft-B's TCAS issued an increase RA, indicating to increase the rate of descent. At the same time, the TCAS display showed a downward arrow beside the symbol corresponding to Aircraft-A, indicating that Aircraft-A was descending.

Because Aircraft-B had not responded to his earlier turn instruction, at between 1554:49 and 1554:52 the ATC trainee instructed Aircraft-B to turn to a heading of 140°. Aircraft-B did not respond to this instruction.

At 1554:54, a downward arrow was indicated beside the symbol of Aircraft-B on Aircraft-A's TCAS display, showing that Aircraft-B was descending.

At 1554:55, the ATC watch supervisor took over from the ATC trainee, and instructed JAL957 to descend, but there was no corresponding aircraft in the sector.

Aircraft-A and Aircraft-B continued to descend to almost same altitude, while approaching each other.

Between 1555:02 and 1555:05, before the paths of both aircraft crossed, the ATC watch supervisor instructed Aircraft-A to climb to FL390, but Aircraft-A did not respond.

At 1555:06, Aircraft-A's TCAS issued an increase RA to increase the rate of climb, but Aircraft-A continued to descend.

At around 1555:05, just before the aircraft crossed, the angle of Aircraft-B's control columns moved from pitch down to pitch up, and Aircraft-B ceased to descend. The time of closest proximity between the aircraft was around 1555:11, and Aircraft-A passed under Aircraft-B. The point of closest proximity was above the sea about 7 nm (about 13 km) south of Yaizu NDB at between 35,500 ft and 35,700 ft.

Because Aircraft-A pitched down around the time that the aircraft crossed, and afterward pulled up, its vertical acceleration varied considerably between positive and negative. Consequently, persons and objects were tossed and fell, and as a result many persons were injured and ceiling panels etc. in the cabin were damaged. On the other hand, the vertical acceleration of Aircraft-B increased but remained positive, so there were no injuries to the passengers or crew and no damage to the cabin.

After passing by Aircraft-B, Aircraft-A notified to Tokyo ACC that the risk of collision had been averted. Afterward, Aircraft-A requested to Tokyo ACC to turn back to Tokyo International Airport, as there had been injuries, and after receiving clearance returned to the airport.

After passing by Aircraft-A, Aircraft-B notified to Tokyo ACC that it had descended in response to an RA, and was climbing back to its previously cleared altitude.

Aircraft-B subsequently landed at New Tokyo International Airport.
(See Attachment 2 for details of the flight history)

3.2.2 Analysis of the Air Traffic Control System

3.2.2.1 Flight Strips of Aircraft-A and Aircraft-B, and Advance Forecast

Aircraft-A and Aircraft-B were flying under the control of the air traffic controllers handling Tokyo ACC's Kanto South C sector.

Normally when an aircraft takes off, its flight strip is printed out by a printer at the air traffic control console of each sector, and is then arranged in the console's strip rack. When a newly printed-out flight strip is sorted into the rack and inserted between other strips already arranged in it, then by comparing the estimated time and altitude of passing over a waypoint (fix) printed on the strip with information on the strips of other aircraft, the controller can estimate the possibility of confliction between the aircraft and other aircraft.

The strips are "posted" to the rack by the sector's coordinator, as would have been done for Aircraft-A and Aircraft-B. At the time of inserting Aircraft-A's strip in the rack, it would have been compared with the strip of Aircraft-B, and this is thought to be an effective method of evaluating the possibility of confliction between two aircraft. By the coordinator's annotating ("marking") the strip, it should be possible to bring things to the attention of the radar controller in advance, but such tasks were not specified as procedures and it is considered that they were not carried out in actuality either. (Refer to Appendix 3.)

3.2.2.2 The ATC instruction to Aircraft-A to climb to FL390

As stated on the section 2.1.1, although Aircraft-A had been assigned a cruising altitude of FL390 at the time of ATC departure clearance, while Aircraft-A was climbing towards the cruising altitude, at 15:45:25 JST the ATC trainee instructed it to climb to and maintain FL350 for the interim.

At that time, the data block of Aircraft-C was displayed on PVD of Kanto South C sector, and was in the "radar point out" state (transfer of a radar target with which radio contact has not yet been established by the sector).

Aircraft-C's flight planned route did not pass through Kanto South C sector, but was to have passed over Miyake Island to the south of Kanto South C sector, over the sea south of Kushimoto, Wakayama Prefecture, then to its planned destination of Kansai International Airport. However, during the flight through Kanto South B sector, it was instructed by ATC to fly direct to Kushimoto. This took Aircraft-C north of its planned route, passing 10 miles south of the island of Oshima, and took it

through Kanto South C sector. Prior to the volcanic eruption of Miyake Island, even in the event that a short cut route was assigned, there was a route from Miyake Island direct to Kushimoto and then on to Kansai International Airport, and so there was need to pass through Kanto South C sector.

It is thought that the reason Aircraft-C, initially flying at FL390, was in the “radar point out” state was because there was no aircraft in confliction with it. After Aircraft-A took off from Tokyo International Airport at 15:36, it is considered that ATC trainee assigned FL350 as its cruising altitude because he considered the possibility of confliction with Aircraft-C.

In verbal statements, the ATC trainee stated that because Aircraft-C had commenced its descent, he issued the instruction to Aircraft-A to climb to FL390, but it is considered he issued the ATC instruction to climb to FL390 to the Aircraft-A at 15:46:38 without a command having been issued to descend Aircraft-C. Regarding the relationship between Aircraft-A and Aircraft-C, the reason for this is thought to be that as the coordinator had negotiated with controller of Kanto South C sector to allow Aircraft-A to climb to FL390, the trainee judged that it was possible to climb Aircraft-A. The coordination to allow Aircraft-A to climb was not found on the recordings of the console communications, including direct lines, but because the coordinator stated that he had received this sort of coordination request from the Kanto South B sector and that he had verbally informed the radar AG controller, it is considered that this coordination was carried out between the adjacent sectors by talking directly.

However, at this time Aircraft-C continued cruising at FL390 without changing altitude. For this reason, as described in section 3.2.2.4, at this time Aircraft-C had already changed from “radar point out” to “radar hand off” and the trainee was pressed to establish radio contact with it and make it descend. At this time Aircraft-B is still considered to have been outside Kanto South C sector’s airspace.

3.2.2.3 Radar hand off of Aircraft-B, Entry to the strip and Establishment of Radio Communication

- (1) At 15:46:51, because the adjacent sector initiated for radar hand off of Aircraft-B, the letters “HND” were displayed in the data block of Aircraft-B of Kanto South C sector’s PVD and began to flash. At 15:47:47 Kanto South C sector made a computer operation to receive the hand off of Aircraft-B, and as a result the display of “HND” in the data block changed to “OVR”, and subsequently disappeared. Also, the reception of the radar hand off of the Aircraft-B and the establishment of radio communication as mentioned in (2) below, were manually

recorded on Aircraft-B's flight strip.

Generally, at a time of a radar hand off or establishing radio communication with an aircraft, the controller examines on the PVD possible conflicts with other aircraft which may cross its flight path in the next few minutes. Controllers usually handle a few tens of aircraft simultaneously, and at this stage cannot foresee the possibility of conflicts. If they do not have time later to reexamine the possibility of conflicts with other aircraft, it is considered that they will pay less attention to aircraft judged as having no conflicts.

- (2) According to ATC communication records and ATC radar records, Aircraft-B called Kanto South C sector at 15:48:14 to establish radio contact, and Kanto South C sector responded to this call at 15:48:18 and radio communication was established. At this time Aircraft-B was about 75 nm (about 140km) west of the CPA with Aircraft-A and flying east at FL370.

At this time Aircraft-A was flying west about 50 nm (about 90km) east-northeast of the CPA with Aircraft-B, climbing through FL230. Given the positions of both aircraft at this moment, it is considered that a controller aware of Aircraft-B could have predicted a possible conflict between it and with Aircraft-A, but could not normally judge that Aircraft-A and Aircraft-B would approach closely.

3.2.2.4 The forgetting of the presence of Aircraft-B by the ATC trainee

Generally, radar hand off is a simple mechanical operation and habitual to a controller. The controller confirms the flight route and destination of the aircraft received by the hand off, then by examining its relationship with other aircraft fixes it in his consciousness. There is a further opportunity to examine the aircraft's relation with other traffic when receiving its radio call to establish contact after the hand off, and it is considered that this further reinforces the controller's awareness of the aircraft.

Considering the radar hand off of Aircraft-B, the establishment of radio communication with it, and subsequent control duties, the following possibilities are thought to have contributed to the ATC trainee forgetting about the presence of Aircraft-B until the CNF alert:

- ① Normally, a controller will fix aircraft that enter the airspace for which he or she has responsibility at the time of radar hand off and at the establishment of radio contact. Because radar hand off is a mechanical operation which is routinely and habitually carried out by controllers in the course of their duties, the trainee did not confirm the position and other details of Aircraft-B when carrying out this operation, and the presence of Aircraft-B was not fixed in his memory.

- ② The radar hand off and the establishment of radio communication with Aircraft-B was noted on its flight strip, and the ATC trainee responded properly to Aircraft-B's radio call.

However, as mentioned in section 3.2.2.2 above, prior to this the ATC trainee had issued an instruction to Aircraft-A to climb to FL390, although Aircraft-C was continuing in cruise at FL390. At around this time, therefore, the ATC trainee was pressed by the need to establish radio communication with Aircraft-C, the state of which had already changed from radar point out to radar hand off, and to descend it.

The ATC trainee issued a descent instruction to Aircraft-C at 15:47:02, by which time radar hand off had already completed, and called it again at 15:47:56, but as he had not established radio communication with it, there was no response on either occasion. After that, at 15:48:22, the controller of Kanto South B sector, who had been in contact to Aircraft-C up to that time, instructed Aircraft-C to change frequency to Kanto South C sector. Consequently, Aircraft-C called to establish radio communication at 15:48:37 and the ATC trainee immediately ordered it to descend to FL350, which Aircraft-C acknowledged.

In this way, because the radar hand off and establishment of radio communication with Aircraft-B was conducted after the ATC trainee instructing Aircraft-A to climb to FL390 and during the period between his first attempt to establish radio contact with Aircraft-C and his instructing it to descend, his attention was focused on Aircraft-A and Aircraft-C, and he did not pay sufficient attention to grasping the position of Aircraft-B on the PVD and evaluating the presence or absence of conflicting traffic.

- ③ The ATC trainee had communicated with Aircraft-D (JAL Flight 952) which had a similar flight number to Aircraft-B (JAL Flight 958) just before he established radio contact with Aircraft-B. After Aircraft-D had been in the airspace of Kanto South C sector for about 20 minutes, the ATC trainee instructed it to contact Narita Approach. Immediately thereafter, Aircraft-B called Kanto South C sector to establish radio communication. Thus, when the ATC trainee received the call from Aircraft-B, he confused its flight number with that of Aircraft-D and so was not able to become aware of it.
- ④ Just after the ATC trainee was called by Aircraft-B and had responded it, he received a call to establish radio contact from another aircraft. As a result, he did not have sufficient time to ensure the position of Aircraft-B on the PVD.
- ⑤ Around this time, the ATC trainee made and received ten radio communications in the space of one minute. The action to check for the presence or absence of

conflicting traffic is carried out in the interval between radio communications, but this would have been difficult at the time that of establishment of communication with Aircraft-B.

However, after that, there were several 5 to 10 minutes periods in which there were no communications, and given that the ATC trainee who worked under the watch of his ATC watch supervisor was already qualified to carry out air route radar control service for the West Kanto sector, it is considered that the situation at the time of radar hand off of Aircraft-B and the establishment of radio contact with it was not beyond his traffic handling capability.

- ⑥ As mentioned in section 3.2.2.6 below, following the events above, the ATC trainee was unable to pay sufficient attention to reconfirming the traffic situation on the PVD during the time when the level of communications with aircraft was reduced because he was receiving an explanation of his work performed up to that time from his ATC watch supervisor.

3.2.2.5 The forgetting of the presence of Aircraft-B by the ATC watch supervisor

As described in section 3.2.2.2 below, at the time it was judged that there was a high risk that separation between Aircraft-A with Aircraft-C would be lost, Aircraft-A had been assigned to maintain FL350 provisionally but Kanto South C sector's coordinator and the controllers of Kanto South B sector in charge of the air space to the east and south of Kanto South C sector coordinated to allow Aircraft-A to climb to FL390, and it is considered that the ATC trainee instructed Aircraft-A to climb to FL390 to at 15:46:38.

After that, however, according to transcript of ATC communications, while Aircraft-C continued without changing altitude, at this time the coordinator performed a lot of tasks to coordinate with another ATC facility. Given this situation, it is considered possible that in order instruct Aircraft-C to descent, the ATC watch supervisor herself coordinated with Kanto South B sector to change Aircraft-C from radar point out to radar hand off. This coordination for radar hand off of Aircraft-C was not retained on the transcript of ATC communications, but because the control suite of Kanto South B sector, with which Aircraft-C was in contact until that time, is located immediately to the right of the Kanto South C sector suite, it is considered that this coordination was performed by talking directly without using the direct line.

At 15:47:02, the Kanto South C sector had already received radar hand off of Aircraft-C, which continued at FL390, at the time the ATC trainee first instructed it to descend to FL350. However, Aircraft-C did not call Kanto South C sector to

establish radio contact until 15:48:37. The reason for this is considered to be that Kanto South B sector's instruction to Aircraft-C to change frequency to Kanto South C sector was delayed until 15:48:22.

Whilst these tasks in relation to Aircraft-C were being performed, at 15:46:51 the adjacent sector to the west of Kanto South C sector initiated hand off of Aircraft-B, and Kanto South C sector initiated operations to receive this hand off at 15:47:47. Aircraft-B called with Kanto South C sector to establish radio contact at 15:48:14. Since the radar hand off of Aircraft-B the establishment of radio contact with Aircraft-B it occurred while the ATC watch supervisor was pressed to coordinate with Kanto South B sector regarding communication with Aircraft-C, it is considered that a situation resulted in which her attention left the PVD and control communications, and she forgot the presence of Aircraft-B.

As mentioned in section 3.2.2.6, subsequently, at the time when the level of communications with aircraft had subsided, the ATC watch supervisor explained the work which had been carried out up to that time to the ATC trainee, but it is considered that because during that time she did not reconfirm the air traffic situation on the PVD, she remained in the state of having forgotten about Aircraft-B.

3.2.2.6 The period in which the ATC watch supervisor carried out the explanation to the ATC trainee

Given that transcript of ATC communications show that the level of radio traffic gradually reduced from around 15:52, and the ATC watch supervisor's statement of "When the air traffic flow was orderly, I carried out explanation to the ATC trainee", it is considered at that time the air traffic flow was fairly orderly. There were four communications between 15:52 and just after 15:54, when the CNF alert was issued, and it is considered that the ATC watch supervisor's explanation about the work which had been carried out up to that time was made between these communications.

It is estimated that at that time, the ATC watch supervisor and ATC trainee made to reconfirm the air traffic situation on PVD, and working to re-acquire the traffic situation afresh, they would have been able to look for the presence of conflicting traffic, but because they did not do so, they remained in the state of having forgotten about Aircraft-B.

Furthermore, there were no air traffic control standards, procedures etc. relating to the rights and wrongs of ATC watch supervisors giving explanations to controllers while undergoing OJT, the aspects of the air traffic situation that must be explained, important notices at the time of explanation, the methods of explanation etc.

3.2.2.7 The situation at time of the CNF alert

According to his statement, the ATC trainee first became aware of the presence Aircraft-B when the CNF alert appeared on the PVD, and he then understood that Aircraft-A and Aircraft-B were gradually approaching each other.

At the time that the CNF alert was issued at 15:54:15, DFDR data etc. show that Aircraft-A was climbing through FL369 and Aircraft-B continued in level flight at FL370.

The time when the specified 5 nm separation was lost is estimated to have been at around 15:54:49. Given that CNF is specified to issue an alert three minutes before separation between converging aircraft is lost, the alert would normally be expected to have been issued at around 15:51:50. The reason that the CNF alert was delayed by about 2.5 minutes from the expected time was due to Aircraft-A's left turn just before Yaizu NDB, the proximity of the projected trajectories of Aircraft-A and Aircraft-B calculated by air route radar data processing system only first became less than the value described in section 2.12.4.2 at this time.

Considering the time necessary for ATC communications, the time for the aircraft to react to control inputs by the flight crew, etc., under the situation at the time of CNF alert it would already have been very difficult to enforce the specified separation (5 nm lateral separation, 2,000 ft vertical separation). It is therefore thought likely that the ATC trainee, who had forgotten the presence of Aircraft-B, would have been psychologically unsettled under this urgent situation.

According to the transcript of ATC communications, at 15:54:22 ATC trainee attempted to call Aircraft-A, and by this time the CNF alert had been operating for around seven seconds. The ATC trainee, who had not confirmed the presence of Aircraft-B prior to this, would have had to judge the relative altitude and relative position between Aircraft-A and Aircraft-B and their headings, and decide how to avoid the conflict, and it is thought that 4–5 seconds would have been necessary for these actions. Accordingly, it is considered that the ATC trainee noticed the CNF alert on the PVD no earlier than 2–3 seconds after it started, then responded to it.

(Refer DWG 10 attached)

3.2.2.8 The mistaking of Aircraft-A and Aircraft-B, and the instruction to descend Aircraft-A to FL350

In his statements, the ATC trainee stated that he had instructed Aircraft-A to descend having mistaken its flight number with that of Aircraft-B. The Kanto South C sector which he had been controlling was congested, and it is considered that he was unsettled psychologically by the urgent situation at time the CNF alert was

issued, mistook the flight number and instructed Aircraft-A to descend. It is also considered that as the ATC watch supervisor was also unsettled psychologically, she did not notice the ATC trainee's descent instruction with the mistaken flight number, and when Aircraft-A read back the descent instruction, both controllers did not realize that the flight number read back was different from the flight number intended. Furthermore, as the coordinator thought that descending Aircraft-A was feasible, he did not notice the misspoken flight number.

The followings are the examinations concerning these series of correspondence with ATC controller

- (1) As mentioned in section 2.12.4.1, at the time the CNF alert was issued at 15:54:15, the altitude of Aircraft-A indicated on the PVD was FL367. It is therefore considered probable that when the ATC trainee made to call Aircraft-A at 15:54:22 he intended to make it descend, but because Aircraft-A was in a climbing turn, its altitude was indicated as FL369 from 15:54:19, and he reconsidered to make Aircraft-B descend and discontinued the call to Aircraft-A.
- (2) According to his statement, the ATC trainee stated that he issued the instruction to descend to FL350 at 15:54:27 having judged that it was appropriate to make Aircraft-B descend, and was not aware of having issued the instruction to Aircraft-A.

The situation at that time was that Aircraft-A and Aircraft-B were converging while both at approximately FL370, with Aircraft-A climbing toward FL390, and Aircraft-B in level flight. Given that it would have been easier to make Aircraft-B descend from level flight rather than to make the climbing Aircraft-A descend, and that Aircraft-C, which had had a possibility of conflicting with Aircraft-A, had already descended to FL350, it is considered to have been appropriate to make Aircraft-B descend. Consequently, it is considered the flight number issued in the command was not the flight number intended by the ATC trainee, as agrees with his statement.

Regarding such a mis-speaking of the flight number, it is considered that the need for urgent action to avoid a collision unsettled the ATC trainee psychologically, and as he made his decision by visually comparing the radar information of Aircraft-A and Aircraft-B under urgent situation, he mixed up the flight numbers in the data blocks of both aircraft. Further, the leader lines linking the target symbols indicating the positions of the aircraft with their corresponding data blocks had become crossed, and it is considered that it may have been difficult to discriminate the information of Aircraft-A and B in this state.

When Aircraft-A had responded to the ATC instruction with its flight number, the

ATC trainee had an opportunity to realize that the response had not been transmitted from the aircraft intended, and so revise the instruction or flight number. But, it is considered that as the aircraft were converging, the ATC trainee was unsettled psychologically, and thinking of the next instruction to issue, he was preoccupied and was unable to realize that the response was not from Aircraft-B, as he believed, but was actually from Aircraft-A.

During the read back from Aircraft-A, the TCAS RA voice alert was issued and was recorded in the transcript of ATC communications. However, because it was in the background to the response from the flight crew, it is considered that ATC trainee and the ATC watch supervisor could not have recognized this as an RA voice alert.

- (3) Since that four months had passed since the ATC trainee began training on the sector, in the case of this accident, it is considered when the CNF alert was issued the ATC watch supervisor should not have left the instructions to the aircraft concerned to the ATC trainee, but it was appropriate that she handle them herself. Further, Tokyo ACC's "Air Traffic Service Operation Manual" specified that "The ATC watch supervisor should provide appropriate advice and instruction, and may take over the console depending on the situation". However, it is possible that when the CNF alert was issued, since the ATC watch supervisor herself also had forgotten the presence of Aircraft-B, she was unsettled psychologically and was unable immediately to override the ATC trainee.
- (4) According to her statement, the ATC watch supervisor stated that she could not have recognized that the ATC trainee had mistaken Aircraft-A with Aircraft-B when he issued the descent instruction. Given that the ATC watch supervisor had judged that Aircraft-B should be descended, the ATC trainee momentarily called Aircraft-A up but immediately discontinued, and it is rare to discontinue a communication with an aircraft then immediately to reissue a command to the same callsign, it is considered that the ATC watch supervisor believed that the ATC trainee had given the instruction to Aircraft-B etc.
- (5) When Aircraft-A responded, it is considered that the ATC watch supervisor had an opportunity to notice the different flight number and to respond, but it is considered that because she had been unsettled psychologically due to the unexpected CNF, she believed that the response came from Aircraft-B and did not notice the different flight number.
- (6) The coordinator also realized that Aircraft-A and Aircraft-B were converging as a result of the CNF alert, but he stated "Although it would have been normal to descend Aircraft-B, I thought that it was possible to establish the altitude

separation by descending Aircraft-A.”

It is considered that if the coordinator had routinely monitored the PVD, it would have been possible that he could have advised the radar controller. Tasks of the coordinator, as described in section 2.13.2.2, is to supplement the identification of aircraft displayed on radar screen, and to generally supervise the sector.

However, the main tasks of the coordinator as also described in section 2.13.2.2 and in Tokyo ACC’s “Air Traffic Service Operation Manual”, are to coordinate communicates with adjacent sectors and airports, there is no requirement to routinely monitor the PVD. Further, it is considered during the period around the accident, frequent coordination was being carried out with other air traffic facilities over direct lines. Moreover, it is considered likely that actions such as inscribing information changes from the flight data processing system regarding aircraft due to enter the sector on the flight strips, and posting newly-printed strips were being carried out. It is therefore considered that the although the coordinator became aware of the CNF alert, could not judge the rate of climb of Aircraft-A, and so he did not think that there was any particular problem with the ATC trainee’s descent instruction to Aircraft-A.

Further, although it is mentioned in the Tokyo Air Traffic Control Department’s “ATC Operation Manual” (which overrules Tokyo ACC’s “ATC Procedure” manual) that “the coordinator should supervise the sector”, since it is also necessary that the coordinator perform the tasks mentioned above, it is considered that the ATC watch supervisory tasks should be specified that the methods of handling aircraft in an emergency state like accident or hijacking were decided, then the communications and coordination with relevant facilities, and the correspondence as said sector to change request of altitude or route from aircraft should be decided.

- (7) Although the coordinator was not required to routinely monitor the PVD, it is considered that if he had been aware of the presence of Aircraft-B and had had the chance to recognize the relationship between Aircraft-A and Aircraft-B between 30 seconds to 1 minute before the CNF alert appeared on the PVD, he would have been able to recognize before the aircraft had converged to within the 5 nm specified lateral separation that vertical separation would be lost. In the 30 seconds to 1 minutes before the CNF alert was issued, the relative distance between Aircraft-A and Aircraft-B was between 20 and 27 nm (about 37–50 km), but given that the altitude of Aircraft-A would climb above FL350 while Aircraft-B was level at FL370, and so he would have been able to understand that the prescribed separation limits (5 nm lateral or 2000 ft vertical) would be

violated. In this case, the coordinator could have alerted the radar controller. However, around this time, as stated in (6) above, it is possible that the coordinator was performing duties such as annotating the strips of aircraft due to enter the sector with information changes and posting new strips, and it is considered that he could not have monitored the PVD.

3.2.2.9 The heading change instruction to Aircraft-B

- (1) According to the transcript of ATC communications, between 15:54:27 and 15:54:38 the ATC trainee instructed Aircraft-A to descend, and received the response from Aircraft-A to this instruction.

In normal ATC radio communications, following a transmission, the response from the other station should be confirmed before the next transmission is made. However, the ATC trainee instructed Aircraft-B to fly magnetic heading 130° at between 15:54:38 and 15:54:41, immediately after the response from Aircraft-A had been received.

During the interval between 15:54:27 and 15:54:38 when the descent instruction to Aircraft-A was made and the response received, the same altitude of FL370 was indicated for both Aircraft-A and Aircraft-B and the relative distance between the two was becoming short. It is considered likely that the ATC trainee, who thought he had given the descent instruction to Aircraft-B, considered this situation and instructed the heading change to Aircraft-B as he judged that an altitude change instruction alone would not be sufficient to ensure separation. Further, according to the transcript of ATC communication, because Aircraft-A's microphone key remained "ON" for one to two seconds after the end its response, when the ATC trainee issued the instruction to change heading to 130°, the operator's name part of Aircraft-B's callsign was lost, although the numerical part was clearly audible.

Further, Aircraft-B's TCAS had issued an RA before the ATC trainee instructed the heading change to 130°, but he could not have realized this.

- (2) The Commission considered the possible outcomes of the horizontal evasive maneuver if instructed by ATC that does not compete when the TCAS RA's vertical avoidance direction.

The result of a 25° bank turn to turn the aircraft to 130° by engaging the AP was computed under the wind direction and velocity and the aircraft magnetic heading and airspeed recorded on Aircraft-B's DFDR at 15:54:43 at two seconds after the time the heading change to 130° was instructed. As a result, the relative distance when Aircraft-B crossed forward flight path of Aircraft-A in

front of it was calculated as 0.67 nm (about 1,240 m). In this case, Aircraft-B had not reached 130° at the point of time when it crossed the flight path of Aircraft-A.

Further, because Aircraft-B's AP had already been disengaged at 15:54:38 when the heading change was instructed, a calculation was made assuming that at 15:54:41 the aircraft commenced a roll from level under manual control with rate of 3°/sec. to bank angle of 30° which is maintained during the turning maneuver, as is considered in maximum normal flight operations, then rolled wings level onto magnetic heading 130°. The resulting relative distance when Aircraft-B crossed the flight path of Aircraft-A in front of it was calculated as 1.01 nm (about 1,870 m).

(Refer to attached DWG 21)

- (3) ATC trainee instructed Aircraft-B to fly heading 130°, but because he did not receive a response, it is considered that at between 15:54:49 and 15:54:52 he instructed to fly magnetic heading 140°. However, at this point of time both aircraft were just over 20 seconds from crossing, and as it is estimated that the time from commencing a turn to the magnetic heading changing by 1° takes about 5 seconds, and about nine seconds is required to reach the standard turn bank angle of 25°, and so even if the ATC instruction of heading change at this point of time had been executed, it is estimated that it would have been insufficient to ensure the separation of both aircraft.

Further, there was no response from Aircraft-B to these heading change instructions from Tokyo ACC. The reasons for this will be described in section 3.2.4.3.

3.2.2.10 The descent instruction to the non-existent JAL flight 957

According to the transcript of ATC communications and radar recording, at between 15:54:55 and 15:54:57, forty seconds after the CNF alert had been issued, the ATC watch supervisor took over from the ATC trainee and instructed JAL flight 957 to "Begin descent". However, since there was no aircraft with that callsign within the sector's airspace, there was no response from any aircraft. At that time, approximately 15 seconds before the closest approach of Aircraft-A and Aircraft-B, it is considered that while in a psychologically unsettled state due to the urgent situation, the ATC watch supervisor was making decisions while visually comparing the radar information of Aircraft-A and Aircraft-B, and mixed up in her head Aircraft-A's flight number of JAL907 with Aircraft-B's flight number of JAL958.

As mentioned in 2.12.4.1, at around 15:54:55 the altitude of Aircraft-A indicated on the PVD was FL371, and the altitude of Aircraft-B was indicated as FL369, so Aircraft-B's was displayed as lower than Aircraft-A. The ATC watch supervisor thought that the ATC trainee had already instructed Aircraft-B to descent, but because there was no conspicuous indication that Aircraft-B was in descent, it is thought that the ATC watch supervisor intended to re-order Aircraft-B to descend, but addressed the command to the non-existent JAL flight 957, without being aware of the error.

3.2.2.11 The climb instruction to Aircraft-A

According to the transcript of ATC communications, the ATC watch supervisor instructed Aircraft-A to climb between 15:55:02 and 15:55:05. As described in section 2.12.4.1, the altitude of Aircraft-A displayed on PVD at around 15:55:02 was FL367, and altitude of Aircraft-B was indicated as FL369, but at 15:55:03 the displayed altitude of Aircraft-B had changed to FL366, indicating that both aircraft were in descent.

According to her statement, the ATC watch supervisor thought that he had issued a descent instruction to Aircraft-B, and also thought that Aircraft-A should be climbed. It is considered that for this reason she intended instruct Aircraft-A to climb to FL390.

The operation of Aircraft-A at this time is described in section 3.2.3.8.

3.2.3 Analysis of Aircraft-A's Maneuvers

3.2.3.1 Flight History of Aircraft-A

The Standard Instrument Departure (SID) clearance issued by Tokyo ACC for Aircraft-A, relayed by a delivery controller at Tokyo International (Haneda) Airport, was "via URAGA FIVE Departure, OCEAN Transition" and to turn left near YAIZU (a navigational fix Yaizu NDB connecting to the OCEAN Transition). This flight route was to cross another airway. At first, the AAIC considered Aircraft-A's flight history from the viewpoint of whether or not this ATC clearance had afforded Aircraft-A sufficient vertical separation from other traffic.

No crossing altitude restriction at YAIZU was established in the Minimum Edition (INSTRUMENT APPROACH CHARTS, VISUAL LANDING CHARTS AND STANDARD INSTRUMENT DEPARTURE) of the AIP Japan edited by JCAB. According to the statements of the flight crew of Aircraft-A and the transcript of ATC communications, it was established that no altitude restriction,

for example to cross YAIZU at an altitude assigned by ATC, had been issued to Aircraft-A. The flight route between YAIZU and SAKAK proceeding to the OCEAN transition is intersected at almost right angles by several airways, such as airway G597 connecting XMC (Kowa VORTAC) and XAC (Oshima VORTAC), and airway V17 connecting LHE (Hamamatsu VOR) and XAC. Accordingly, if an altitude restriction, for example to cross YAIZU at an ATC assigned altitude, had been established in the AIP Minimum Edition, Aircraft-A would have had sufficient vertical separation from other aircraft after crossing YAIZU.

The ATC trainee was vectoring Aircraft-A to YAIZU at the time of the accident. If the AIP Minimum Edition had stated that aircraft should cross YAIZU at an ATC assigned altitude, it is estimated that Aircraft-A would have been capable of crossing YAIZU at a cruising altitude of FL390 with sufficient margin, despite being radar vectored, by increasing its rate of climb while reducing airspeed, or by applying greater climb thrust than the accident aircraft, and accordingly there would have not been a lack of vertical separation between Aircraft-A and Aircraft-B (which was cruising at FL370).

3.2.3.2 Left Turn of Aircraft-A above YAIZU

Based on Aircraft-A's DFDR data and ACMS data, the statements of the flight crew, the transcript of ATC communications and so on, it was estimated that at around 15:44:33 when it was cleared by Tokyo ACC to proceed direct to YAIZU, Aircraft-A was in climb cruise with the AP engaged at a magnetic heading of 270°, a magnetic course of 271° and a ground speed of approximately 400kt due to head winds.

Based on the DFDR data, it is estimated that at around 15:53:50, while climbing through an altitude of approximately 36,500 ft about 3 nm before YAIZU, Aircraft-A started to make a lead-turn (a turn to begin stably acquiring the next heading, with the turn radius such as not to depart greatly from the airway) to the next magnetic course (207°), with the AP causing Aircraft-A to roll approximately 25° left.

Aircraft-A needed to turn left through approximately 64° to acquire the next magnetic course (207°). The upper winds recorded on the DFDR at this time were approximately 82kt out of 275°, resulting in the aircraft needing to correct its magnetic heading by about 10° against the wind. Accordingly, it is considered that the AP would have rolled Aircraft-A out onto a magnetic heading of approximately 218°.

However, it was estimated that during the climbing turn Aircraft-A was

instructed by ATC to descend. This was followed by the AP being disengaged, resulting in a situation in which the Captain would have had to perform the roll out manually while scanning the approaching Aircraft-B. It was considered that this situation made it difficult for the Captain to focus his attention on Aircraft-A's attitude and he had no time to take into account the wind correction of the aircraft's heading, resulting in Aircraft-A's magnetic heading at the time of the roll-out being 207°.

The continuous change of Aircraft-A's magnetic heading during the roll-out maneuver caused the pilots to observe Aircraft-B with a continuously changing relative angle. Therefore, it is considered that the pilots failed to become aware that the aircraft were on a collision course. It is considered that after the roll-out, that the relative angle between the two aircraft became constant, enabling Aircraft-A's pilots to be aware that they were on a collision course with Aircraft-B.

3.2.3.3 Issuance of TA Alerts by Aircraft-A's TCAS

The recordings of the TCAS revealed that a TA alert was triggered by Aircraft-A's TCAS during the climbing turn at 15:54:19, by which the intruder was displayed as a yellow symbol on Aircraft-A's TCAS display together with an synthetic voice alert of "TRAFFIC, TRAFFIC", approximately four seconds after the "CNF" alert began to be displayed at Tokyo ACC. Thus, it is considered that Aircraft-A's pilots were able to confirm that Aircraft-B, which they deemed had been flying above Aircraft-A, was flying almost co-altitude at FL370 by the altitude information on the TCAS display and the altimeter. Further, it is estimated, based on the recordings of the TCAS, that neither an up arrow nor down arrows were displayed in Aircraft-B's TA symbol due to its flying at a constant altitude.

Judging from the ATC radio communications and TCAS data recordings, Aircraft-A did not request Tokyo ACC for traffic information when the TA was triggered despite descriptions of "...a Traffic Advisory (TA) only. However, pilots shall search for the approaching aircraft, and also it will be preferable to make confirmation to ATC if you don't have ATC traffic information" in the AIC published by JCAB. It is possible that Tokyo ACC's transmission of "Hem, Japan air niner zero seven, corre... Disregard" one second after the TA alert was cleared followed one second later by an instruction to Aircraft-A to descend was one a factor in the pilots' not requesting traffic information from ATC.

The pilots stated that the TA was issued after they were instructed by Tokyo ACC to descend to FL350. However, analysis of the TCAS and DFDR data and the ATC communications revealed that the sequence was first the issuance of the TA,

second the ATC instruction, and then the issuance of the RA. Because the first portion of the word “Disregard” was radioed at almost the same time as when the TA aural alert was cleared, it is likely that the pilots misunderstood the sequence.

3.2.3.4 Initiation of Descent of Aircraft-A

- (1) According to the DFDR data and the statements of the Captain, it is estimated that the Captain of Aircraft-A, which had been instructed by Tokyo ACC to descend to FL350 between 15:54:27 and 15:54:32, disengaged the AP at 15:54:32 in order to take prompt action. It is considered that the disengagement of the AP was based on the Captain’s judgment that maneuvering under control of the AP was inappropriate for taking prompt action, since with the AP engaged the aircraft maneuvers within a G-limit to avoid imposing variations in the load factor on the passengers, resulting in slow maneuvers. Subsequently, replying to the ATC instruction between 15:54:33–15:54:38, the aircraft informed Tokyo ACC of its call sign, that it was descending to FL350 and that it had traffic in sight. An RA synthetic voice command of “CLIMB, CLIMB, CLIMB” was also recorded on the ATC recorder at the same time as the reply message between 15:54:35 and 15:54:38.
- (2) According to the DFDR data, the thrust levers moved aft between 15:54:32 and 15:54:34 before the issuance of the RA. At around 15:54:33, the fuel flow began to decrease, and at around 15:54:34, the pitch angle began to decrease. It is considered that this was the result of the Captain manually initiating a descent to follow the ATC instruction: either he manually retarded the thrust levers to override the engaged auto-throttle, or the increase in airspeed as a result of his pushing forward on the control column caused the auto-throttle to decrease the engine thrust.
- (3) According to the DFDR data, the thrust levers moved aft between 15:54:35 and 15:54:38 at the same time as the RA was issued. It is considered that this was the result of: either the Captain momentarily increasing the engine thrust manually in response to the RA, or the auto-throttle automatically advanced the thrust levers to increase engine thrust due to the slight increase in the aircraft’s pitch and the Captain’s relaxation of pressure on, or release of, the thrust levers which he had earlier retarded to manually override the auto-throttle. However, it was not determined which scenario caused the movement of the thrust levers.

The DFDR data revealed that the auto-throttle, which had been engaged in “VNAV” mode until 15:54:35, was not in any mode between 15:54:36 and 15:54:39. Additionally, the autothrottle annunciator, which had indicated “THR REF”, did

not indicate any mode at 15:54:38. It is considered that this was due to the Captain disengaging the auto-throttle and taking manual control of the engines.

- (4) Based on the result of an investigation using a flight simulator, described in subsection 2.12.3.2 (1), it is considered that Aircraft-A would have been able to reach an altitude of 38,100 ft at around the time of the CPA. Thus, it is considered that if Aircraft-B had not descended as a result of evasive action, the two aircraft would not have converged at around the time of the accident because Aircraft-A would have been able to achieve a vertical separation of 1,000 ft, albeit not attaining the 2,000 ft minimum IFR vertical separation required at this altitude.

3.2.3.5 Analysis of the relationship between the RA and the Flight History of Aircraft-A

- (1) According to the TCAS data recordings, it is estimated that while the Captain was initiating Aircraft-A's descent, its TCAS triggered an RA at 15:54:35 (16 seconds after the TA was issued), with the color of the intruder's symbol on the TCAS display changing from yellow to red and the synthetic voice command of "CLIMB, CLIMB, CLIMB" being annunciated. Based on the fact that a positive vertical speed was recorded on the DFDR at that time, it is estimated that Aircraft-A had continued to climb due to inertia even just after the pilot had started operations to make it descend.
- (2) Between 15:54:33 and 15:54:38, while climbing at around FL371, Aircraft-A replied to Tokyo ACC that it was descending to FL350 and had traffic in sight. Based on the fact that a voice of "CLIMB, CLIMB, CLIMB" was also recorded on the ATC recorder between 15:54:35 and 15:54:38, it is considered that the RA was triggered at 15:54:35.

The ATC radio communications recording revealed that after Aircraft-A replied to ATC instruction to descend, Tokyo ACC did not contact with Aircraft-A with other instructions or to correct the flight number.

According to the DFDR data, Aircraft-A's altitude at this point in time was FL372, with a vertical separation of 200 ft from Aircraft-B which was flying at FL370. A fuel flow of more than 5,500 lb/hr was recorded on the DFDR at this time. Based on the result of the flight simulator test described in section 2.12.3.2 (3) and information on the engine acceleration performance in the aircraft manufacturer's documentation, it is considered that Aircraft-A would have been able to reverse its descent to climb. In addition, as described in section 3.2.3.7 below, it was considered that Aircraft-A would have been able to climb without entering a dangerous situation such as buffet and/or stall.

- (3) According to the DFDR data, Aircraft-A reached a peak altitude of FL372 at 15:54:40 while continuing to turn left, and subsequently its altitude began to decrease. It is estimated that the Captain's starting to operate the controls to make the aircraft descend following the ATC instruction, and continuance of these operations even after the issuance of the RA, resulted in Aircraft-A, which had continued climbing due to inertia, beginning to descend.
- (4) According to the DFDR data, it was estimated that Aircraft-A reached the heading at which it should have rolled out at around 15:54:44, but it continued turning, gradually increasing its bank to the left reaching a maximum bank angle of 33.9°, and subsequently rolled out on a magnetic heading of around 207°. The reason is considered a consequence of the facts that the Captain, flying manually, had to grasp the direction of rollout in the horizontal plane while at the same time starting a descent to comply with the ATC instruction, while keeping Aircraft-B in constant sight to confirm its proximity.
- (5) According to the statements submitted by the FO who was seated in the left jump seat, and the trainee pilot who was sitting in the right seat of Aircraft-A (see the notes in sections 2.1.2.3 and 2.1.2.2), it is considered likely that the FO advised the Captain with the phrase "Captain, the DC-10 is descending!" Based on the Captain's statements (see note in section 2.1.2.1), it is considered likely that he did not perceive the advice.

3.2.3.6 ATC instructions to Aircraft-A and the Captain's Decision to Descend contrary to the RA

According to the Captain's statements, his decision to descend was based on the points listed below. He also stated that he had to make a decision within a very short space of time, and decided that it was appropriate to descend following the ATC instruction rather than to climb in accordance with the RA partly because.

- ① The sequence was first the issuance of the TA, second the ATC instruction and then the issuance of the RA.
- ② It is considered that ATC instructions are issued for the purpose of maintaining separation between known aircraft. Since air traffic controllers comprehensively handle multiple aircraft within the controlled airspace for which they are responsible, grasping the whole traffic situation, it was considered likely that the air traffic controller issued the instruction for descent taking into account other factors, including Aircraft-B.

- ③ The Captain had made visual contact with Aircraft-B and was also aware of its symbol on the TCAS display.
- ④ The altitude of Aircraft-A was lower than that of Aircraft-B indicated on the TCAS display when Aircraft-A was instructed by the ATC controller to descend.
- ⑤ It takes substantial time for engine thrust to increase from the idle thrust selected for descent to the thrust required to climb.
- ⑥ Because aircraft stall margin decreases at high altitudes (due to the low density of the air), a climb due to evasive maneuvers may cause a loss in airspeed that may lead to a aircraft stall.
- ⑦ Careless pitch-up maneuvers made at high airspeed may lead to buffet and/or stall attributed to flying in the transonic region.

The ①–⑦ above list the reasons based on the statements of Captain why Aircraft-A did not obey the climb RA. In addition, there considered to be a further reason described in item ⑧ below.

- ⑧ The Captain of Aircraft-A did not sufficiently recognize the importance of compliance with an RA and the risk of maneuvering contrary to an RA.

These points are now considered one by one in this section and in section 3.3.3.7 below.

(1) The issuance of the RA after the ATC instruction

As described in section 3.2.3.3, the statements of Aircraft-A's Captain concerning the sequence of the ATC instruction, the TA and the RA, contradict the other evidence. In fact, the ATC instruction was received after the issuance of the TA. Immediately thereafter, the RA was triggered while Aircraft-A was reading back to Tokyo ACC. It is considered that the Captain continued descending despite the climb RA because at that time he had already decided to descend following the ATC descent instruction and had started operating the controls to do so. He was in an imminent situation where he had to make a decision in a very short space of time, and it is considered that it would have been psychologically difficult for him to change the actions he had started once he had decided.

(2) As to the Captain trusting the ATC instruction and following it

The Captain of Aircraft-A, while aware of Aircraft-B having visually acquired it and from its the symbol on the TCAS display, and having received an instruction from ATC to descend, had to decide within a very short time period whether to comply with the ATC descent instruction or with the RA's instruction to climb. It is considered that he descended following the ATC instruction deeming that the controller had instructed Aircraft-A to descend in order to establish safe separation

taking into account the relationship between Aircraft-A and Aircraft-B.

In addition, although it is considered that the prevailing visibility was good at the time of the accident, it is considered possible that even though the Captain had Aircraft-B in sight, he thought the controller had issued the instruction to descend taking into account the whole traffic situation including Aircraft-A, Aircraft-B and other nearby aircraft, grasped from the radar display.

- (3) The Captain's awareness of Aircraft-B both visually and from information on the TCAS display

It is considered that the Captain decided that he was able to avoid a risk of collision by visual evasive maneuvers in addition to complying with the ATC instruction, without needing to comply with the RA. However, as described in section 3.2.5.2 below, it is considered practically impossible for pilots to precisely grasp the motions of another aircraft visually in high speed, high altitude flight until the two aircraft are very close.

- (4) As to the Captain's judgment that Aircraft-A was flying below Aircraft-B

According to the DFDR data, the ATC communications recordings and TCAS data recordings, it is considered that Aircraft-A was flying below Aircraft-B at the time of the TA, as the Captain stated. However, although it is considered that the two aircraft were flying at almost co-altitude when the ATC instruction to descend was issued, it was considered possible that the Captain judged to be able to easily avoid a confliction by complying with the ATC instruction based on his assessment that Aircraft-A was flying below Aircraft-B at the time.

- (5) The above mentioned items ⑤-⑦, which are concerned with aircraft performance in the case of an evasive maneuver obeying a climb RA, are considered in detail in section 3.2.3.7 below.

- (6) Regarding the awareness of the importance of complying with RAs and the risk of maneuvering contrary to an RA, Japan Air Lines' rules regarding TCAS are that when an RA is issued, pilots should basically comply with the RA, and the operating procedure is also prescribed. In particular, Aircraft-A's AOM had the note "Pilots are authorized to deviate from their current ATC clearance to the extent necessary to comply with a TCAS II resolution advisory", and Aircraft-A's AOM Supplement described in detail that when an RA is issued, pilots should initiate evasive maneuvers complying with the RA, and describe the operating procedures in detail. Japan Air Lines had also given training on TCAS to pilots including Aircraft-A's Captain; in particular, periodic flight simulator training included scenarios of close

proximity with another aircraft and maneuvering in response to an RA, giving actual experience.

However, Japan Air Lines' rules regarding TCAS did not describe the specific situation in which the RA and ATC issue contradictory instructions, and although the caution "any change in vertical speed that does not comply with the RA may negate the effectiveness of the other aircraft's compliance with the RA" was described in Aircraft-A's AFM, it was not described in Aircraft-A's AOM and AOM Supplement, which are referred by pilots on a routine basis.

In addition, the periodic simulator training did not include the pilot's judgment under the specific situation in which the RA and ATC issue contradictory instructions, and the risk of maneuvers opposite to the RA.

It is therefore considered that the Captain of Aircraft-A did not sufficiently recognize the importance of compliance with the RA and the risk of maneuvering contrary to the RA.

As described in the section 3.2.11.2 below, a video seminar held by Japan Air Lines in 1998 addressed subjects including the risk of maneuvering contrary to the RA in compliance with an ATC instruction and the TCAS/TCAS coordination function. Therefore, it was considered that the Captain of Aircraft-A and the flight crew of Aircraft-B had had an opportunity to obtain understanding of these subjects. However, it is considered that the pilots' brief learning in a one-time seminar would have been insufficient to fix these subjects sufficiently in their memories.

Additionally, the OM Supplement prescribed "when the RA is issued, immediately comply with the RA unless the Captain considers it unsafe to do so". This means that pilots do not have to comply with the RA "if the Captain considers it unsafe to do so". However, there was no concrete description regarding the Captain's judgment of "unsafe to do" in the OM Supplement.

3.2.3.7 Aircraft-A's reversal of descent to climb at High Altitude

Among the reasons of the Captain's decision to carry out the descent maneuver following the ATC instruction and contrary to the climb RA, ⑤—⑦ of section 3.2.3.6 show the Captain's concerns about the aircraft's climb performance in high speed/high altitude flight. This is considered in detail in this section.

- (1) The time required to recover to climb thrust (equal to MCT at the altitude in the case of this accident)
 - ① Regarding the time required for the engine thrust to recover from idle thrust to climb thrust, the AOM for the older type of Boeing 747, which the Captain

referred to states that “At high altitude, the acceleration from idle to cruise thrust normally takes around 20–30 seconds, although 1 minute may be required some cases”. On the other hand, the AOM Supplement for the Boeing 747-400 (same series as Aircraft-A) states regarding engine response that “at high altitude, the delay in engine response to thrust lever advance is considerably longer than in low altitude, and increases with altitude”.

According to information obtained from the aircraft manufacturer, after the aircraft is established in descent with the engines at idle thrust, it takes about 20 seconds for the engine thrust to recover to the thrust required for climb. Furthermore, it is considered that in the case of climbing after a descent had been established, there is a further delay until the aircraft begins to ascend due its inertia.

The AAIC examined the recovery time from idle thrust to climb thrust in the simulator test flight described in subsection 2.12.3.2 (6). As a result it was found that the time required for the N1 to recover from idle to MCT was approximately 18 seconds at an altitude of 30,000 ft and approximately 24 seconds at 40,000 ft, and it was confirmed that it took about 20 seconds to recover from idle thrust at around the altitude of Aircraft-A at the time of the accident.

Although the operation from idle to climb thrust in high altitude flight may cause engine surge under conditions of certain weather etc., the Boeing 747-400 aircraft, including Aircraft-A, incorporates a system to automatically recover from engine surge.

In addition, as a result of comparing descriptions in the AOM, AFM etc., and aircraft manufacturer’s data to the data obtained from the simulator test flights, it is considered that the flight simulator used in this investigation would have reproduced the aircraft’s actual performance with considerable precision.

- ② The following are the considerations of the engine thrust response to movement of the thrust levers under the condition the engines thrust is reduced momentarily (that the N1 is at about 80%).

According to data recorded on the Aircraft-A’s ACMS indicating the values of N1 and the angles of the thrust levers, shown in Attached Figure 19, the thrust levers were pulled back from the climb positions. During this period, the time lag from movement of the thrust levers until the N1 started to decrease in response was approximately one second.

Then, at around the time N1 had reduced to 87%, the thrust levers were advanced once. During this period, the time lag until the beginning of the

increase in N1 in response to the advancement of the thrust levers was about two seconds.

Subsequently, the thrust levers were again retarded and remained at a mid-point between the climb thrust and the idle position for about five seconds, around which time N1 indicated at about 76%. Then, the thrust levers were retarded to their idle positions, and during this period the time lag until the beginning of the decrease in N1 responding to the movement of the thrust levers was about two seconds.

In the simulator test flight to investigate the engine thrust response to the movement of the thrust levers described in subsection 2.12.3.2 (2), it was found that when the thrust levers were maintained in their idle positions for 5 seconds before being advanced to the climb thrust positions, the time to recover the climb thrust was 10 seconds. During this period, the minimum value of the N1 was around 73%.

Based on the above findings, it can be stated that the time lag in the N1's response to the movement of the thrust levers is about 10 seconds in the case that the thrust levers are advanced to the climb thrust positions after being maintained at their idle positions (N1 of 70%–80%) for a while.

- ③ Under the assumption that Aircraft-A climbed in compliance with the climb RA, it was found, based on the result of the simulator test flight described in subsection 2.12.3.2 (3), that it would have reached altitudes around 37,800 ft at around the time of the CPA in the accident.
- ④ Based on the findings confirmed in the above items of ①–③; that about 20 seconds is required for the engine thrust to completely recover from idle thrust to the climb thrust described in item ①; that about 10 seconds is required for N1 to recover from 70%–80% to the climb thrust in item ② and the establishment of the altitude achievable as a result of the simulator test flight in item ③, it was estimated that Aircraft-A could have achieved sufficient climb thrust necessary to comply with the climb RA without difficulty.
- ⑤ However, based on the facts that the Captain of Aircraft-A had not experienced a situation in which the thrust levers were rapidly advanced after being maintained at their idle positions to recover climb thrust in high altitude flight, and that JAL's TCAS training program had not given pilots knowledge and/or training concerning aircraft performance and maneuvers in the above mentioned situation, it is considered that the Captain was concerned about the time required for engine thrust to recover completely from idle thrust to the climb thrust.

(2) The stall margin in high altitude flight and the kinetic energy required to climb

Based on Aircraft-A's performance chart and the result of the simulator test flight described in subsections 2.12.3.2 (5) and (7), it was estimated that stall speed of Aircraft-A when in equilibrium under the conditions of altitude, weight and atmospheric temperature at the time of the accident was 215kt (CAS). The CAS of Aircraft-A when it was descending at around the time of the accident was approximately 280kt. Therefore, it is considered that Aircraft-A had a small margin of speed over the above-mentioned stall speed. It is estimated that Aircraft-A would have been able to gain altitude to some extent using this airspeed margin had for climb by transforming kinetic energy (KE) into potential energy (PE).

Furthermore, taking into account that the thrust margin may have been considerably reduced due to Aircraft-A being in high altitude cruise, firstly assuming that the thrust margin is used for compensating the drag induced by the increase in pitch angle and not for climbing, and secondly assuming that the KE from an excess airspeed of 20 kt obtained by reducing the CAS of 280 kt to 260 kt (1.2 times the stall speed) is converted into PE and utilized for climbing, it is estimated that Aircraft-A would have been able to gain more than 1,000 ft of altitude. (Refer to Note below.)

Based on the above scenario, it was considered that the altitude achieved by a climb could have been increased in conditions of a high altitude and poor thrust margin by not only depending on engine thrust to climb but also by trading excess KE for PE as much as possible.

Additionally, based on the result of the simulator test flight described in (5) and (7) of section 2.12.3.2, it is also considered that a climb by transforming excess KE into PE would have allowed Aircraft-A to gain altitude without stalling.

Note: With respect to being able to gain more than 1,000 ft of altitude by transforming KE into PE, we find:

$$KE = mv^2/2, \quad PE = mgh$$

Where: m = Mass, v = Speed, g = Acceleration due to gravity, h = Altitude

A numerical subscript (1) indicates v and h before climb

A numerical subscript (2) indicates v and h after climb

Total energy is expressed by the following equation:

$$\text{Total energy} = KE + PE = \text{constant}$$

Thus,

$$mv_1^2/2 + mgh_1 = mv_2^2/2 + mgh_2 = \text{constant}$$

where $v_1 = 290\text{kt (CAS)} = 491\text{kt (TAS)} = 253 \text{ m/s (TAS)}$
 $v_2 = 260\text{kt (CAS)} = 459\text{kt (TAS)} = 236 \text{ m/s (TAS)}$
 $g = 9.8 \text{ m/s}^2, \quad h_1 = 37,000\text{ft} = 11,300\text{m}$

Substituting these values into the above equation gives the difference in altitude ($\Delta h = h_1 - h_2$) after climbing:

$$\Delta h = 424\text{m} = 1,390 \text{ ft} > 1,000 \text{ ft}$$

(3) The risk due to careless pitch-up maneuvers in transonic flight

It was estimated that since Aircraft-A was nearing its critical Mach number, the Captain was worried that careless pitch-up maneuvers could result in airflow separation induced by shock waves typically in the transonic flight region.

Aircraft-A's AOM, which requires the pilots to initiate immediate corrective actions to establish safe separation when a RA occurs and, if necessary, to make appropriate pitch and thrust adjustments to satisfy the RA, incorporates the following notes to remind the pilot's attention.

Note: When stick shaker is activated or initial buffet is produced in evasive maneuvering, pilots should quickly carry out Approach to Stall Recovery maneuvers.

Note: When high-speed buffet is produced in evasive maneuvering, pilots should continue evasive maneuvers while relaxing Pitch Force as necessary to reduce the buffet.

There is a description concerning TCAS operation in the Advisory Circular (AC 20-131A) created for the design requirement to meet TCAS operation that explains that when a climb evasive maneuver complying with a climb RA is executed at a cruise altitude with a certain buffet margin, inhibiting the climb RA may be appropriate in the cases when TCAS may command maneuvers which may significantly reduce stall or buffet margin unless the pilot considers it possible to climb.

However, TCAS installed in Boeing 747-400 series aircraft are not required to inhibit the climb RA because the aircraft manufacturer's evaluation concerning the above-mentioned TCAS design requirement indicated the aircraft's capability of climbing with sufficient margin of stall or buffet, even in high altitude flight.

In addition, based on the result of the simulator test flight described in subsection 2.12.3.2 (7) regarding climb performance at around the maximum operating altitude, it is considered that if the aircraft's climb maneuvers would

have gained sufficient altitude to avoid a collision with the other aircraft without buffeting, and there was no compromise with the aircraft performance that would have necessitated inhibiting the climb RA.

Furthermore, there is a description concerning pilot response in Attachment-A Guidance Material to Chapter 4 of Volume IV, ANNEX 10 to the ICAO convention (hereinafter referred to as “ICAO ANNEX 10 Guidance Material”) that the typical vertical rate needed to avoid a collision is 1500 ft/min, based on assumptions of a pilot response time of 5 seconds and a vertical acceleration of 0.25G to establish the escape vertical rate. Thus, it is considered that slow evasive maneuvers with a vertical acceleration of 0.25G are sufficient to achieve the rate of climb or descent of 1,500 ft/min commanded by an RA.

Pilots should respond promptly to achieve the above-mentioned vertical acceleration and vertical rate, and the RA command is designed to allow pilots to perform these maneuvers. In addition, the Boeing 747-400 series aircraft (Aircraft-A) are designed such that they can perform climb RA maneuvers without buffet or stall at high altitude, so the TCAS RA is not required to be inhibited due to inadequate performance. However, even in these cases, pilots are reminded that excessive evasive maneuvers complying with the RA may cause buffet or stick shaker stall warning.

- (4) Regarding the Captain’s concern about Aircraft-A’s performance as described in (1)–(3), it is considered that the aircraft would actually have been able to achieve climb thrust in a shorter time than the Captain thought if he had decided to climb when the RA occurred. And it is considered that slow evasive maneuvering paying attention to the stall margin and a potential risk of buffet or stall associated with transonic flight could have gotten Aircraft-A to climb complying with the RA without precipitating into buffet or stall. Further, the simulator test flight described in section 2.12.3.2 (3) showed that in the case of climb complying with the RA, the aircraft would have shifted gradually to climb after remaining for a while at FL372. Additionally, the simulator test flight described in section 2.12.3.2 (5) showed that the aircraft would have been able to safely gain altitude even in the case of continuing pitching the aircraft nose up with a rate of 1°/sec with N1 being at 93%.

The purpose of the simulator test flights was not to collect precise quantitative data regarding flight performance but to grasp the qualitative flight situations considering the possibility of Aircraft-A’s climb and the extent of altitude gain achievable in the case of executing a climb maneuver after having once initiated a descent. Therefore, it was considered that the results of the simulator test

flights were entirely reliable.

The ICAO ANNEX 10 Guidance Material describes in section 3.5.8.3.1 that “This altitude separation goal, A_1 , must vary as a function of altitude in order to adequately compensate for altimetry errors. In the ACAS implementation described in Section 4, A_1 varies from 90 m (300 ft) to 210 m (700 ft)” and in section 3.5.8.4.2 “A prime consideration is the minimization of any departure from an ATC clearance”. Furthermore, the Advisory Circular (AC-120-55A) describes “Excursion from assigned altitude, when responding to an RA, typically should be no more than 300 to 500 feet to satisfy conflict”. Therefore, it is considered to be sufficient that excursion from the assigned altitude necessary to avoid a conflict is 300 to 500 ft.

Based on the above descriptions, it was considered that the Captain’s evasive maneuvers complying with the climb RA could have gotten Aircraft-A to climb such that it would have avoided conflicting with Aircraft-B.

Additionally, it was desirable for the Captain to perform evasive maneuvers (despite slow maneuvers) complying with the climb RA to the greatest extent possible, even if, as he had suspected, there was difficulty in achieving the TCAS commanded rate of climb or the possibility of stall or buffet. In particular, provided that the intruder aircraft also complies with a RA, even if there is a situation in which the pilot can not fully comply with the RA maneuvers to the extent commanded, maneuvering in contradiction to the RA results in increasing the hazard since there may be TCAS/TCAS coordination with the intruder aircraft.

However, the Captain had not experienced such circumstances of climb performance and possibility of buffet or stall at high altitude as considered in this section. Additionally, Japan Air Lines’ AOM and AOM Supplement did not specify aircraft performance in the case of climb maneuvers complying with a RA, and the training syllabus did not include procedures for complying with TCAS commands in high altitude flight. Therefore, it is considered possible that the Captain, who suddenly encountered such circumstances, would have been concerned about Aircraft-A’s performance.

3.2.3.8 Aircraft-A’s continuing descent and the Captain’s Decision Contrary to the RA

- (1) It is considered that the flight crew of Aircraft-A did not advise the Captain that he should comply with the climb RA.

However, it was considered possible that although the FO advised the Captain saying “Captain, the D(C)-10 is descending!”, the Captain was not aware of the

FO's advice. Based on the possibility that the Captain actually heard the FO's advice, it was considered possible that method of the FO's advisory would have been inappropriate. Regarding the content of the advice, it is considered desirable that the Pilot-Not-Flying (PNF) should not only have informed the Pilot-Flying (PF) of what he saw but also should specifically advise the PF to comply with the climb RA. Based on the fact that the FO of Aircraft-A, who was responsible for giving such advice, had difficulty in seeing the information on the TCAS screen from his jump seat, it is considered possible that a lack of information for giving specific advice to the Captain to climb, or a lack of knowledge about the importance of compliance with an RA and the risk of maneuvers opposite to the RA, were contributing factors to the insufficiency of the FO's advice.

Regarding that the trainee pilot of Aircraft-A did not advise the Captain, it is considered possible that the trainee pilot missed Aircraft-B's variation of altitude on the TCAS display, or he did not read the variation of altitude due to focusing his attention only on following visually the approaching Aircraft-B. In addition, it is also considered possible that deference to the difference in flight experience between the instructor and trainee and/or the seniority system was a possible factor in the trainee pilot's lack of advice.

Although the description of work sharing among the flight crew in Aircraft-A's AOM Supplement indicated that a PNF should cross-check the traffic information on the TCAS display, it was considered that Japan Air Lines' CRM training did not implement training on the work sharing concerning TCAS operation.

It is also considered that the flight crew of Aircraft-A had insufficient knowledge about the TCAS/TCAS coordination with an intruder when a RA occurs and the consequent risk of maneuvering opposite to an RA. This is considered to be attributable to the insufficiency of Japan Air Lines' operation manual's expressions to get pilots to understand the risk of maneuvers opposite to an RA, and insufficient training for pilots on TCAS operation.

- (2) According to DFDR and ACMS data, at 15:54:52 Aircraft-A descended below FL369 with a rate of descent of 2,700 ft/min. Around this time the symbol corresponding to Aircraft-B, which had been in cruise at FL370, was indicated as co-altitude on Aircraft-A's TCAS display, and then a down arrow was displayed to the right of the symbol at 15:54:54. If a sufficient training on evasive maneuvers in compliance with an RA taking into account the work sharing

among flight crew had been implemented, it is estimated that Aircraft-A's flight crew would have been able to judge that Aircraft-B was also descending by observing the down arrow indication on the TCAS display, despite it being impossible to visually grasp Aircraft-B's maneuvers precisely.

However, it was considered that it would have been essential for Aircraft-A's flight crew to receive simulator flight training concerning TCAS operation, including a practical work sharing program, in order to make use of the tiny down arrow in recognizing Aircraft-B's descent maneuver. Since it was estimated that Aircraft-A's flight crew did not receive such training, it is considered to have been difficult for them to recognize Aircraft-B's descent from the down arrow in the imminent situation. In addition, it was considered that the advice believed to be made by Aircraft-A's FO that Aircraft-B was descending was based on his visual judgment. Other than that, there was no advice to the Captain. Therefore, it is considered that no flight crew member of Aircraft-A recognized the down arrow on the TCAS display.

Aircraft-A's subsequent trajectory assuming that that the flight crew had received the above-mentioned training and that Aircraft-A's Captain had started climbing when the flight crew identified Aircraft-B's descent by observing the down arrow on the TCAS display, was confirmed in the simulator test flight described in subsection 2.12.3.2 (4). As a result of the test, although Aircraft-A would not have yet started climbing at around the time of the CPA, it was estimated that Aircraft-A would have been able to pass above Aircraft-B.

(Refer to Attached Figure 18)

(3) According to the statements of Aircraft-A's flight crew, it is considered that while the Captain was descending contrary to the climb RA, no flight crewmember gave the Captain suitable advice concerning Aircraft-B's descent. It was considered that the advice believed to be given by Aircraft-A's FO about Aircraft-B's descent was given by visually judging Aircraft-B's maneuvers, not by making use of the indications on the TCAS display, which the FO could not see well from the jump seat. Based on the above descriptions, it was considered that all of Aircraft-A's flight crew focused their attention on visually following the abruptly approaching Aircraft-B, and consequently they did not fully make use of the TCAS information.

(4) As described in the following subsection 3.2.5.2 (3), it is considered to be impossible for pilots to accurately judge visually an intruder aircraft's attitude and/or heading, especially the vertical separation against the intruder, when

approaching at high speed at high altitude.

This is considered to be for the following reasons: Since there is no visually distinct reference object behind an intruder in high altitude flight, like the horizon, it is difficult for pilots to accurately judge the attitude of their own aircraft and the intruder, vertical or lateral separation against the intruder and the intruder's maneuvers needed to avoid a potential collision by eyesight alone until the aircraft are in considerably close proximity. Additionally, it is in practice difficult for pilots to accurately judge the intruder's maneuvers even after closure to close proximity because of high-speed flight.

Under these circumstances, although there was the possibility of the advice made by Aircraft-A's FO to be indicating Aircraft-B's descent, all of Aircraft-A's flight crew were visually following Aircraft-B without accurate judgment of the vertical separation and Aircraft-B's maneuvers needed to avoid a potential collision. Therefore, it was considered that the flight crew finally deemed that it would be possible to execute maneuvers visually to avoid a collision, resulting in Aircraft-A continuing to descend.

- (5) According to the ATC radio communications recording, Tokyo ACC instructed Aircraft-A "CLIMB AND MAINTAIN FLIGHT LEVEL 390" during the four seconds from 15:55:02, but Aircraft-A did not reply to the instruction.

It is considered that this was because the flight crew did not hear the ATC instruction as they had continuously focused their attention on visually following the abruptly approaching Aircraft-B.

Even if the flight crew had heard the ATC instruction, it was considered that they would have had no time to reply due to concentrating on visual evasive maneuvers to avoid a collision with the approaching Aircraft-B.

(Refer to Attached Figure 10)

- (6) The DFDR data revealed that Aircraft-A almost rolled out on a magnetic heading of 207° but remained banked left about 4.7°. It is considered that this situation (left bank) would have made it more difficult for the flight crew to judge the vertical separation between Aircraft-A and Aircraft-B.

3.2.3.9 Aircraft-A's Evasive Maneuvers to Avoid a Collision

- (1) According to the DFDR data, it was estimated that the Captain's further pitch-down maneuver resulted in the further increase in nose-down pitch at 15:55:05, and the vertical acceleration reached a value of -0.55G at 15:55:06 and the nose-down pitch angle reached the maximum value of 10.8° at 15:55:07.

According to the recordings of the TCAS and DFDR data, although Aircraft-A's TCAS issued an Increase Climb RA with a commanded vertical rate of 2,500 ft/min together with a synthetic voice of "INCREASE CLIMB, INCREASE CLIMB" at 15:55:06, it is estimated that Aircraft-A continued descending.

Regarding the Captain's further pitch-down maneuvers during descending, he stated that judging that continuing the descent maneuver as it was apparently put Aircraft-A on a collision course because of the abrupt approach of Aircraft-B, and he made a split-second decision that he there was no time to avoid a collision by slow evasive maneuvers and exerted further forward pressure on the control wheel.

Regarding the Captain's continuance of the descent after the Increase Climb RA, it is considered that he was unable to judge that reversing from descent to climb was an appropriate procedure because of a combination of the following possible reasons: He did not recognize the Increase RA due to concentration on the evasive maneuvers; it was psychologically difficult for him to reverse the procedure once he had decided upon it; he did not sufficiently recognize the risk of descending contrary to the climb RA; and he concentrated on executing the evasive maneuvers to avoid a collision visually, without explicit advice from other flight crewmembers to climb to comply with the climb RA in a situation in which it was difficult for him to judge the vertical separation with Aircraft-B.

- (2) According to the DFDR data, at around 15:55:08 the fuel flow rates of Aircraft-A decreased to values corresponding to almost engine idle thrust and the rate of descent was 8,192 ft/min. This value of the rate of descent was the maximum value that capable of being recorded by the DFDR. The change in altitude recorded on the DFDR within one second at this time was 222 ft (equivalent to a descent rate of about 13,320 ft/min). Based on the above findings, it was estimated that Aircraft-A was descending rapidly at a rate in excess of the maximum value of descent rate capable of being recorded on DFDR. The rate of descent decreased to 7,976 ft/min at 15:55:11.
- (3) According to the DFDR data, the further large forward pressure was exerted on the control wheel for about 1 second at around 15:55:05, before which time the control wheel had been slightly pressed. The nose down pitch angle reached a maximum value of 10.8 ° and the vertical acceleration was -0.55G

At around 15:55:08, the nose down pitch angle changed from 10.8° to 7.0° and the vertical acceleration reached a value of approximately +1.33G. Therefore, it is estimated that Aircraft-A experienced large variations in vertical acceleration

between negative and positive values, and it is estimated that the majority of injuries in the passenger cabin were caused by these large variations in vertical acceleration. Specifically, it is estimated when the vertical acceleration of about $-0.55G$ was produced a large number of passengers and CAs were lifted together with galley carts, etc. and one galley cart broke through the ceiling panel and entered the space above the cabin ceiling at around 15:55:06, and immediately thereafter the passengers, CAs and galley carts and so on were smashed against the floor or seats at around 15:55:08 when the vertical acceleration of about $+1.33G$ was produced.

3.2.4 Analysis of Aircraft-B's Maneuvers

3.2.4.1 Issuance of the TA by Aircraft-B's TCAS

Based on the DFDR and AIDS data of Aircraft-B, the ATC radio communications recordings and so on, it is estimated that at around 15:54:00 Aircraft-B was in cruise west of the accident occurrence point at an altitude of FL370, a magnetic heading of 095° , a magnetic course of 096° and a ground speed of 568kt.

It is estimated that at around 15:54:00 a symbol corresponding to Aircraft-A was displayed on Aircraft-B's TCAS display with an up arrow to the right of the symbol.

It is estimated that at around 15:54:18, the TCAS on Aircraft-B issued a TA and was in the situation where it was able to detect that Aircraft-A, which had been flying 100 ft below Aircraft-B, was gradually climbing and approaching to almost co-altitude.

From to the recordings of the TCAS data and the ATC radio communications, it is considered that Aircraft-B did not request traffic information from Tokyo ACC when the TA occurred, despite the descriptions in the AIC published by the JCAB that it is preferable to confirm with ATC if you don't have traffic information in the event of a TA.

3.2.4.2 Aircraft-B's Descent Maneuvers complying with the RA

According to the DFDR data and the statements of Aircraft-B's flight crew, based on the findings that an OFF indication of Aircraft-B's autothrottle, which had been engaged, was recorded on the DFDR between 15:54:26–15:54:29, it is estimated that the FO (PF), who was in training for upgrade to Captain, disengaged the autothrottles as a precaution against a potential RA.

According to the recordings of TCAS data, it is estimated that at 15:54:34

Aircraft-B's TCAS issued a descend RA commanding a vertical rate of $-1,500$ ft/min and annunciated synthetic voice of "DESCEND,DESCEND, DESCEND".

According to the statements of Aircraft-B's Captain and the DFDR data, based on the findings that the AP, which had been engaged, was disengaged at 15:54:39, five seconds after the descend RA was issued, it is estimated that the FO disengaged the AP to comply with the descent RA, in accordance with the descriptions in Aircraft-B's AOM and AOM Supplement.

At around 15:54:43, Aircraft-B's altitude began to decrease. This is considered to have been because the FO commenced executing a descent maneuver to comply with the descend RA. At this time, it was estimated that the Captain assisted the FO in exerting further forward pressure on the control wheel because the sink rate at that time was low, and subsequently Aircraft-B achieved a rate of descent to satisfy the descend RA vertical speed command.

According to the recordings of the TCAS data, it is estimated that at 15:54:49, a down arrow was displayed to the right of a symbol corresponding to Aircraft-A on Aircraft-B's TCAS display.

The AIC, published by the JCAB, describes in section "6. Pilot responsibility" that "When a pilot deviates from ATC clearance in order to comply with an RA, the pilot is not considered to be violating article 96-1 of the Civil Aeronautics Law".

3.2.4.3 Aircraft-B's Reply to Tokyo ACC's Instruction to Change Heading

- (1) According to the ATC radio communications recordings, Tokyo ACC instructed Aircraft-B to fly heading 130° for spacing between 15:54:38–15:54:41, but Aircraft-B did not reply. The flight crew of Aircraft-B stated that they did not hear the ATC instruction.

It is estimated that it was difficult for the flight crew to hear the ATC instruction made by the Tokyo ACC based on the following reasons.

- ① According to the ATC radio communications recordings, the DFDR data and the recordings of the TCAS data, since the ATC instruction to Aircraft-B to change heading was issued by Tokyo ACC immediately after the RA aural annunciation had ended, the flight crew may have had their attention focused on coping with the RA.
- ② Based on to the statements of the Captain of Aircraft-B, during a time period of 15:54:38–15:54:41 while Tokyo ACC was instructing Aircraft-B to change heading, it is considered that while the FO (PF) was executing the descent maneuvers to comply with the descend RA, the Captain was advising the FO about Aircraft-B's descent attitude based on his judgment that the sink rate

at that time was low.

- ③ During the time while the ATC instruction was being issued for Aircraft-B to change heading, Aircraft-B's AP was disengaged. Therefore, it is considered possible that the aural warning of the AP disengagement overlapped with the ATC instruction.
 - ④ According to the ATC radio communications recordings, the DFDR data and the recordings of the TCAS data, the ATC instruction to Aircraft-B was issued immediately after Aircraft-A had replied to Tokyo ACC in response to ATC instruction to Aircraft-A to descend to FL350, but the first part of the voice transmission addressed to Aircraft-B, concerning the callsign, was lost. The reason for this is thought to be that although Aircraft-A's radio transmission was over, its VHF transmitter remained keyed ON for a short period after the pilot had finished speaking, and as a result the start of the voice message transmitted by ATC to Aircraft-B was suppressed. Accordingly, it is considered possible that the lack of callsign in the received instruction made it difficult for Aircraft-B's flight crew to ascertain whether the instruction had been intended for them or not.
- (2) According to the ATC radio communications recording, Tokyo ACC instructed Aircraft-B to fly heading 140° for spacing between 15:54:49–15:54:52, but Aircraft-B did not reply. The flight crew of Aircraft-B stated that they did not hear the ATC instruction.

It is thought that it was difficult for the flight crew to hear the ATC instruction made by the Tokyo ACC based on the following reasons.

- ① According to the recordings of TCAS data, at around 15:54:49, 15 seconds after the descend RA had been issued, it was estimated that Aircraft-B's TCAS issued an Increase Descent RA with a greater commanded vertical rate and issued a synthetic voice annunciation of "INCREASE DESCENT, INCREASE DESCENT". It is estimated that the aural annunciation of the Increase Descent RA overlapped the ATC instruction.
- ② According to the statements of Aircraft-B's flight crew and the DFDR data, it is estimated that, at this point of time, the Captain took actions to extend the spoilers and the FO (PF) exerted further forward pressure on the control wheel responding to the Increase Descent RA. Therefore, it is considered that a combination of the Captain's call-out of extending spoilers and the noises and/or mechanical vibrations caused by the spoilers' extension were possible factors.

- ③ It is considered that Aircraft-B's flight crew might not catch the instruction from Tokyo ACC because they concentrated their attention on Aircraft-A that was approaching Aircraft-B and the evasive maneuver.
- (3) Based on the above findings, Aircraft-B's flight crew did not reply to the instructions issued by Tokyo ACC for Aircraft-B to first fly heading 130° and then heading 140°. It was likely that because the flight crew were in the situation where the maneuvers to comply with the descent RA took precedence over other matters, a combination of their concentration on the maneuvers, the Captain's advice concerning the FO's control wheel inputs, the TCAS aural annunciation and the noises caused by the spoilers' extension were possible factors that made it difficult for the flight crew to hear the ATC radio communications.

3.2.4.4 Aircraft-B's Evasive Maneuvers

- (1) According to the DFDR data, the angle of Aircraft-B's control wheel changed from aircraft nose-down direction to aircraft nose-up direction during the 5 seconds before the CPA. In particular, the angle changed significantly at 15:55:05 and 15:55:08. Based on the statements of Captain and FO (PF) of "the other aircraft looked as if was considerably nose down and I could see the top of its fuselage", it is estimated that the Captain and FO pulled their yokes almost simultaneously, deciding it preferable to climb to avoid a collision. A value of vertical acceleration of + 1.84G was recorded on the DFDR at around this time.
- (2) Based on the statements of the Captain and the FO (PF) that while they continued pulling the yoke without relaxing pressure even though they felt the aircraft buffeting, a large aircraft instantaneously passed below, it is estimated that the two aircraft passed through the CPA at around this time. And it is estimated that the time of the CPA was around 15:55:11, as described in section 3.2.1.

During these series of maneuvers, the maximum value of vertical acceleration imposed on Aircraft-A was +1.84G, but no negative G was experienced. Therefore, there were no injuries in Aircraft-B because no passengers or CAs were lifted.

- (3) The DFDR data revealed that the spoilers were retracted at around 15:55:15. It is estimated that the spoilers were retracted to get Aircraft-B to return to normal flight, because Aircraft-B did not have to rapidly descend at around this time.
- (4) Aircraft-B's climb maneuvers immediately before the CPA were contrary to the TCAS command. However, the following factors were considered to have contributed to the above maneuvers.

It is estimated that Aircraft-B descended while its pilots were visually observing Aircraft-A, based on the fact that Aircraft-B's flight crew reported that Aircraft-A was also descending despite Aircraft-B's descent in complying with the descend RA.

It is estimated that Aircraft-B executed the evasive climb maneuver to avoid a collision after visually judging Aircraft-A's abrupt descent under the imminent situation where the two aircraft continued descending and converging. As a result, Aircraft-B's climb maneuvers were contradictory to the descend RA, but in this case it is estimated that such climb maneuvers were appropriate to avoid a collision with Aircraft-A.

- (5) According to ATC radio communications recordings, after the CPA, Aircraft-B informed Tokyo ACC that it had descended to comply with an RA and was climbing back to its original altitude.

3.2.5 Visual Recognition of other aircraft and Avoidance Maneuvers at High Altitude

Concerning the characteristics of visual recognition of another aircraft at high altitude, it is necessary to consider the high altitude environment and the conditions of aircraft in high altitude, high speed flight.

Because there are no reference objects in the background at high altitude, it is difficult to judge the attitude of one's own aircraft or other aircraft, the altitude difference with other aircraft or distances from them. Depending on the weather conditions, contrails may be formed, and it may be possible to recognize the existence of an aircraft flying far away by its contrail even if the aircraft itself is invisible. Further, even if a distant aircraft flying at high speed is visible as a point, it may draw near in a short period of time.

In this accident, it is considered that both aircraft visually acquired each other by their contrails, and this played a part in the later visual acquisition of the other aircraft.

3.2.5.1 Mutual Visual Acquisition of both aircraft while distant before TA issuance

(1) Aircraft-B viewed from Aircraft-A

According to the statements of the flight crew of Aircraft-A, ATC radar and communications recordings and DFDR data, at around 15:46, Aircraft-A received an instruction from Tokyo ACC to climb to FL390, and climbed toward YAIJU.

During the climb, the flight crew of Aircraft-A saw an aircraft with a contrail approximately 40 nm distant in the direction of 11 o'clock, and stated that this aircraft later appeared on the TCAS display, when it was confirmed as being at

around 25 nm distant and flying at FL370.

(2) Aircraft-A viewed from Aircraft-B

According to the statements of the flight crew of Aircraft-B, while Aircraft-B was flying toward OSHIMA VORTAC, it is considered that its flight crew saw an aircraft with a contrail in the direction of 11 o'clock.

(3) Characteristics of Visual Recognition of distant aircraft at High Altitude

According to their statements, the flight crews of Aircraft-A and Aircraft-B, were able to recognize the presence of each other's aircraft at a distance at which it is considered difficult to detect the presence of other aircraft by eyesight alone by their contrails. After that, as they stated that were able to confirm the other aircraft on the TCAS display. It is therefore considered that the flight crews mutually acquired each other's aircraft visually.

In this accident, at the stage prior the issuance of the TCAS TAs, because of the great distance between the aircraft, it is considered that the crews would have only been able to see the other aircraft's contrail, or even if the other aircraft itself were visible they would only have seen it as a point. Given that since the aircraft were at high altitude there were no reference objects against which to judge the attitudes of their own aircraft or other aircraft, that it was difficult to recognize the horizon due to clouds, and that the bank angle of Aircraft-A was changing at around the time its TCAS issued a TA alert, it is considered that it would have been difficult to grasp the position etc. of the other aircraft.

In particular, it is estimated that in consideration of the above-mentioned factors, the recognition of the altitude difference between the own ship and the other aircraft before the TA alerts were issued would have been very difficult by eyesight alone, and it would therefore have been difficult to recognize the altitude difference without the information on the TCAS display.

3.2.5.2 Mutual Visual Recognition of Both Aircraft from the time of TA issuance to just before the CPA.

(1) Visual Recognition and Judgment of Flight Crew Members

Even though the flight crews of Aircraft-A and Aircraft-B were able to see each other's aircraft, a near miss occurred.

The influence of the human visual system on this abnormally close proximity were studied as follows:

Generally, it is considered the visibility of objects is proportional to their visual angle, and in the case of a moving aircraft that is approaching at extremely high relative speed, in order to become visible to the human eye the

aircraft must approach to such a distance that it appears as some size.

In order to avoid a collision in the case that two aircraft approach each other at high speed at an obtuse crossing angle, it is necessary that the pilots accurately grasp the movement of the other aircraft while it is still at a great distance. For example, if two aircraft with the same speeds as those in this accident were approaching head-on, the closure rate would be 15 nm/min.

However, an aircraft at great distance is visible only as a point, and so it is difficult to discern its movements. Moreover, by the time the other aircraft has approached to a distance where its movement can be discerned, it will only be a short time before the CPA.

In the geometry of the approach in this accident, if the distance between Aircraft-A and Aircraft-B were approximately 5 nm, Aircraft-B would subtend an angle of approximately 0.3° viewed from Aircraft-A. This angle becomes approximately 1° at a distance of around 1.5 nm, approximately 2° at a distance of around 0.8 nm, then increase rapidly with further diminishing proximity. Also, because Aircraft-A is longer than Aircraft-B, the angle subtended by Aircraft-A viewed from Aircraft-B would have been 1.3 times greater than the visual angle subtended by Aircraft-B viewed from Aircraft-A. At the relative speed of approach in this accident of approximately 400 m/sec. (approximately 0.22 nm/sec), it requires around 16 sec for the size of the approaching Aircraft-B viewed from Aircraft-A to grow from approximately 0.3° to about 1° , a further 3 sec for it to grow from 1° to around 2° , at which point the aircraft are approximately four seconds from CPA, thence the size increases abruptly.

Note: A visual angle of 1° is approximately equal to that subtended by a 10 cm long object viewed at a distance of 6m.

(2) Aircraft-B viewed from Aircraft-A before the RA

According to DFDR data, Aircraft-A was in a turn before its TCAS issued the RA. It is considered that it would have been difficult to judge that it was possibility approaching Aircraft-B while its heading and bank angle were changing. At the time that the heading of Aircraft-A was towards the south-southwest, according to sunrise and sunset charts Aircraft-B, which was approaching from 30° to the right, would have been backlit by the sun when viewed from Aircraft-A.

Further, it would have been difficult for the Captain of Aircraft-A seated in the left seat, to have been able to discern the movement of Aircraft-B which was approaching from the right.

Considering the above, it is estimated that it would have been difficult for the crew of Aircraft-A to have judged that Aircraft-B was on a collision course until the end of Aircraft-A's turn, whereupon the relative direction of Aircraft-B would have stopped changing and it would have appeared in a fixed position on the windshield, indicating a collision course.

(3) Aircraft-B viewed from Aircraft-A from the issuance of the RA to the CPA

According to his statement, the Captain of Aircraft-A had Aircraft-B in sight at around the time the RA was issued, and Aircraft-B was approaching from forward right at the same altitude. It is considered that while Aircraft-A was turning, it would have been difficult to visually judge from the relative position of Aircraft-B that the aircraft were on a collision course. Given that the Captain of Aircraft-A could see Aircraft-B by its contrail, etc., he complied with the ATC descent instruction, and continued to descend contrary to the climb instruction of RA. In regard to this decision, it is considered possible that since he had Aircraft-B in sight, the Captain of Aircraft-A thought that he could perform avoidance maneuvers visually at the last moment. But, as mentioned (1) above, as both aircraft were approaching at very high relative speed, it is considered that it would have been difficult to accurately estimate the motion of the other aircraft to avoid collision even at 10 sec. before the CPA, when the distance between the aircraft would have been around 4 km (around 2.2 nm). Also, given that the heading direction of Aircraft-A after the end of its turn was around 10° from the planned course due to winds from the right, it is considered that it would have been difficult to estimate the approach with Aircraft-B from the indication of its position on the ND.

The Captain of Aircraft-A stated that during the continuing descent after the RA, just before the CPA, because the relative position of Aircraft-B did not appear to be changing, I looked that if things continued as they were there would be a collision. It is considered that at this point of time, the Captain of Aircraft-A judged that the aircraft were in the dangerous situation of being on a collision course, and trying to deviate from the collision course he applied further nose down. He stated that immediately after that, Aircraft-B appeared to fill the forward windshield while he was trying to fly beneath it, and the collision was avoided”.

Further, according to DFDR data, at the time when the Captain of Aircraft-A applied further nose down, the altitude of Aircraft-B was actually lower than that of Aircraft-A, but because the aircraft had been converging at

high altitude and high speed, it is considered that he could not have precisely estimated the mutual height relationship visually.

(4) Aircraft-A viewed from Aircraft-B from the issuance of the RA to the CPA

According to DFDR data and the analysis of AIDS data of Aircraft-B, since Aircraft-B was in almost straight flight, it is considered that its crew it would have been able to recognize that the aircraft were on a collision course before the crew of Aircraft-A, which was turning. It is estimated that it would have become easy for the crew of Aircraft-B to recognize that the aircraft were entering a collision course after the RA was issued. The Captain of Aircraft-B stated that Aircraft-A appeared to be approaching from forward left while its appearance was not changing, and it is thought that he recognized that he recognized visually that the aircraft were on collision course after Aircraft-A had completed its turn.

It is estimated that as the size of Aircraft-A viewed from Aircraft-B became approximately 1.7° at around 15:55:05, at which point it would have been possible to discern its attitude. According to the statements of Aircraft-B's pilots, Aircraft-A appeared to be in a large nose down attitude, and judging that it was trying to increase its rate of descent, they quickly pulled back on the control columns while increasing thrust to avoid a collision. According to Aircraft-B's DFDR data, the effect of pulling the control columns appeared at 15:55:06, when the vertical acceleration increased greatly on the positive side, and rate of descent reduced greatly. It is considered that just after that, the collision was avoided with Aircraft-B passing over the top of Aircraft-A.

3.2.5.3 Avoidance Maneuvers during each stage of the Approach of the Aircraft

(1) Avoidance by complying with ATC instructions

In this accident, both Aircraft-A and Aircraft-B were equipped with TCAS. At the time when the CNF alert was issued at Tokyo ACC and the TCAS Tas were issued on Aircraft-A and Aircraft-B, Aircraft-A was climbing to FL390 in compliance with an instruction from Tokyo ACC, while Aircraft-B was in level flight at FL370. Since both aircraft were operating under Instrument Flight Rules, in principle safe separation should be ensured if the aircraft comply with instructions from air traffic control. If air traffic control establishes normal Instrument Flight Rules separation, separation of 5 nm laterally or 2,000 ft vertically should be obtained.

The number of aircraft operating in accordance with Instrument Flight

Rules was controlled by the Air Traffic Flow Management Center, but as the relation with weather condition and the situation of air traffic congestion, etc., concerning establishment of separation, at a time, the ATC instruction which exceeded the principle was issued and also as the situation of air traffic was changed hourly, it is possible for such situation to occur as that the maintenance of separation was over the expectation, and became difficult.

Pilots are required to communicate with air traffic control to request clearance in the case of deviation from the course instructed by ATC. However, in this accident, at the time that the TAs were issued, it is considered that the flight crews were not able to anticipate a situation occurring that would have necessitated a change of course.

(2) Mutual Visual Acquisition before TA issuance and Avoidance by complying with the Right of Way

At the time the TAs were issued, it is considered that flight crews of Aircraft-A and Aircraft-B had mutually sighted each other's aircraft. However, as described in sections 3.2.5.1 and 3.2.5.2, it is considered difficult to judge safe separation purely visually. Also, while the flight crew would have been able to confirm the existence of the other aircraft on the TCAS display, it is possible that there was insufficient accuracy concerning the direction, the rate of altitude change and flight route of the other aircraft at that time. Consequently, it is necessary for flight crews to try to confirm the other aircraft by both visual search and using information on the TCAS display together.

Concerning the case of performing avoidance maneuvers in accordance with the right of way, according to the Article 181 of Operating Standards, Civil Aeronautic Regulations, it is specified that "An aircraft seeing another aircraft to the right shall yield the way", and the same rules was established in the regulations in Article 182, Article 186 and Article 187 of said Operating Standards. In order to conduct flight safely by complying with the right of way rules, it is prerequisite that both aircraft sufficiently mutually confirm the flight situation. However, in the case of this accident, as the aircraft were flying at high altitude at which there were no objects for comparison, and moreover, since relative distance between the aircraft was initially great, it is considered that it would have been difficult to mutually confirm at an early stage whether the situation was appropriate to avoid the other traffic by following the right of way. Further, while it is necessary to recognize the movement of the other aircraft with sufficient accuracy in order to judge from information on the TCAS display

whether to avoid other traffic by complying with the right of way, it is considered that this would not have been possible at this stage due to the distance between the aircraft.

Further, even if Aircraft-A and Aircraft-B continued to approach each other, the situation would persist for sufficiently long that it would be expected that an appropriate instruction to ensure separation would be issued by ATC. And, as both aircraft were equipped with TCAS, as the situation developed it is considered possible that such a situation would continue for a period of time such that the avoidance from approach by this equipment would be expected.

If an aircraft which is flying in accordance with Instrument Flight Rules judges by visual search and information on the TCAS display that there is the risk of a loss of separation with another aircraft, reports such to air traffic control, then maneuvers to avoidance a collision in accordance with the right of way, etc., then the air traffic flow will become confused. In particular, in the sector in which the accident occurred, where there are many aircraft descending from cruise or taking off then climbing to join air ways, if it is not under the situation that it is clear sufficiently to be necessary for course change, it is considered that it is difficult that flight crewmembers perform the course change in accordance with the right of way early.

(3) Avoidance Maneuvers after TA Issuance

As described in section 3.2.3.3, Tokyo ACC called Aircraft-A just after its TCAS issued a TA. However, the flight crew of Aircraft-A stated that the TA had been issued after the descent instruction from Tokyo ACC. It is considered that from the point of view of the Captain of Aircraft-A, there would not have been sufficient time margin to respond to the TA.

On Aircraft-B, it is considered that the auto throttle was disengaged after the issue of the TA, as preparation in anticipation of an RA.

Concerning visual acquisition of the other aircraft at the time of issuance of a TA and the response thereafter, the AIC issued by JCAB describes “While trying to visually acquire the other aircraft, if no traffic information had been provided by the air traffic control facility, it is desirable to confirm the traffic with the air traffic control facility”.

Also, the AIC (English version), PANS-OPS issued by ICAO, the AFMs and AOMs of Aircraft-A and Aircraft-B, and the Advisory Circular issued by the FAA, state that pilots should not perform avoidance maneuvers as the result of a TA, and that in the event of a TA, should try to visually acquire the other aircraft.

Combining the descriptions in the PANS-OPS issued by ICAO and the AFMs of Aircraft-A and Aircraft-B, the reasons that avoidance maneuvers should not be performed only as the result of a TA are that at the point in time a TA is issued, the accuracy of the direction of the other aircraft is not always sufficient, and it is also difficult to interpret its rate of altitude change and course. Consequently, the purpose of the TA is to support the pilot's visual acquisition of the other aircraft, and warn about possible issuance of an RA.

In the situation that an intruder aircraft is equipped only with a Mode-A transponder, so the own aircraft's ACAS only operates in traffic advisory mode, while it is possible for the aircraft to approach either other without an RA, visual acquisition of the intruder at the time of the TA would enable the pilots to clearly recognize the movement of the intruder, and if the pilots judged that given the aircraft were on a collision course, to communicate this to the air traffic control facility and carry out avoidance maneuvers.

Further, the AFMs on Aircraft-A and Aircraft-B, during climb or during descent, in the condition as TA issued, it is described as that it is not regarded the changing slowly the vertical speed on basis of the information on The TCAS screen as avoidance maneuvers.

In view of these facts, the following are concluded concerning the visual recognition of intruder aircraft at TA issuance and the following response:

- ① If an aircraft's pilots are able to confirm the movement of an intruder aircraft visually, in addition to information on the intruder from the TCAS display and from ATC, and judge that the aircraft are on a collision course, it is considered that they should perform a heading change in accordance with the right of way and report to that the effect to the air traffic control facility.
- ② There may only between ten and twenty seconds from a TA to the issuance of an RA, and in the case that an RA is issued it is necessary to perform the operations to comply with it quickly. The TA is considered as a means of warning the pilot concerning the possibility of an RA, and in the case that an avoidance maneuver is not performed as a result of the TA as in the above paragraph, it is preferable to take precautions and to prepare for a possible RA when a TA is issued. This is considered the appropriate response for the case that both aircraft are TCAS-equipped. Also, if there is time to spare, it is desirable to request traffic information from air traffic control.

However, it is necessary to keep in mind the possibility that the intruder aircraft is equipped only with a Mode A transponder, so the own aircraft's

TCAS will function in TA-only mode and will not issue an RA even if the aircraft approach closely.

(4) Avoidance Maneuvers to comply with an RA

Aircraft-A's Captain judged that the conditions would allow him to avoid the other aircraft by descending, and so performed a descent. Details concerning this judgment are described in section 3.2.3.6, but the following factors were involved.

- ① The Captain had the other aircraft in sight, and was aware that it was indicated on the TCAS display.
- ② The Captain considered that the ATC instruction to descend was transmitted in order to maintain separation with the other aircraft. He also considered that air traffic controllers carry out control while understanding the general flight situation in the controlled airspace for which they are responsible, and that it was possible that the instruction had been issued considering factors other than the intruder aircraft.
- ③ The Captain had not been sufficiently aware of the importance of complying with RAs, and the dangers of operating the controls opposite to the RA's avoidance instruction.

As mentioned in (1) above, in the condition that a loss of separation may occur, according to the manuals issued by ICAO, the TCAS installed on aircraft should automatically issue an RA avoidance instruction to preserve sufficient separation. As the Captain of Aircraft A had the other aircraft in sight and he had also recognized it on the TCAS display, it is considered that he judged to be able to avoid the approach with the other aircraft by visually performing avoidance maneuvers at the last moment. However, since it is considered to be difficult at high altitude to visually estimate the movement of another aircraft which is approaching at very high speed until the distance has considerably reduced, and that it is also considered difficult to grasp the vertical separation with the other aircraft, it is effective to comply with the TCAS RA to avoid dangerous approach. However, as the AIC states "In the event of carrying out avoidance maneuvers in accordance with an RA, while visually searching for the aircraft with which there is risk of collision, the pilot must...", it is required that the pilot attempt to visually acquire the other aircraft without necessarily complying mechanically with RA instruction.

Further, in this accident, it is estimated that the descent instruction from air traffic control was communicated the incorrect flight number. Moreover, as described in section 3.2.9.2 (2), even if the ATC instruction were not mistaken in

such a way, it is still possible that the instruction will be contrary to the TCAS avoidance instruction. For example, there is a 2–13 second time delay in the aircraft position and altitude information displayed on the air route radar PVDs that air traffic controllers use to carry out their control duties.

If in case that ATC issues an instruction contrary to an RA, it is necessary to comply with the RA as the RA instructions are mutually coordinated between the TCAS units on both aircraft, if both aircraft are TCAS-equipped. Also, since at the time an RA is issued the situation has already been reached in which it is impossible to secure safe separation by complying with ATC instructions, and considering that there time delays of 2–13 sec in the position and altitude indications displayed on the air route radar displays, it is necessary to perform avoidance maneuvers to comply with TCAS, which is equipped as a backup system to ensure separation alternatively. Further, because the air traffic control and TCAS systems to ensure safe separation are separate and independent, there is no way to ensure safety in dense traffic if one aircraft complies with an ATC instruction contrary to a TCAS RA while other aircraft comply with TCAS. Therefore, it is necessary to recognize sufficiently the importance of complying with an RA avoidance instruction at the time it is issued.

On the other hand, concerning response of the air traffic control facility, in the case that they are notified by an aircraft that it is performing avoidance maneuvers in accordance with an RA, when they recognize that the aircraft is maneuvering in response to an RA they should not transmit new instructions but offer whatever traffic information can be considered as necessary to the extent that it is practically possible.

Also, Advisory Circular (AC-120-55A) issued by the FAA states, “Even if a TCAS RA maneuver is inconsistent with the current clearance, respond appropriately to the RA. Since TCAS tracks all transponder-equipped aircraft in the vicinity, responding to RA for an intruder assures a safe avoidance maneuver from that intruder and from other mode C-equipped aircraft.”, and “ATC may not know when TCAS issues RA's. It is possible for ATC to unknowingly issue instructions that are contrary (opposite) to the TCAS RA indications. Safe vertical separation may be lost during TCAS coordination when one aircraft maneuvers opposite the vertical direction indicated by TCAS and the other aircraft maneuvers as indicated by TCAS.”. Further, Guidance Material (CAP579) concerning TCAS issued by the CAA, in describing about the responses of pilots to an RA, states that “If pilots receive simultaneously an instruction to maneuver from ATC and an RA, and both conflict, the advice given by ACAS

should be followed.”.

According to the report “Analysis of operational evaluating result on Airborne Collision Avoidance System Installation” issued by ENRI (Feb. 1995), an analysis of domestic pilot reports of 77 cases of RA issuance in the period from the end of 1992 to Feb. 7, 1994, showed that 36 of the RAs had occurred while on an air route, and stated “had been approaching in altitude because of complying with ACAS on air route, or could not find the encountering to danger as to be kept small altitude difference”.

(5) Avoidance Maneuvers at the Final Stage of an encounter

Following an instruction from Tokyo ACC, the flight crew of Aircraft-A performed a descent contrary to the climb instruction of the RA, while the flight crew of Aircraft-B descended in compliance with the RA issued by the TCAS on their own aircraft. As a result of both aircraft continuing to descend, it resulted that they both made evasive maneuvers visually just before the CPA. It is estimated that the seeing the abrupt descent of Aircraft-A, the pilots of Aircraft-B pulled up to avoid a collision, and it is considered that this was an appropriate maneuver.

(6) Summary of Close Proximity Avoidance Methods for Aircraft flying under Instrument Flight Rules

Aircraft with a risk of near miss or collision should maneuver to avoid each other with ample time margin in order to prevent the situation progressing to a state of imminent collision as described in (5) above, necessitating avoidance maneuvers at the final stage.

Given that it is difficult to visually recognize the movement of an intruder aircraft at an early point in time for aircraft flying at high altitude and at high speed, as described in section 3.2.5.1 and in (2) above, it is difficult to expect that the avoidance maneuvers can be performed appropriately on basis of the right of way on the assumption of visual contact with an intruder aircraft.

An aircraft flying under instrument flight rules operates in accordance with ATC instructions from an air traffic control facility. Therefore, as described in subsection (1) above, it is first necessary to ensure that ATC instructions maintain the prescribed separations between aircraft. In order to do this, it is necessary that air traffic control recognize at an early stage when aircraft may be approaching each other, and give precise instructions.

Even if ATC instructions are complied with, however, it is possible that a situation in which prescribed separation cannot be maintained may arise. In

such occasions, as described section (2) above, it is considered that pilots should try to grasp the intruder aircraft both visually and using the TCAS display, and should perform avoidance maneuvers in accordance with the right of way after reporting doing so to air traffic control. But at high altitude and at high speed, where it be difficult to discern the movement of the intruder aircraft either visually or precisely enough using the TCAS display, and where the aircraft is operating under instructions from ATC under instrument flight rules, the judgment of the necessity and timing of the avoidance maneuvers and report to ATC may be difficult, and in practice it would be difficult to perform such actions for avoidance at this stage.

It is required that aircraft should not perform avoidance maneuvers solely as the result of a TA, since it may not be possible to grasp sufficiently the movement of the intruder aircraft from only the information on the TCAS display, and it is also required that in the case that a TA is issued, the pilots try to acquire the intruder aircraft visually. Also, it is considered that TAs are issued to alert pilots to the possibility of an RA, and to allow them to prepare accordingly. It can then be considered that pilots confirm the intruder aircraft visually following a TA, and then perform avoidance maneuvers after reporting to air traffic control.

If such avoidance maneuvers are not carried out, it is considered appropriate to wait for the RA, if any, then to perform the avoidance maneuvers complying with it, because there may only be a short time between a TA and the issuance of an RA, and because the RA avoidance instruction is coordinated between the own ship and the intruder. However, as described in the above subsection (3), in the case the intruder aircraft is only equipped with a mode A transponder, and so the own TCAS will operate in TA-only mode, there will be no RA issued, and it is therefore necessary to keep in mind the possibility of reaching a condition of dangerous proximity.

In the case that RA issued, as described above subsection (4), it is effective to maneuver in accordance with the RA instruction to avoid collision. Considering the RA, the direction of the RA instructions are coordinate between the TCAS units of the two aircraft concerned, it becomes effective to avoid the approach by both aircraft performing the avoidance maneuvers complying exactly with their respective RAs. Consequently, it is necessary for flight crew to recognize sufficiently the necessity of complying with RA avoidance instructions.

3.2.6 The closest distance and the altitude difference between the two aircraft

3.2.6.1 Synthetic analysis by the Electronic Navigation Research Institute

Based on analysis in cooperation with the Electronic Navigation Research Institute of the recorded ATC radar data and the TCAS data logged by the ACMS of Aircraft-A and by the AIDS of Aircraft-B, the calculated values of the closest distance and the altitude difference between the two aircraft in this accident are given below. The methods of analysis methods are summarized below in(1) and (2).

	Mean value	Standard deviation
Closest distance	135m	30m
Altitude difference at the time of closest distance	130ft (about 40m)	70ft (about 20m)

Note: The range of “Mean value $\pm$ Standard deviation” falls within the margin of error of the calculation. However, in general, the probability of the true value being within the error range is 68%.

(1) Analysis of the closest distance

① Analysis of recorded ATC radar data

The recorded ATC radar data gave the flight paths of Aircraft-A and Aircraft-B as discrete values at regular intervals of time concurrent with the antenna’s rotation, as well as series of points that contain the scatter errors in the azimuth measurements of the two aircraft. From this data, the chains of points corresponding to Aircraft-A and Aircraft-B were connected as smoothly as possible, with approximating curved lines used to connect the neighborhood of each point to form a path. The resulting curves showed the flight paths of the two aircraft in three-dimensional X, Y and Z coordinate space, and provided continuous X, Y and Z values as a function of time (t). As a result, it is possible to obtain the X, Y and Z coordinates in 3-D space of Aircraft-A and Aircraft-B at arbitrary time, and to specify the closest distance between them.

② Improving accuracy by the use of TCAS data recorded by the ACMS

The following method was used to improve the accuracy of the calculations.

The ACMS of the Aircraft-A had recorded the TCAS-computed azimuth and distance data of Aircraft-B measured from Aircraft-A. However, since the TCAS program had transformed measured distance data into predicted and rounded figures, no actual distance data could be obtained.

Regarding the positions of Aircraft-A and Aircraft-B at the time of closest proximity, it is considered that the positions of the aircraft represented as X, Y

and Z coordinates lie within the population distribution represented by the average value and standard deviation. Therefore, pairs of position samples were taken — the one position sample from the population distribution of Aircraft-A, the other from the population distribution of Aircraft-B — and the paired samples tested for whether they conformed with the TCAS-computed azimuth and distanced data. By this means a collection of position samples which conformed to the TCAS computed data were obtained. Subsequently, the estimate of the closest distance between the aircraft was re-examined and its accuracy was improved. As a result, the estimated value of closest distance has an average value of 0.073 nm (135 m) and a standard deviation of 0.017 nm (30 m). As a note, the closest distance was measured (slant range) between the two aircraft's TCAS antennas.

Just prior to the closest proximity, Aircraft-B crossed the path of Aircraft-A above it from right to left, with an angle of intersect of about 100° projected onto the horizontal plane. The ground speed of Aircraft-A was approximately 490kt (about 250 m/s) and that of Aircraft-B about 550kt (about 280 m/s).

(2) Analysis of the altitude difference

① Analysis of recorded ATC radar data

Given the two flight paths as defined in the (1) ① above, the calculated altitude difference between Aircraft-A and Aircraft-B at the time of the closest proximity was 130 ft (about 40 m), and the standard deviation in the vertical direction was about 38 ft (12 m). The since altitude is broadcast by transponders as discrete values with no error information, the calculated standard deviation and range of error are small.

Furthermore, given that the characteristic error of the altimeter of each aircraft was 40 ft, the calculated standard deviation of error would have been 70 ft (about 20 m).

② Improving accuracy by the use of TCAS data recorded by the ACMS

The ACMS data of the altitude difference between the two aircraft was in units of in 100 ft. However, the value of the altitude difference was derived from the smooth curved line of altitudinal variation averaged with respect to time. Any pair of data on the altitude of the two aircraft might have given any answer in almost any cases even when their applicability to the calculation accuracy had been examined. Consequently, it was revealed that the ACMS data was worthless for improving the calculation accuracy. For this reason, the value of the altitude difference determined was as calculated in (2) ① above.

(Ref. Figure 22)

3.2.6.2 Analysis based on the flight crews' oral statements

According to the statement of the Captain of Aircraft-A, his aircraft passed under Aircraft-B, and at that time, the entire fuselage of Aircraft-B appeared to fill the forward windshield. The heading (magnetic course) and speed of each aircraft just prior to the closest proximity were estimated based on DFDR data. Given that the altitude difference had been 130 ft (the calculated mean value in the section 3.2.6.1 above), the validity of the computed closest proximity distance (also given in section 3.2.6.1 above) was evaluated by varying the closest horizontal distance and comparing the size that Aircraft-B would have appeared from Aircraft-A with the Captain's statement.

- (1) If the closest distance between the aircraft had been 105 m, equivalent to "mean value minus standard deviation", and the altitude difference had been 130 ft, the closest horizontal distance would have been about 100 m. In this case, at the point in time when Aircraft-B crossed directly ahead of the nose of Aircraft-A, the horizontal distance would have been about 140 m, and the angle of elevation about 21°; and at the time of the closest distance, the angle of elevation would have been about 28°. Furthermore, Aircraft-B would have appeared to traverse the width of the left (Captain's side) windshield of Aircraft-A in about 0.36 seconds. Further, the visual angle of Aircraft-B from Aircraft-A at the time of that Aircraft-B was directly in front of Aircraft-A would have been about 17°, and the largest value of visual angle about 30°.
- (2) Given a closest proximity distance of 165 m equivalent to "mean value plus standard deviation" and an altitude difference of 130 ft, the closest horizontal distance would have been about 160 m. In this case, at the point in time when Aircraft-B crossed directly in front of Aircraft-A, the horizontal distance would have been about 230 m and the angle of elevation about 15°; and at the time of closest distance, the angle of elevation would have been about 20°. Furthermore, Aircraft-B would have appeared to cross the width of the left windshield of Aircraft-A in about 0.64 seconds. Further, the visual angle of Aircraft-B from Aircraft-A at the time that Aircraft-B was directly in front of Aircraft-A would have been about 12°, and the largest visual angle about 18°.

The validity of the closest distance given in the section 3.2.6.1 above as $135 \text{ m} \pm 30 \text{ m}$ was examined based on findings of the above analysis. An altitude difference of 130 ft and a closest distance of 105 m would have given the same result

as stated in (1) above, and an altitude difference of 165 ft would have given the same result as stated in (2) above. In both cases, there was no contradiction with Aircraft-A's Captain's statements that Aircraft-A passed under Aircraft-B, and that the whole fuselage of Aircraft-B filled the front windshield.

If the closest distance value had been less than 105 m, it is possible that a part of the left wing and fuselage of Aircraft-B might have passed out of sight. On the other hand, if the closest distance value had been greater than 165 m, there may have been less belief that the aircraft had passed under Aircraft-B. Consequently, the calculated values in section 3.2.6.1 are consistent with the Captain's impressions at the point of closest approach as described in his statements.

(Ref. Figure 22)

3.2.7 The Coordination between Flight Crewmembers

3.2.7.1 The coordination among the flight crew of Aircraft-A

The Aircraft-A had four flight crewmembers — the Captain, the First Officer and two pilots training for upgrade to First Officer. Japan Airlines' OM states that "the Captain shall bear ultimate responsibility for aircraft operations." In addition, the OM states that if the Captain judges that it is necessary to ensure the safety of flight, he/she may make quick decisions based on his/her best judgment of the circumstances, irrespective of stipulated rules and regulations; and if the Captain makes a judgment regarding flight operations, each flight crew member shall proactively give helpful advice to him.

According to the statements of the flight crewmembers of Aircraft-A, even after the RA warning of "Climb" was issued, the Captain stated to the other flight crewmembers that he would continue descent. It is possible that the no flight crew member gave proper advice about Captain's management of the flight at the appropriate moment. Such advice should have included a suggestion about climbing to follow the RA indication, expressed in such a manner that the Captain would have been able to recognize it clearly.

Since the statements of all flight crewmembers of Aircraft-A described in detail how Aircraft-B neared and passed by, it is considered that almost all the attention of all the flight crewmembers may have been directed to looking outside for taking evasive maneuvers. Thus, the PNF may not have properly performed his duty, namely, his responsibility of monitoring the TCAS traffic display as defined in the AOM Supplement.

The Captain and the three other flight crewmembers were on duty in the cockpit of Aircraft-A. The Captain concentrated on management of the flight to maintain the

aircraft's attitude and carry out escape maneuvers. It is possible that the other flight crewmembers may have been able to fulfill their duties, including checking the TCAS display, etc, and bring about a possible change of the Captain's judgment by providing appropriate advice about Aircraft-B. In respect to this matter, the two trainees, who were seated in the right-front and right-rear seats, from their standpoint of receiving training, may have been too inexperienced to advise the Captain.

The first officer was seated in the left jump seat providing advice about the trainees' activities. According to Japan Air Lines' OM, "The copilot shall assist the PIC during the whole flight, and, in the case of an unexpected situation occurring with the PIC, immediately take over his/her tasks". However, according to the statements of Aircraft-A's flight crewmembers, the first officer, who was seated behind the Captain's seat, may have been in a position in which his view of the ND, which functions as TCAS display among others, was obstructed by the back of the Captain's seat, control wheel, etc. If the trainee in the front seat had taken over flying, it is considered that the first officer would have been able to assist him by carrying out practical PNF activities even while keeping his rear-positioned seat. And if the first officer judged that a situation had arisen that trainee had was having difficulty in coping with, he should have taken over the trainee's PNF duty as much as practicable. Moreover, the first officer, while giving the trainee guidance, should have kept the instruments within easy sight so as to be able to give appropriate advice to the Captain as necessary. However, at the time of the accident, when there were no operator's written regulations governing the matter, it is thought that the first officer's seat was in an inconvenient position for giving the trainee guidance in this respect.

It is considered possible that the first officer of Aircraft-A advised the Captain of the descending traffic, but the Captain may not have been aware of this or, since the advice only indicated the condition of the other aircraft based on apparent fact, the first officer's message might not have been regarded as proper advice. The advice ought to have contained a clear indication to follow the RA and climb. On this point, although the first officer had recognized the RA aural warning, he might have had difficulty seeing the TCAS display for information on the conflicting traffic, so the first officer's difficulty in positively recognizing from the TCAS display that the own aircraft should climb may have been involved.

In relation to the Captain's activities, CRM training ought to have been given on creating an atmosphere and environment on the flight deck such that other flight crewmembers would have felt able to give appropriate advice whenever, in their

judgment, the safety of the flight was in jeopardy.

Moreover, for the training of the trainees, when the trainee was acting as PNF seated in the first officer's position, the role of first officer seated in the jump seat ought to have been defined. And, if the first officer judged that they had encountered a situation in flight in which the trainee had difficulty coping, the first officer should have taken over the trainee's PNF duties as much as practicable.

3.2.7.2 The coordination among the flight crew of Aircraft-B

The flight crew complement of Aircraft-B consisted of the Captain (the Pilot in Command, and Pilot Not Flying), the First Officer (who assumed flying duties as Pilot Flying), and the Flight Engineer. As the First Officer was in training for upgrade to Captain, the flight crew as a whole may have had a higher level of judgment compared with a regular flight crew complement.

The statements of the flight crewmembers of Aircraft-B indicate that they had no memory of some communicated messages transmitted by Tokyo ACC, or that they were hardly able to catch what the controller said. However, after the descend RA was annunciated, in response the first officer's (PF) inadequate descent maneuver, the Captain (PNF) advised "descend more please", thus bringing about a suitable correction to the descent rate. Concurrently with the annunciation of the increase descent RA, the Captain announced "extending speed brakes", followed by this action, and also turned on the seatbelt sign in accordance with PNF duties. Furthermore, when the conflicting Aircraft-A increased its descent still further, both the Captain and the first officer almost simultaneously pulled back on the control yokes. Consequently, it is considered that the adequate operations were demonstrated in the brief space of time, although the situation pressing. During that time, since the Captain of Aircraft-B advised the first officer about his awareness of the movement of the other aircraft and about the descent rate, it considered that his response actions were appropriate under the circumstances. Further, the task-sharing responsibilities for both the PF and PNF stated in Aircraft-B's OM Supplement are considered to have been carried out appropriately.

There is no specific regulation about the responses of the flight engineer to TCAS activation. Japan Air Lines' OM indicates that the "Flight engineer shall monitor ATC radio communications, flight path (mainly altitude), etc. in order to give back up assistance to the PIC and the first officer". In this accident, it is thought that the flight engineer exercised his responsibility with regard to coordination among the flight crewmembers of Aircraft-B.

3.2.8 The Coordination between ATC Controllers

3.2.8.1 The Coordination between the ATC trainee and the ATC watch supervisor

It is estimated that up to the time that the CNF alert was issued, the ATC trainee and the ATC watch supervisor had both forgotten the presence of Aircraft-B. At the time when the ATC trainee was establishing communication with Aircraft-B and was calling Aircraft-C, it is considered to be likely that the ATC watch supervisor was carrying out coordination work with the adjacent sector that should be originally have been conducted by the controller seated at the radar coordinator's console.

Further, at a time when it was judged that air traffic flow was settled, the ATC watch supervisor conducted an explanation of the tasks accomplished up till that time, but since both the ATC watch supervisor and the ATC trainee were concentrating on the contents of the explanation, it is considered that their grasp of the Air traffic situation on the PVD became insufficient.

When the ATC watch supervisor administered training to the ATC trainee seated at the radar R/G console, she should have maintained a condition in which she was able to supervise the ATC trainee, she should have concentrated leading and supervising the ATC trainee on the duties for he was responsible, and if she encountered a situation where she judged that the ATC trainee would having difficulty coping, as the case of an unexpected CNF, aircraft in an urgent situation etc., she should have responded and taken over from the ATC trainee at once.

In this accident, it difficult to say that appropriate coordination existed between the ATC trainee and the ATC watch supervisor. But the standards and manuals had not been compiled for ATC watch supervisors that described concrete methods for training and about the coordination with between ATC trainee and ATC watch supervisor, and neither had any particular training had been conducted in this regard.

3.2.8.2 The coordination between ATC controllers in the same sector

In urgent situations, it is difficult for the coordinator to immediately support the work of the radar controller, but at the time in this accident before the CNF alert was issued, it is considered that it was possible to support and advise the person on the radar control console.

As to the situation that it is difficult for the coordinator to provide support to the radar controller at once in the urgent situations, as described in section 2.13.2.2, while the radar controller directly communicates with aircraft, the main work being

to respond to the flow of air traffic in real time, the coordinator's tasks include coordination with other facilities, issuing clearances to aircraft before take off etc., and these tasks are carried out to adjust the flow of traffic a comparatively long time scale. Further, it is considered that in an urgent situation, if he had advised without grasping the situation sufficiently, it might have confused the situation further.

In the case of this accident, it is considered to have been possible to that the coordinator could have advised and supported the radar controller before the issue of the CNF alert as follows:

- ① On the rack of the console in which the strip of Aircraft-A was arranged, as the coordinator inserted the strip of Aircraft-A, which had taken off from Tokyo International Airport at 15:36, into the rack, he could have compared it to the strip of Aircraft-B which was already in the rack, examined the possibility of conflict between Aircraft-A and Aircraft-B, and called this to the attention of the radar controller by annotating the strip.+
- ② The procedures until hand off of Aircraft-C, which are considered to have been conducted by direct verbal communication with the adjacent sector, are nominally the duty of the radar coordinator. However, it is considered that if necessary, the coordinator should also participate positively to coordinate the process from change of radar point out to radar hand off through to completion of establishment of radio communication. However, in the case of the accident, it is considered that many of the necessary coordination regarding Aircraft-C was conducted by the ATC watch supervisor, and it is considered that this was a factor in the ATC watch supervisor's failure to hear the communication with Aircraft-B, and her inability to be aware of Aircraft-B on the PVD.
- ③ It is estimated that if the coordinator had had a chance to inspect the PVD and had recognized the presence of Aircraft-A and Aircraft-B, as described in section 3.2.2.8 (7), in the 30 sec. to 1 min. before the CNF was issued, it would have been possible for him to recognize that a situation could develop in which it would no longer be possible to maintain the prescribed separation between Aircraft-A and Aircraft-B, and he could have brought this to the attention of the radar controller.

However, it is considered that he would not have had the chance to perform such actions at this time, because he was busy handling contact coordination with other facilities, posting new strips, transferring aircraft information changes to the strips, and so forth.

In any case, in order to prevent air traffic controller human errors, it is required that air traffic controllers cooperate, it is necessary to confirm even matters which are considered to be known already, and an atmosphere is also required which allows them to do so easily. Further, there were no standards specified for coordination and cooperation between air traffic controllers, and no specific training was conducted.

3.2.8.3 Coordination with adjacent sectors

In relation to this accident, it is considered that the mutual exchange of intentions regarding the handling of Aircraft-C was not performed smoothly between the controllers of Kanto South C sector and Kanto South B sector. It is considered that the ATC watch supervisor had judged that the altitude separation between Aircraft-A and Aircraft-C should be established quickly, and for this reason that it was necessary that Kanto South C sector establish radio communication with Aircraft-C early. But it is considered possible that the radar controller of Kanto South B sector thought that if were to perform an altitude change of Aircraft-C when he received the hand off of Aircraft-A from Kanto South C sector, he would be able to establish separation with time to spare. Furthermore, it is considered that the air traffic controller of Kanto South B sector did not instruct Aircraft-C to change frequency immediately, even after he had completed its hand-off to Kanto South C sector.

In the case of cooperatively performing work, the work coordination should be conducted at an appropriate time within a short period, but there should not be a difference in the mutual understanding. For this reason, work coordination should be conducted concretely and simply, standards setting out the minimum specialist terms or phases for work coordination are necessary, and samples of such terms etc. should be illustrated.

Further, coordination between sectors should not depend on simple and direct conversation if the control consoles are adjacent, since it is necessary that the mutual understandings be conveyed conduct accurately. If such work coordination is carried out by direct conversation without using a direct line, it cannot be confirmed whether the partner in the coordination is communicating with an aircraft or other facility, and there is the possibility that information will not be communicated precisely and understanding will not be obtained. Usage of direct lines for work coordination is brief and is considered effective.

3.2.9 Coordination between flight crews and air traffic control

In the investigation of this accident, it became clear time and again that to ensure the flight safety of aircraft it is extremely important that the coordination between flight crews and air traffic control should function smoothly, and that necessary information should be transmitted accurately and appropriately. This section considers the coordination between flight crewmembers and air traffic controllers, and in particular examines the information communication with between aircraft and air traffic facilities.

3.2.9.1 Details of the information communicated in this accident

In order to grasp the situation at the air traffic facility while the aircraft were approaching each other, and to highlight the communication of information between aircraft and air traffic facilities concerning avoidance of close proximity between aircraft, details of the communications in this accident is shown as follows.

(The times listed below and in the following sections 3.2.9.1 and 3.2.9.3 are the times of commencement of the events.)

15:54:15; A CNF alert was displayed on the PVD of Kanto South C sector, Tokyo ACC.

(In the case of that both aircraft fly straight, a CNF is issued 3 min. before predicted loss of separation, but in this accident, the issuance of CNF was delayed by about 2min. 30 sec. and was issued 56 sec. before the time of closest proximity of the two aircraft.)

15:54:18; TA issued on Aircraft-B

15:54:19; TA issued on Aircraft-A

15:54:27; Tokyo ACC confused the flight numbers of Aircraft-A and Aircraft-B, and instructed Aircraft-A to descend FL350 instead of Aircraft-B.

15:54:33; Aircraft-A responded by reading back the instruction to descend to FL350, stating its own call sign.

15:54:34; Descent RA issued on Aircraft-B. Aircraft-B commenced descent to comply with the RA.

15:54:35; Climb RA issued on Aircraft-A. Aircraft-A continued to descend in accordance with the instruction from ATC, but contrary to the RA instruction.

15:54:38; Tokyo ACC instructed Aircraft-B to change heading to 130°, but received no response.

15:54:49; Tokyo ACC instructed Aircraft-B to change heading to 140°, but received no response.

15:54:55; Tokyo ACC instructed JAL 957 to descend. The corresponding aircraft did not

exist.

15:55:02; Tokyo ACC instructed Aircraft-A to climb to FL390, but received no response.

15:55:11; Closest proximity between Aircraft-A and Aircraft-B.

15:55:21; Aircraft-B informed Tokyo ACC that RA issued and that it was descending,
etc.

15:55:32; Aircraft-A informed Tokyo ACC that it was clear of conflict.

15:59:22; Aircraft-A informed Tokyo ACC that it had had a near miss with a DC-10.

3.2.9.2 Analysis of information communication in this accident

(1) CNF issued at Tokyo ACC

CNF is a collision avoidance system that is independent of TCAS installed on aircraft. As described in section 2.12.4.2, it is specified that CNF be issued 3 min. before prescribed separation is lost, and as described in section 2.12.2.2, it designed to issue a warning at an earlier stage compared to the TCAS TA and RA, which are issued less than one minute from the predicted CPA. Thus, in the case in which loss of separation between aircraft is expected, the air traffic controller can be made aware of the impending situation and issue appropriate instructions to the relevant aircraft with time to spare. And even if an air traffic controller has forgotten about an aircraft, the CNF function should make it possible to alert the controller so that an instruction to secure separation may be transmitted at an appropriate time. But if the issue of the CNF alert is for some reason or other and the air traffic controllers do not realize an impending loss of separation, then ensuring separation by communication of ATC instructions becomes very difficult or no longer possible.

In this accident, the issue of CNF was delayed about 2min. 30sec. from the specified 3 min. before loss of IFR separation, but as described in section 3.2.2.7, because Aircraft-A turned just before reaching YAIZU NDB, this was the first point in time at which the projected time to loss of separation became less than the specified value.

After the CNF, it is estimated that the ATC trainee and the ATC watch supervisor, who had forgotten about the presence of Aircraft-B until this time, then issued instructions by radio while being in a psychologically unsettled state.

(2) The descent instruction to Aircraft-A from Tokyo ACC

As described in section 3.2.2.8, in this accident, it is estimated that after CNF alert was issued, the ATC trainee confused Aircraft-A with Aircraft-B and

instructed Aircraft-A to descend to FL350. On the other hand, Aircraft's RA had indicated a climb instruction for avoidance. In this accident, it is considered that Tokyo ACC had earlier transmitted a descent instruction unrelated to the RA before the RA was issued. The instructions of an air traffic facility and TCAS indications on an aircraft are independent, and because there is no coordination between the two, the ATC instruction transmitted by an air traffic facility and the RA avoidance indication on an aircraft do not always agree.

Further, as described in section 2.12.4.1, as the aircraft information displayed on the air route control PVD is refreshed approximately every 10 sec., the air traffic controller cannot continuously grasp changes of altitude and position of an aircraft. Also, there is a delay of approximately 2–3 sec. from aircraft information being received by air route control radar until it is updated on the PVD. In the case of this accident when a CNF alert was issued only a short time before the CPA, it is considered that was is difficult for the controllers to instruct appropriate altitude changes referring to displayed information about the state of the aircraft 2 to 13 sec. previously.

In this accident, as a result of the air traffic controller mis-stating the flight numbers, an instruction was issued that was contrary to the indication of the RA. But it is possible for such situation to arise even if communications are conducted correctly.

Further, as described in section 3.2.3.6, it is considered that the pilot of Aircraft-A thought that air traffic control facility was conducting the air traffic control on the basis of judging the whole of flight situation, including the relations with other aircraft, on PVD, and followed the ATC descent instruction.

(3) Aircraft-A's reporting of avoidance maneuvers to Tokyo ACC

Aircraft-A was operated it to make it descend in accordance with the descent instruction from Tokyo ACC, and when the climb RA was issued, it is considered that its crew intended to descend in compliance with the ATC instruction. And Aircraft-A had reported to Tokyo ACC that it was descending to FL350 by reading descent instruction. Because of this, Aircraft-A did not inform Tokyo ACC about the RA. Aircraft-A reported about the "near miss" to Tokyo ACC after passing the CPA.

As to the situation that Aircraft-A did not report the issuance of the RA to Tokyo ACC, it had already reported that it was descending, and the Japan Air Lines Operation Order specified that ATC be notified "at the time of deviating from an ATC assigned altitude". Also, although the terms and phrases to use in the case

notifying ATC of performing maneuvers in accordance with an RA were defined at the time, no sample terms or phrases had been given for the case of that an aircraft maneuvers in accordance with an ATC instruction but contrary to an RA.

In consideration of the above, Tokyo ACC instructed Aircraft-A to descend, and after Aircraft-A had followed this instruction, but not the RA, it is estimated that Tokyo ACC was not in a situation to receive the report concerning the RA from Aircraft-A. Further, Aircraft-A had transmitted its own call sign in reading back the descent instruction to Tokyo ACC, but it is considered that the both ATC trainee and the ATC watch supervisor at Tokyo ACC had confused Aircraft-A with Aircraft-B, and did not notice then they had instructed Aircraft-A to descend.

(4) Aircraft-B's reporting of avoidance maneuvers to Tokyo ACC

It is estimated that Aircraft-B had descended to comply with the RA. And Aircraft-B reported that it had descended in compliance with an RA to Tokyo ACC after it had passed the CPA with Aircraft-A and had completed collision avoidance maneuvers.

As described in section 2.14.1.3, according to Japan Air Lines' OM (Operation Manual) SUPPLEMENT, it is described that in the event an RA is issued, "After the necessary operations are completed, the following of the RA should be reported to air traffic control as soon as possible", and there is a description to the same effect also in the Operation Order. The meaning of "After the necessary operations is completed" does not clearly describe what point of time is intended, as is also described in section 3.2.10.2. According to the AIC, it is described as that the report should be made after danger of collision is avoided. As mentioned above, it is considered that Aircraft-B's report of avoidance maneuvers to Tokyo ACC was performed in accordance with the company manuals.

From the point of view of air traffic control, if an aircraft that is maneuvering in response to an RA does not report on the issuance of the RA as early as possible before the danger of collision has passed after going through the CPA, it will not be possible to take appropriate measures such as issuing instructions without the fear that the situation will be exacerbated. Further, systematic training concerning TCAS is necessary for air traffic controllers so that they respond appropriately following receipt of a report about an RA.

If Aircraft-B had transmitted to Tokyo ACC the report that it was descending to follow an RA at a point of time that it was commencing the descent, it is possible that the flight crew of Aircraft-A, which was descending according to the ATC instruction, could have monitored this report as they were on the same frequency,

and could have realized that Aircraft-B had had an RA and was descending soon after the issue of their own RA.

(5) Instruction of heading change to Aircraft-B and climb instruction to Aircraft-A from Tokyo ACC

Tokyo ACC transmitted ATC instructions to both aircraft while they were approaching each other three times: at 15:54:38 a heading change to 130° to Aircraft-B; at 15:54:49 a heading change to 140° to Aircraft-B again; and at 15:55:02 a climb instruction to FL390 to Aircraft-A. But, Aircraft-B did not respond to either instruction addressed to it. The analysis concerning these is described in section 3.2.3.8 (5) and section 3.2.4.3.

In the case in which RA is issued and that flight crewmembers are concentrating on the maneuvers to follow the RA, it is considered that possibility is high that they are in a situation as to be unable to hear instructions from ATC, but it is considered necessary that flight crews to report on RA issuance and avoidance maneuvers to ATC in order to that ATC does not issue instructions that cause further confusion. Therefore, in the case that an RA is issued, the PNF should report to ATC that the aircraft is maneuvering in response to an RA, and after reporting he should visually acquire Aircraft-B and to monitor the TCAS information display, then he should advise the PF appropriately as necessary.

(6) Tokyo ACC's descent instruction to the non-existent JAL 957

At 15:54:55, Tokyo ACC instructed JAL 957 to descend, but as there was no corresponding aircraft in the airspace, there was no response from any aircraft. The analysis of this is described in section 3.2.210. The ATC watch supervisor who issued this instruction was in a psychologically unsettled condition and had mixed up in her head the flight numbers of Aircraft-A (JAL 907) of and Aircraft-B (JAL 958) and consequently, it is considered that she stated the incorrect the flight number on the instruction originally intended for Aircraft-B.

(7) Instructions from Tokyo ACC after RAs issued on aircraft

As to the situation that during urgent conditions Tokyo ACC had transmitted heading change instructions to Aircraft-B and a climb instruction to Aircraft-A and also a descent instruction to a non-existent JAL 957, factors are that: it is considered that ATC trainee and ATC watch supervisor believed that they had instructed Aircraft-B to FL350 descend instead of Aircraft-A; they thought that altitude change instructions alone would be insufficient to give adequate separation; they had not received a report from Aircraft-B to the effect that it was performing avoidance maneuvers responding to an RA; and the ATC trainee and

ATC watch supervisor did not have sufficient knowledge related to TCAS.

According to the description of air traffic control system standards as described in section 2.14.1.5, in the case that a report is received from an aircraft to the effect that it was maneuvering responding to an RA, it is considered that air traffic controller should not transmit further instructions to the aircraft but should respond by giving advisory traffic information etc. to the extent practically possible. However, although the description concerning the response of the air traffic controller in the case when he or she receives a report of an RA exists in the air traffic control system standard, the terms and phrases used by pilots to report responses to an RA were described in the AIC but were not described on air traffic control system standard. Moreover, it is necessary for the systematic training concerning TCAS to be conducted to air traffic controllers in order to that they respond appropriately in the case a report is received from an aircraft to the effect that it is complying with an RA.

3.2.9.3 Problems of the information communication in this accident

(1) Unreliability of information communication in urgent situations

This accident was reviewed from the point of view of information communications between aircraft and ATC, as described in section 3.2.9.1. In the time between CNF issuance and the CPA, three radio communications were conducted between Aircraft-A and Tokyo ACC: a descent instruction to FL350 to Aircraft-A from Tokyo ACC at 15:54:27; the read back of this instruction from Aircraft-A at 15:54:33; and the climb instruction to FL390 from Tokyo ACC to Aircraft-A. However, it is considered that the descent instruction at 15:54:27 was the result of an incorrect flight number being communicated, and that in the read back at 15:54:33, the air traffic controllers did not notice that the flight number was different from the one they had intended. Further, there was no response from Aircraft-A to the climb instruction at 15:55:02.

Two radio communications were conducted between Aircraft-B and Tokyo ACC in the same time period: a heading change instruction to 130° from Tokyo ACC to Aircraft-B at 15:54:38; and a heading change instruction to 140° from Tokyo ACC to Aircraft-B at 15:54:49. There was no response of either of these instructions from Aircraft-B. Further, an instruction was issued from Tokyo ACC to the non-existent JAL 957, and there was no response to this instruction.

A total of 6 radio communications are listed here, but in all cases either errors were involved or the instructions were not received and understood. According to

these facts, it is considered that the reliability of the information communication becomes lowered in unexpected urgent situations such as following the issue of CNF and RA.

(2) Response of air traffic facilities to the issuance of RAs

The methods and terms are established for air traffic control to enable it to transmit necessary information in a short a period of time as possible. But, on the other hand, individual ATC radio communications are established as the required minimum, and there is a loss of redundancy.

Because the ATC radio communication is not redundant, in the sense that information is communicated only once in a single radio transmission (twice if the read back of the radio communication is counted), if the content of the information is mistaken, then the communication fails, and this can have serious consequences. In particular, in an urgent situation such as the danger of impending collision, a situation may occur in which information communication by ATC radio communication breaks down because mistakes cannot be corrected calmly, the movement of an aircraft cannot be assessed by careful visual observation, and due to a misstatements or failure to hear transmissions properly.

According to air traffic control system standards, in the case that an air traffic facility receives a report from an aircraft to the effect that it is complying with an RA, it is specified that the facility should not transmit instructions to the aircraft concerned, but provide information concerning relevant aircraft to a great an extent as practical. In an urgent situation such as when an RA is issued, since the reliability of the information communication by voice radio communication becomes lowered, it is effective to withhold ATC instructions under such conditions. But, for that to occur, it is necessary that the air traffic facility first realize that an RA has been issued.

(3) Securing reliability of information communication

In this accident, besides the fact that Tokyo ACC had mis-spoken an ATC instruction, the controllers were unaware that RAs had been issued on Aircraft-A and Aircraft-B, and transmitted several instructions for avoidance prior to the CPA.

In the case of entering such an urgent situation, in order that information communication be conducted appropriately, it is effective to ensure redundancy of information communication. Concretely, it is considered that air traffic facility should collect information concerning RA issuance on aircraft, etc. by the following means.

- ① By the means of information communication utilizing air traffic control radar etc. (e.g. Mode S data link), indicate that an RA has been issued on an aircraft on the PVD.
- ② Voice radio communication concerning RA issuance between an aircraft and air traffic facility should be re-examined to ensure that necessary information are communicated.
- ③ Aircraft should report to ATC when they cannot comply with an RA. Further, it is desirable that aircraft positively confirm ATC instructions, positively report RA issuance and their flight situation, and positively the request of traffic information from air traffic facilities.

3.2.9.4 Promotion of coordination between flight crewmembers and air traffic controllers

Sections 3.2.9.1–3.2.9.3 examined the information communication between aircraft and ATC in the situation in this accident, and mentioned the problems. In order to that such information communications be conducted as smoothly and appropriately as possible, it necessary to promote proper coordination between flight crews and air traffic controllers on the basis of common recognition, meaning that there should be mutual cooperation to positively ensure the safety of flight.

As flight crewmembers and air traffic controllers usually have a chance of contact only through voice radio communication, a foundation of mutual recognition should be established in which that mutually grasp the each other's duties and working conditions, and in which there is promotion of understand through the exchange of information and opinions. As many air traffic controllers and flight crewmembers as possible should be involved, as there should be mutual visits to workplaces to create chances for interchange.

3.2.10 Analysis of regulations related to TCAS

3.2.10.1 Points of analysis of regulations

In this accident, the Captain of Aircraft-A continued to descend complying with ATC instruction, but did not comply with the TCAS instruction to climb. And it is presumed that the other flight crewmembers of Aircraft-A did not appropriately advise the Captain to comply with an RA because they were concentrating on visually tracking the intruder aircraft in the same manner as the Captain. Aircraft-A did not inform ATC of response to the TCAS instruction because it did not comply with the RA, and although Aircraft B descended complying with an RA, it informed ATC that of the fact only after point of closest proximity had passed.

ARAIC investigated how Japanese regulations, ICAO regulations, operator's regulations, ATC regulations, US. regulations and European regulations prescribe the response to an RA and the information given to ATC about RA compliance by aircraft, and condensed down to the following points:

- (i) Pilots may deviate from an ATC clearance if complying with an RA
- (ii) Pilots should comply with an RA as a matter of principle

Concerning the relationship between an ATC instruction and an RA

- (iii) There is potential danger in maneuvering opposite to an RA command
- (iv) Phraseologies used by pilot to notify to ATC
- (v) The timing of when pilots should notify to ATC
- (vi) The role assigned to each flight crew member

3.2.10.2 Japanese Regulations

As mentioned in section 2.14.1.1, TCAS equipage of aircraft is mandated by Japanese Civil Aeronautics Laws and Japanese Civil Aeronautics Regulations. In addition, operational regulations related to TCAS operation are prescribed in the AIC. Related to the points above, the AIC states as follows:

- (i) When an RA is initiated and a pilot deviates from an ATC clearance, the pilot is not considered to be violating article 96-1 of the Civil Aeronautics Law.
- (ii) “Pilots should comply with an RA” and also “When an ATC instruction conflicts with an RA instruction, pilots should comply with the RA” are not mentioned.
- (iii) Not mentioned.
- (iv) Phraseologies corresponding to circumstances such as “after modifying vertical speed to comply with a TCAS RA”, etc. are described
- (v) The AIC states that “Pilots who deviate from an ATC clearance in response to an RA shall promptly return to the terms of the previous ATC instruction or clearance when the conflict is resolved and they shall notify the appropriate ATC unit by use of the following phraseologies as soon as possible on the radio frequency.”, it is interpreted that pilots may notify ATC after the conflict is resolved.
- (vi) Not mentioned.

Note: prescriptions related to (ii), (iii) and (vi) above are not described, but AIC section 5 “Aircraft operators involvement” states that operators shall stipulate detailed ACAS operational procedures in each Airline Operations Manual.

3.2.10.3 ICAO Regulations

As mentioned in section 2.14.1.2, Annex 6, which are the ICAO regulations binding upon every contracting state of ICAO, prescribes the obligation to equip TCAS on aircraft starting from January, 2003, and states that TCAS should be operated in accordance with Annex 10. Annex 10 prescribes requirements for the performance of TCAS. In addition, there are related prescriptions in PANS-OPS, PANS-RAC, etc. The points mentioned in section 3.2.10.1 are described as follows:

- (i) PANS-OPS describe procedures to be followed by pilots who deviate from an ATC instruction or ATC clearance in response to an RA.
- (ii) “Pilots should comply with an RA” and also “Pilots should comply with an RA when an ATC instruction conflict with an RA instruction” are not mentioned. PANS-OPS further explain the same rules regarding the procedures related to TCAS instruction, “nothing specified in it shall prevent pilots-in-command from exercising their best judgment and full authority in the choice of the best course of action to resolve a traffic conflict.”
- (iii) Annex 10 Volume IV Chapter 4 Appendix A describes the potential danger of maneuver opposite to the RA indication. But this Appendix A is Guidance Material which describes only the technical performance of TCAS and has no binding force. In addition, because Annex 10 prescribes only the performance requirements of TCAS etc. as aircraft equipment, it is considered that there are few opportunities for flight crewmembers or other staff members engaged in aircraft operation to read this material.
- (iv) PANS-RAC describes phraseologies used by air traffic controllers and pilots corresponding to an RA.
- (v) As PANS-OPS prescribes as “pilots who deviate from an air traffic control instruction or clearance in response to a resolution advisory shall promptly return to the terms of that instruction or clearance when the conflict is resolved and shall notify the appropriate ATC unit as soon as practicable, of the deviation, including its direction and when the deviation has ended.”, it can be understood as that pilots may notify ATC after the conflict is resolved.
- (vi) Not mentioned.

Note: PANS-RAC has been amended as PANS-ATM from November, 2001.

3.2.10.4 Manuals of the aircraft operator

Manuals of Japan Air Lines which operates Aircraft-A and Aircraft B, related to TCAS operation, are constituted by many subdivided manuals.

First there is the OM, which describes matters common to all aircraft types, and supplements the Operation Manual. Furthermore, the OM comprises the OM itself, which describes constant matters, the OM SUPPLEMENT, and Operations Order which describes temporary matters. And as a further supplement to the Operation Manual, there are the AOM which is specific to each aircraft type, the AOM SUPPLEMENT, and the AOM Bulletin which describes temporary matters related to these manuals.

Furthermore, the AFM describing aircraft limitations and aircraft operational methods prepared for each aircraft type.

In these manuals, the points mentioned in section 3.2.10.1 are described as follows:

- (i) The AOM and AFM of Aircraft-A, and the AFM of Aircraft-B state that pilots are authorized to deviate from their current ATC clearance to the extent necessary to comply with a TCAS resolution advisory. The AFM applied to Aircraft-A is prepared only in English.
- (ii) The OM SUPPLEMENT, AFM, AOM and AOM SUPPLEMENT applied to Aircraft-A and the AFM, AOM and AOM SUPPLEMENT applied to Aircraft-B describe that pilots should comply with an RA, or describe definite procedures to comply with an RA.

The OM SUPPLEMENT says that the pilot shall immediately comply with an RA unless he considers it unsafe to do so, but gives no definite explanation about the cases in which the pilot considers it unsafe to comply with an RA. AOM applied to Aircraft-A prescribes that “pilots shall execute the following operations when the TCAS issues an RA”, and that “PF shall disengage an autopilot and adjust the control pitch angle and the thrust for complying with an RA when it is necessary to execute an avoidance maneuver”. Aircraft-A’s AOM SUPPLEMENT prescribes that “when a corrective RA which instructs to change the flight path is issued, execute an avoidance maneuver in accordance with the following procedures”, and describes definite operational procedures to execute an avoidance maneuver complying with an RA, for example, to “operate the aircraft in accordance with the RA Pitch Guidance Command on the PFD, having the Airplane Symbol on the PFD come to just outside of Red Line”, etc.

As mentioned above, the OM SUPPLEMENT says “unless he considers it unsafe to do so” and the AOM of Aircraft-A says “if it is necessary to execute an avoidance maneuver”. Therefore these two manuals leave the room for the Captain's judgment. But the AOM SUPPLEMENT prescribes clearly that pilots should execute an avoidance maneuver in accordance with an RA instruction.

Moreover, the AFM applied to Aircraft-A (in English) and the AFM applied to

Aircraft-B (in Japanese) enumerate the exceptional cases in which pilots may not comply with an RA instruction, such as the case that the pilot considers it unsafe to comply with an RA, the case of obvious TCAS II system failure, the case that the pilot have better information about the cause of the RA and can maintain safe separation from a nearby aircraft, etc. But, in the OM SUPPLEMENT and AOM, there are no corresponding descriptions. Also, these two manuals do not mention that pilots should comply with an RA when an ATC instruction conflicts with the RA instruction.

- (iii) The AFM of Aircraft-A and the AFM of Aircraft-B say “safe separation could be compromised if current vertical speed is changed, except as necessary to comply with the RA. This is because TCAS II-to-TCAS II coordination may be in progress with the intruder aircraft, and any change in vertical speed that does not comply with the RA may negate the effectiveness of the other aircraft's compliance with the RA.”, etc. The AOM and AOM SUPPLEMENT of both Aircraft-A and Aircraft-B do not describe matters corresponding to the above.

The AOM SUPPLEMENT of Aircraft-B describes about the mutual coordination function of TCAS in a general explanation related to TCAS with a conspicuous layout, saying that each TCAS issues an RA that is the opposite direction to the other after coordinating with the other automatically through the Mode-S Transponders. On the other hand, in AOM SUPPLEMENT of Aircraft-A, although there is a description in the explanation about TCAS system that, in case that the TCAS equipped in the intruder is also engaged, TCAS Vertical Guidance operates coordinating with the intruder's TCAS, this description may be comparatively easily overlooked because of the layout in which this description appears once in several pages of explanation about TCAS system. Moreover, in the AOM SUPPLEMENT of Aircraft-A, there is no description such as an RA instruction is made to the opposite direction to each aircraft.

- (iv) Operations Order describes phraseologies corresponding to such circumstances as “after modifying vertical speed to comply with a TCAS RA”, etc.
- (v) The OM SUPPLEMENT and Operations Order state that if an RA is issued, pilots shall notify the appropriate ATC unit as soon as possible when the conflict is resolved, etc.
- (vi) The AOM and AOM SUPPLEMENT of Aircraft-A, and the AOM SUPPLEMENT of Aircraft-B describe about the assigned roles of PF and PNF when an RA is issued. Among them, concerning the advice from PNF to PF in the case that the maneuver taken by PF is opposite to an RA instruction, although it is described as a general prescription in OM that advice should be given, there is

no particular definite description for TCAS operation in either manual.

The assigned roles of PF and PNF mentioned in the AOM of Aircraft-A are not always the same as those mentioned in the AOM SUPPLEMENT. In particular, the description that “when being able to recognize other traffic, call out to that effect.” mentioned in the AOM is not found in the AOM SUPPLEMENT. Moreover, although the AOM SUPPLEMENT states that while an RA is being issued, other crewmembers in the cockpit should search for the other traffic visually, comparing with the TCAS display (if possible), the AOM mentions that PNF should try to acquire the other traffic visually, but does not refer to comparing with the TCAS indication.

Furthermore, the description in the AOM SUPPLEMENT of Aircraft-A is not always the same as that mentioned in AOM SUPPLEMENT of Aircraft-B. For example, the latter says that PF informs of executing an avoidance maneuver to the other flight crewmembers when an RA is issued, but the former does not contain such a description.

Manuals of Japan Air Lines related to TCAS operation are not always easy for flight crewmembers to understand because: the prescriptions are dispersed among several manuals; the prescriptions which are considered to be constant for a long period are contained in Operations Order which is to describe temporary matters; the matters mentioned in AFM are not always contained in the AOM or the AOM SUPPLEMENT which are habitually referred to by flight crewmembers; for even basic matters which are considered to be common for every aircraft type, existence of description and contents of description differ between aircraft types; etc.

It is considered that descriptions in the AOM and AOM SUPPLEMENT mentioned above, and are influenced by the descriptions contained in the manuals prepared by the aircraft manufacturers which are referred to by Japan Air Lines when it prepared its own manuals mentioned above. However, aircraft operators should study the contents of matters described in AFM and also in the AOM and AOM SUPPLEMENT, to ensure consistency of description among manuals, including manuals for different aircraft types, should improve the layout of texts, should positively provide flight crewmembers with necessary and useful information, and should try to prepare manuals which are easy to understand and easy to use by flight crewmembers.

3.2.10.5 Regulations applied to air traffic control

As mentioned in section 2.14.1.5, "Procedures to comply with Resolution Advisory", etc. are prescribed in Air Traffic Control Procedures as regulations applied

to air traffic control. Corresponding to the above regulations, an AIC titled "Operation of the Airborne Collision Avoidance System (ACAS)" is prepared, and describes phraseologies used by pilots to notify to ATC about RAs and the timing of when pilots should notify ATC.

Points raised in section 3.2.10.1 are as follows:

- (i) The AIC states "Once an aircraft departs from an assigned ATC clearance in compliance with an RA, the controller ceases to be responsible for providing ATC separation between that aircraft and other aircraft affected by the direct consequence of that RA maneuver.". And Air Traffic Control Procedures describes that ATC instructions should not be issued when an aircraft is operated in compliance with an RA. But, this procedure is applied only when the aircraft informs ATC that it is complying with an RA. If the aircraft does not inform about the RA, though ATC instructions are issued, pilots deviate from ATC instructions by their own judgment.
- (ii) Since it is a pilots' matter whether an aircraft will comply with an RA or not, it is not mentioned in the regulations applied to air traffic control.
- (iii) Since the potential danger to maneuver opposite to the RA instruction is a pilots' matter, it is not mentioned in the regulations applied to air traffic control. However, it is considered that air traffic controllers should have knowledge that safe separation may not be maintained if one aircraft does not comply with an RA because TCAS-to-TCAS coordination between approaching aircraft is in progress. There is no description about this in the regulations applied to air traffic control.
- (iv) Phraseologies used by a pilot to notify to the ATC are described in AIC, but not in Air Traffic Control Procedures. Phraseologies to respond to the notification from a pilot are not particularly described, because it is considered that a controller receiving notification from a pilot is not assumed to issue new ATC instructions but to provide traffic information. This respect is the same as the related descriptions in ICAO regulations.
- (v) The timing of when a pilot notifies to ATC about an RA is described in the AIC, but not in Air Traffic Control Procedures.
- (vi) Since the assigned roles of flight crewmembers are a pilots' matter, it is not mentioned in the regulations applied to air traffic control.

Studying the above (i)–(vi) as well as Air Traffic Control Procedures "Procedures complying with Resolution Advisory" and "Supplemental works" mentioned in section 2.14.1.5, a controller does not start to respond to an RA until ATC is informed by an aircraft that it is complying with an RA. The content of the controller response

is that ATC does not issue new instructions. In addition, traffic information is provided to the extent practicable. Air Traffic Control Procedures "Supplemental works" describes that if an aircraft receiving radar traffic information requests an avoidance measures, ATC should give guidance to the aircraft.

3.2.10.6 U.S.A. Regulations

Federal Aviation Regulations (FAR) and Advisory Circular 120-55A "AIR CARRIER OPERATIONAL APPROVAL AND USE OF TCASII" (which is referred to as "AC" in this section) describes as follows related to the points in section 3.2.10.1:

- (i) In an in-flight emergency requiring immediate action, the pilot in command may deviate from any rule of this part to the extent required to meet that emergency.[FAR 91.3(b)]

If a TCAS RA requires maneuvering contrary to "right-of-way rules", "cloud clearance" rules for visual flight rules (VFR) flight, instrument flight rules (IFR), or other such criteria, pilots are expected to follow the TCAS RA's to resolve the immediate traffic conflict. Deviations from rules or clearances should be kept to the minimum necessary to satisfy a TCAS RA.[AC 11b(9)]

- (ii) When an RA occurs, the pilot flying should respond immediately by direct attention to RA displays and should maneuver as indicated unless doing so would jeopardize the safe operation of the flight or unless the flight crew has definitive visual acquisition of the aircraft causing the RA.[AC 11b(2)]

It may not be possible to respond to a TCAS RA and continue to satisfy a clearance at the same time. Even if a TCAS RA maneuver is inconsistent with the current clearance, respond appropriately to the RA.[AC 11b(8)]

- (iii) Safe vertical separation may be lost during TCAS coordination when one aircraft maneuvers opposite the vertical direction indicated by TCAS and the other aircraft maneuvers as indicated by TCAS. As a result, both aircraft may experience excessive altitude excursions in "vertical chase" scenarios due to the aircraft maneuvering in the same vertical direction.[AC 11c(3)]

- (iv) Some phraseologies, which are the same as phraseologies in ICAO regulations, are exemplified.[AC Appendix 5]

- (v) Each pilot in command who, in an emergency, or in response to a traffic alert and collision avoidance system resolution advisory, deviates from an ATC clearance or instruction shall notify ATC of that deviation as soon as possible. [FAR 91.123(c)]

In responding to a TCAS RA that directs a deviation from assigned altitude, communicate with ATC as soon as practicable after responding to the RA. [AC 11b(10)]

- (vi) The non flying pilot should advise the pilot flying when there is a deviation from the vertical flight path indicated by TCAS. The non flying pilot, and any onboard observers, also will assist in the visual search for the intruder and continue to cross-check the TCAS displayed information with other available traffic information to ensure the RA response is being flown correctly. [AC 11b(5)]

3.2.10.7 European Regulations

(1) Regulations of the Joint Aviation Authorities (JAA)

JAA has enacted JAR-OPS, and issued Leaflet No.11 "Guidance for Operators on Training Programs for the Use of Airborne Collision Avoidance Systems" as guidance for JAR-OPS related to TCAS. This Leaflet describes as follows related to the points in section 3.2.10.1:

- (i) If pilots simultaneously receive instructions to manoeuvre from ATC and which are in conflict, the pilot should follow the RA.[Leaflet No.11 3.2.3b. Note 3]

When air traffic issue instructions that, if followed, would cause the crew to manoeuvre the aircraft contrary to an RA with which they are complying. [Leaflet No.11 4.1(9)]

Judging from the above texts, it is considered that pilots may deviate from an ATC clearance if they comply with an RA.

- (ii) When undue proximity to another aircraft (RA) is detected by ACAS, the commander or the pilot to whom conduct of the flight has been delegated shall ensure that corrective action is initiated immediately to establish safe separation unless the intruder has been visually identified and has been determined not to be a threat.[JAR-OPS 1.398]

If pilots simultaneously receive instructions to manoeuvre from ATC and which are in conflict, the pilot should follow the RA.[Leaflet No.11, 3.2.3b. Note 3]

- (iii) If a decision is made to not follow an RA, no changes to the existing vertical speed must be made in a direction opposite to the sense of the displayed RA. Pilots should be aware that if the intruder is also ACAS equipped, the decision not to follow an RA may result in a decrease in separation at CPA because of the intruder's RA response. A decision not to follow an RA also renders the other aircraft's ACAS less effective than if own aircraft was not ACAS-equipped.

[Leaflet No.11, 3.2.3b. Note 2]

(iv) The Leaflet No.11 describes phraseologies used for notification to air traffic control facilities related to TCAS which are the same as those described in ICAO PANS-RAC (which has been amended to PANS-ATM after November 2001.)(Leaflet No.11, 4.2]

(v) The controller is informed of the RA as soon as time and workload permit using the standard phraseology.[Leaflet No.11, 3.2.3b. (ix)]

Verbal reports should be made promptly to the appropriate air traffic control unit:

(?) Whenever any manoeuvre has caused the aeroplane to deviate from an air traffic clearance;

(?) When, subsequent to a manoeuvre that has caused the aeroplane to deviate from an air traffic clearance, the aeroplane has returned to a flight path that complies with the clearance;

(?) When air traffic issue instructions that, if followed, would cause the crew to manoeuvre the aircraft contrary to an RA with which they are complying.

[Leaflet No.11, 4.1]

The Leaflet No.11 says that notification of "TCAS CLIMB" or "TCAS DESCENT" should be initiated as soon as it is convenient to do so.[Leaflet No.11, 4.2.1]

(vi) Proper division of responsibilities between the pilot flying and pilot not flying. Pilot flying should be responding to the RA with positive control inputs, when required, while the pilot not flying is providing updates on the traffic location, checking the traffic display and monitoring the response to the RA.

[Leaflet No.11, 3.2.3b. (?)]

(2) U.K. Regulations

The U.K. is a member nation of JAA, and issued ANO (Air Navigation Order), the Rules of the Air Regulations and CAP 579 as a guidance material related to TCAS, before JAR-OPS was issued. These regulations describe as follows related to the points in section 3.2.10.1:

(i) It shall be lawful for the Rules of the Air to be departed from to the extent necessary for avoiding immediate danger.[ANO part VIII 84(3)]

Notwithstanding that the flight is being made with air traffic control clearance it shall duty of the commander of an aircraft to take all possible measures to ensure that his aircraft collide with any other aircraft.[the Rules of the Air Regulations SECTION IV ,17(1)(a)]

(ii) Pilots are to initiate the required manoeuvre immediately, adjusting flight path, aircraft power and trim accordingly.[CAP 6.2.2]

If pilots receive simultaneously an instruction to manoeuvre from ATC and an RA, and both conflict, the advice given by ACAS should be followed.

[CAP 6.2.4(b)]

- (iii) Manoeuvres should never be made in a direction opposite to that given in an RA; this is because the sense may have been determined following an exchange of data with the established threat. For this reason, RAs may be disregarded only when pilots visually identify the potentially conflicting traffic and decide that no deviation from the current flight path is needed.[CAP 6.2.4]
- (iv) CAP describes phraseologies used for notification to air traffic control facilities related to TCAS which are the same as those described in ICAO PANS-RAC (which has been amended to PANS-ATM after November 2001.) [CAP 7.2.1]
- (v) They are to inform ATC as soon as possible of any deviation from an air traffic control clearance.[CAP 6.2.2]

Verbal reports should be made promptly to the appropriate air traffic control unit:

- (a) Whenever any manoeuvre has caused the aeroplane to deviate from an air traffic clearance;
- (b) When, subsequent to a manoeuvre that has caused the aeroplane to deviate from an air traffic clearance, the aeroplane has returned to a flight path that complies with the clearance;
- (c) When air traffic issue instructions that, if followed, would cause the crew to manoeuvre the aircraft contrary to an RA with which they are complying.

[CAP 7.1]

CAP says that notification of "TCAS CLIMB" or "TCAS DESCENT" should be initiated as soon as it is convenient to do so.[CAP 7.2.1]

- (vi) Crew members not involved in executing this manoeuvre should confirm that the sky ahead is clear of other traffic and continue the visual search for the established threat.[CAP 6.2.2]

3.2.10.8 Problems in TCAS regulations related to this accident

- (1) It is considered that the following factors influenced the Captain of Aircraft-A's decision give priority to an ATC instruction over an RA instruction.
 - (i) Although Japan Air Lines' OM SUPPLEMENT describes that the pilot shall immediately comply with an RA unless he considers it unsafe to do so, there is no description about what are the cases in which a pilot does not comply with an RA by considering it unsafe, and no clear prescription about the importance of pilots complying with an RA.
 - (ii) Although Japan Air Lines' AFM applied to Aircraft-A describes that RA

instructions are issued through mutual coordination with intruder's TCAS and describes the potential danger of maneuvering opposite to the RA instruction, the AOM and AOM SUPPLEMENT which are habitually referred by flight crewmembers do not have clear descriptions about the former matter contained in AFM, and do not contain the latter matter at all.

- (iii) Although AIC issued by Civil Aviation Bureau of Japan describes necessary matters when avoidance maneuver is conducted to comply with an RA, there is no description that pilots should comply with an RA in principle, to what cases it is limited that pilots may not comply with an RA, and about the importance of complying with an RA and the potential danger of acting in opposition to an RA. In addition, it does not mention the order of priority between an ATC instruction and an RA instruction.
 - (iv) ICAO Annex 6 and PANS-OPS do not describe that pilots should comply with an RA in principle and about the importance for complying with an RA. Although ICAO Annex 10 Volume IV, which contains regulations related to aeronautical communications, Chapter 4 Appendix A Guidance Material describes that pilots should be prohibited to oppose to an RA instruction, Annex 6 which contain regulations applicable to aircraft operators does not describe about this matter.
- (2) In this accident, the Captain of Aircraft-B notified ATC that he executed an avoidance maneuver complying with an RA, not at the time when the maneuver to initiate descent was ended but instead after passing through the point of nearest proximity when the avoidance maneuver was completed. This is considered to be affected by the descriptions related to the timing of notifying ATC when an RA is issued, contained in the AIC issued by Civil Aviation Bureau of Japan and in the OM SUPPLEMENT and Operations Order of Japan Air Lines. Furthermore, it is considered to be affected by the expression in ICAO PANS-OPS concerning the opportunity of notifying ATC that can be construed as that a pilot may notify ATC after the conflict is resolved.
- (3) It is presumed that in this accident Aircraft-A did not notify ATC about the RA, because it did not execute an avoidance maneuver complying with an RA though an RA was issued. This is considered as because there is no prescription in ICAO PANS-RAC, the AIC issued by Civil Aviation Bureau of Japan, Operations Order of Japan Air Lines, etc. that an aircraft that cannot comply with an RA, though an RA is issued, should notify ATC of the issuance of an RA.
- (4) As for manuals of Japan Air Lines, since prescriptions related to TCAS are dispersed among several manuals, flight crewmembers may fail to notice some of them when they study or confirm the prescriptions. Including this matter, there is

still room for improvement in these manuals to make them easy to understand when flight crewmembers perform their duties.

ICAO regulations are not directly applied to flight crewmembers. Flight crewmembers are not required to know other nations' regulations, and in fact flight crewmembers do not usually refer to these regulations. In addition, since matters described in AFM are usually described also in AOM or AOM SUPPLEMENT, flight crewmembers perform their daily duties referring to AOM, AOM SUPPLEMENT, etc. which are supplements to Operation Manuals. Therefore, it is necessary to describe necessary information in the manuals which are referred to habitually by flight crewmembers, and to make the manuals easy to understand and easy to use, in order to ensure the appropriate execution of duties by flight crewmembers.

- (5) It is necessary that regulations applied to air traffic control should be substantiated, in order that air traffic control facilities appropriately obtain information related to issuance of an RA on aircraft and provide appropriately an aircraft with traffic information related to other traffics. In addition, it is also necessary to have regulations applied to air traffic control well-coordinated with those applied to aircraft operators, in order to ensure mutual understanding of intentions between aircraft and air traffic control facilities even if they become psychologically upset under pressing situations.

3.2.11 Training concerning TCAS to flight crewmembers

3.2.11.1 Training about the judgment of avoidance maneuvers following an RA

In Japan Air Lines' OM SUPPLEMENT, it is specified that "Except in cases in which the Captain judges that it will be dangerous to perform maneuvers to comply with an RA, an RA should be complied with at once", and in the AOM and AOM SUPPLEMENT of Aircraft-A, the concrete procedures for performing avoidance maneuvers to comply with an RA are described.

Japan Air Lines conducted training of flight crewmembers concerning the methods of operating on the issuance of an RA by classroom and flight simulator training. However, it is considered that training which placed especial emphasis on the judgment related to following an RA, concerning that the RA should be complied with on principle, the distinction of cases in which the RA should be complied with or not complied with, the dangers of maneuvers opposite to the direction of the RA, etc., was not carried out. It is considered that such factors were involved in the lack of awareness of the flight crewmembers of Aircraft-A regarding the importance of complying with an RA and about the dangers of not complying with an RA. Further, as described in sections 3.2.10.2 and 3.2.10.8, there was no description about the

importance of complying with an RA and about the dangers of not complying with an RA even in the AIC issued by JCAB.

In order for flight crewmembers to positively avoid approaching other aircraft by using TCAS, it is necessary to perform sufficient training with a variety of scenarios on: first about the judgment of carrying out avoidance maneuvers in compliance with an RA; that an RA should always be complied with except in exceptional circumstances; what sort of cases exist for following and exceptionally not following an RA; the response in the event that an ATC instruction contradicts an RA; the dangers of maneuvering opposite to the RA direction, etc.

Further, it is desirable to have training that simulates practical situations to provide knowledge as to what kinds of cases exist in which it is appropriate report to ATC that the aircraft is unable to comply with an ATC instruction due to following an RA, with defined phrases such as for example “UNABLE TO COMPLY, TCAS RA”.

3.2.11.2 Classroom training in relation to TCAS

It is estimated that classroom training as described in section 2.14.2.1 was conducted in the approved training in relation to TCAS. It is considered that there were no concrete teaching materials about the dangers of maneuvers in the opposite direction to an RA due to the mutual coordination of TCAS RA directions between aircraft, and the about the dangers in giving priority to ATC instructions over RA indications. However, during the 1998 fiscal year only, a short course was conducted using videos about these dangers and TCAS/TCAS coordination between approaching aircraft, etc., and it is considered that Captain of Aircraft-A and the flight crewmembers of Aircraft-B would have the opportunity to acquire this knowledge. But, it is considered that the FO of Aircraft-A, and the pilots under training for FO did not have an opportunity to view these video materials.

It is considered difficult to say that training regarding such knowledge of TCAS, the appropriate methods of using the TCAS information display for PF and PNF, the methods of confirming the movement of intruder aircraft using the TCAS information display, the terms and phraseology for reporting to ATC concerning TCAS and the timing of such reports, aircraft performance in the case of an RA being issued at high altitude, etc., were adequately addressed in the classroom training.

3.2.11.3 Flight simulator training concerning TCAS

- (1) Japan Air Lines carries out flight simulator training relevant to TCAS as part of

periodic training. In the case of flight crew of Aircraft-A, this training was conducted using a flight simulator equipped with simulated TCAS equipment. An approaching intruder aircraft was displayed on TCAS information display indicator, at first the TA was issued, and when the RA was issued, flight crewmembers received training on performing the avoidance maneuvers to comply with the RA avoidance instruction. For the flight crew of Aircraft-B, because the flight simulator did not have simulated TCAS equipment installed, training of avoidance maneuvers was conducted by sounding the voice alerts of TA/RA. However, it is estimated that no particular training had been conducted concerning the many kinds of situation which could occur in relation to the timing of TCAS alerts and the dangers of opposite maneuvers to the RA.

Further, it is estimated that the training utilizing flight simulator on the case of when the ATC instruction and RA issuance is contrary to each others had not been conducted.

- (2) In the case of responding to an RA climb instruction at high altitude, it is considered that it is possible to enter into buffet and stall depending on the degree of the maneuvering. Further, it is considered possible that flight crews may judge climb maneuvers following RA instruction at high altitudes near the max. operating altitude as being very difficult, even in the conditions of not entering into buffet and stall.

But, since it is possible the RA direction has been coordinated with the TCAS of the intruder aircraft; the climb instruction must still be followed. As described in section 3.2.3.7(3), in the case of an aircraft type being unable to climb at an altitude due to performance limitations, the TCAS function ought to inhibit the climb instruction; however, Aircraft-A was considered by the manufacturer as having sufficient performance to respond to a climb RA even at high altitude, so there was no such inhibition of climb instructions in the TCAS. Also, as described in section 3.2.3.7(2), in the case of climbing following an RA at high altitude, even if it assumed that there is no margin on engine thrust, there is still the possibility of climbing by trading kinetic energy for potential energy.

On the other hand, according to Japan Air Lines' PILOT FLIGHT TRAINING GUIDE in which the contents of periodic training relating to Aircraft-A was described, the actual altitude of TCAS training was at the discretion of the instructor, but according to the so-called chevron training pattern which illustrates using a line chart the altitude of flight training and time progress, it is specified that high altitude is set at 11,000ft or 5,000ft. Because of this, it is estimated that the Captain of Aircraft-A had no experienced no training concerning avoidance

maneuvers relevant to TCAS which assumed high altitudes in the region of 37,000ft, as in this accident.

Further, it is considered that this lack of periodic training on the recovery from buffet at high altitude close to the limit of aircraft performance and climbing by converting kinetic energy to potential energy, etc., were factors in the decision of the Captain of Aircraft-A to give priority to the ATC instruction over the RA indication. Therefore, in periodic training, it is desirable that flight simulator training should be conducted to give experience on avoidance maneuvers following an RA at high altitude, recovery from entry into buffet, which it is possible to encounter depending on the degree of the avoidance maneuvers, etc.

- (3) Regarding Aircraft-A's descent in accordance with an instruction from Tokyo ACC, while TCAS operated normally during this time, it is estimated that the attention of all the flight crewmembers of Aircraft-A was concentrated of the movement of Aircraft-B in order to avoid it.

As to the work responsibilities of the flight crewmembers of Aircraft-A, according to Aircraft-A's AOM and AOM SUPPLEMENT, nominally the PF carries out the avoidance maneuvers by referring to the guidance on the PFD. However in this accident, the PF confirmed the movement of intruder aircraft visually, and it is considered that the PNF confirmed the movement of the intruder aircraft on the TCAS screen as described in the AOM SUPPLEMENT, and advised appropriately as described on AOM. However, in this accident, it is considered that the flight crewmembers of Aircraft-A had not appropriately shared responsibilities such as monitoring the other aircraft visually, confirming changes on the TCAS display information, etc.

For situation in which maneuvers are performed in response to TCAS instructions, it is necessary to conduct appropriate training about the duties of the PF and PNF and the coordination between them, so that coordination between flight crewmembers is conducted as described in the AOM and AOM SUPPLEMENT.

- (4) Regarding flight simulator training, it is necessary to train avoidance maneuvers following TCAS under many kinds of scenario. It is necessary that such training include, practical training on the judgment on whether or not to follow an RA, the dangers of maneuvering opposite to the direction of the RA, the duties and responsibilities of PF and PNF, the conditions in which appropriate necessary advise is to be given, the reporting to ATC regarding TCAS alerts using standard phraseology in different types of situation, and avoidance maneuvers at high altitude. It is desirable practical simulator training is conducted on the resolution of realistic scenarios in CRM, LOFT, etc.

3.2.12 Air traffic controller training

3.2.12.1 Air traffic controller OJT

At the time this accident occurred, the ATC watch supervisor had been administering OJT, which teaches practical skills, to the ATC trainee while air traffic control duties were being carried out. As described in section 2.13.2.4, concerning the method of training enforcement, the “training for personnel not having technical certification” is specified in the Air Traffic Service Process Manual issued by Tokyo ACC, but there are manuals that describe in detail qualification requirements, methods of selection, and concrete important notices as training, etc.

In this accident, during the time leading up to the CNF issuance, the ATC watch supervisor had been explained the tasks performed previously to the ATC trainee. While it is more effective to explain about tasks carried out while OJT is in progress, while events are still clear in memory, this is also time-consuming and there is the fear that the awareness of the air traffic situation on the PVD may become insufficient. Priority should therefore be given to air traffic control duties, and explanation during working should be avoided as much as possible; even in the case of OJT, it should keep to a minimum.

It is considered necessary for ATC watch supervisors to at least note the following points when carrying out explanation of tasks previously accomplished while the trainee on duty in OJT.

- ① To understand the appropriate point of time to explain.
- ② To reconfirm the air traffic situation before explaining. In this case, the ATC watch supervisor has to make mutual confirmation with the ATC trainee.
- ③ The attention of the ATC trainee is directed toward the contents of the explanation from the ATC watch supervisor, and it is easy for his/her to neglect the maintenance of air traffic situational awareness.
- ④ To anticipate new air traffic from the strips, etc. and after the explanation had been completed, to brief the ATC trainee about anticipated new air traffic.
- ⑤ To stop the explanation at once when it is necessary to perform radio communication, and not to resume the explanation until necessary measures was judged to have completed by means of the ATC radio communication.
- ⑥ For aspects for which it is judged that detailed explanation is required, such explanation should be carried out after the OJT duty period is over.

Further, the feasibility of using video tape recordings of aircraft movements on the PVD and audio recordings of air traffic communication to carry out explanations after an OJT duty period should be investigated. Further, for the future safety of

aviation, it is necessary that if an air traffic controller under training reached the limit of his or her capability and feels overloaded, the ATC watch supervisor should override and take over the air traffic control duties. Further, the training environment should be maintained such the air traffic controller under training can personally request take over or report overload without hesitation.

Others matters concerning the ATC watch supervisor are described in section 3.2.12.2.

3.2.12.2 Training of training ATC watch supervisors

When conducting OJT, the ATC watch supervisor should have sufficient understanding of the capability of the ATC trainee, and depending on the air traffic situation, should ascertain the situations which may be left to the judgment of the ATC trainee and in which the trainee may carry out ATC radio communication.

In the case of this accident, it is considered that the ATC watch supervisor had carried out some of the duties of the coordinator in addition to her ATC watch supervisor duties, and as a result it is considered she could not understand sufficiently the air traffic situation within the sector and the tendency of the ATC trainee. The ATC watch supervisor should always maintain awareness of the movements of aircraft in the airspace under his/her jurisdiction, and should carefully have to monitor workload of the ATC trainee and the contents of radio communications.

In the time leading up to the CNF alert issuance, the ATC watch supervisor had been explaining the tasks carried out up to that time to the ATC trainee, but in that situation, it considered to have been necessary to do so while taking notice of the items described in section 3.2.12.1.

As described in section 2.13.2.4, the Air Traffic Service Process Manual issued by Tokyo ACC, described that the “ATC watch supervisor should train to trainee with overall responsibility”. However, in order that the training ATC watch supervisor can properly to fulfill this role, training should be conducted for ATC watch supervisors concerning the methods of carrying out training, and it is necessary that the knowledge and capabilities of training ATC watch supervisors are confirmed before they are allowed to engage in training.

3.2.12.3 Training regarding coordination between air traffic controllers

At Tokyo ACC, there are no manuals which specifically specified about coordination and cooperation within the team of air traffic controllers on duty at a sector. In reviewing this accident, as described in section 3.2.8.2, it is considered that

there were some situations where the coordinator would have been able to advise or to support the radar controller.

It is therefore considered necessary to routinely conduct training in cooperative working, and to establish a workplace environment that facilitates easy and smooth coordination and cooperation between air traffic controllers.

Also, as it is considered that a factor in this accident was that the attention of the training ATC watch supervisor was diverted from the PVD in order to carry out coordination with an adjacent sector, training regarding coordination between sectors should be conducted.

It will be effective to introduce elements similar to CRM and LOFT for flight crews into the training for air traffic controllers.

3.2.12.4 Training concerning the response to CNF alerts

There was no special training for air traffic controllers concerning the response to CNF alerts, as described in section 2.12.4.2. But in order that air traffic controllers are able to respond appropriately in the case of a CNF alert concerning an aircraft that is under the control of the facility, training for response to CNF alerts, including use of radar simulators, training relevant to TCAS, and education about the points listed below should be conducted.

- ① CNF is normally issued 3 min. before predicted loss of standard separation. However, training should show concrete examples that demonstrate the possibility that the issue of CNF is delayed depending on the trajectory of the aircraft, and may be issued with insufficient time to ensure standard separation by transmission of ATC instructions and clearances.
- ② The basic methods of response in cases where a CNF alert is issued unexpectedly.
- ③ On the case of when CNF issued after it is no longer possible to ensure separation by ATC instructions and clearances, the importance points regarding radio communications with an aircraft up to the time of RA issuance.

3.2.12.5 Training related to TCAS for air traffic controllers

Training of air traffic controllers concerning TCAS is as described in section 2.14.2.2, the description on control procedure standard includes the response in cases of receiving a report from an aircraft of maneuvering following an RA. Such training was conducting for 1 hour at the Aeronautical Safety College and 1.5 hours at the Iwanuma Branch of the same College in air route radar training. A general lecture

explaining TCAS was given, and a video tape introducing TCAS was showing.

However, lessons related to TCAS were not conducted before fiscal year 1997 at Aeronautical Safety College and before fiscal year 1994 at the Iwanuma Branch of the college. Because of this, while the ATC trainee was young enough to have received the lecture related to TCAS, the training ATC watch supervisor and coordinator had not had the opportunity to receive such training. Because of this, it is considered that these two persons had insufficient knowledge about the extent of TCAS in the domestic airline fleet, the function of TCAS and the issuance condition of TCAS alerts, the TCAS/TCAS coordination function between approaching aircraft, the report to air traffic control facility related to RA issuance, and the response of the air traffic control facility to notification of RA issuance.

A video tape introducing TCAS is prepared for pilots and gives a general explanation of TCAS, including the principles and nominal parameters relating to TCAS alerts, etc. Regarding air traffic controller-specific classroom training related to TCAS, it is considered to be necessary to include the following:

- ① The extent of aircraft equipage of TCAS.
- ② The nominal RA alert time values at each flight altitude, and typical distances between relevant aircraft at those times.
- ③ The TCAS/TCAS function that mutually coordinates the RA direction between approaching aircraft equipped with TCAS II.
- ④ The appropriate ATC instructions in the urgent situation that an RA is issued, and the appropriate information to offer to aircraft to assist avoidance maneuvers following an RA.
- ⑤ The response to the case when a report from an aircraft is received to the effect that the aircraft that is in climb or descent following an RA: transmission of ATC instructions should be withheld on principle, and instead, ATC should provide appropriate traffic information to the extent practically possible.
- ⑥ The training should introduce the practical examples of TCAS collision avoidance on an aircraft which are described in near miss reports, including those of other foreign countries, etc.

Further, it is necessary to examine the enforcement of such periodic training regarding the above contents was utilizing simulators. Further, in conjunction with increasing the chances to experience flight in the cockpit to appreciate the working environment of flight crewmembers, it is necessary to enable the chance to realize the environment of TCAS alert issuance.

3.2.13 Circumstances of Injuries

3.2.13.1 Injuries to passengers and usage of seat belts

According to passengers' statements, at around 20 minutes after take-off Aircraft-A experienced several motions, immediately followed by an abrupt descent.

It is considered that the situation in the cabin was that the seat belt signs had been switched off, and it was about five minutes after the CAs had started the cabin service, so passengers had unfastened or loosened their seat belts and were starting to relax.

As described in sections 2.10.2 and 2.10.3, passengers sustained injuries mainly due to being lifted owing to the aircraft's abrupt descent, striking the ceiling and then dropping to the floor, onto seats etc., but it is also estimated that some injuries resulted from passengers' being struck by flying hand baggage also lifted by the upset.

Because it was difficult to confirm with all of the passengers whether they had fastened their seat belt or not, an investigation was conducted by randomly selecting just over 10% of the passengers who had not received injuries and interviewing them, and as a result, it was found that over 90% of passengers had their seat belts fastened. Supposing that 90% of the 323 non-injured passengers (291 persons) had fastened seat belts and the remaining 10% (32 persons) did not, the proportion of all passengers who fastened their seat belts and the injury rates for passengers who had fastened their seat belts and passengers who had not was calculated. However, one seriously injured person could not confirm whether or not the seat belt was secure, and 16 minor persons with minor injuries had not fastened their seat belts.

The total number of persons who had fastened their seat belts was calculated by adding the 53 persons of 88 injured persons who confirmed that their seat belts had been fastened, and the 291 persons as mentioned above who had not been injured and who had fastened their seat belts. Since there had been 411 persons on board, it is estimated that about 84% of passengers had fastened their seat belts. Further, subtracting the total of 344 persons who had fastening their seat belts from the total of 411 passengers on board, the total numbers of passengers who had not fastened their seat belts was calculated as 67 persons. Subtracting from the 88 total number of injured persons the 53 persons who had fastened their seat belts, the number injured persons who had not fastened their seat belts was calculated as 35 persons.

The injury rates to passengers who had fastened their seat belts and those who had not were calculated using these totals. It was calculated that approximately 52% of persons who had not fastened their seat belts sustained injury, compared with approximately 15% of persons who had fastened their seat belts sustaining injury.

Similarly, the rates of serious injury among passengers was calculated as about 7.5% for those who had not used their seat belts, about 0.6% for passengers who had.
(Refer to chart showed below)

Numbers of Injured Passengers and proportion of serious injury

Persons who	No.of boarding passengers	No.of injured persons	Rate of injury	No. of Seriously injured persons	Rate of Serious injury
Unfastened seat belts	67	35	52%	5	7.5%
Fastened seat belts	344	53	15%	2	0.6%
Total	411	88	---	7	---

Notes: The number of persons listed as having not fastened their seat belts includes persons who could not confirm whether they had fastened their seat belts or not (17 persons out of the number of injured persons, and 1 person out of the number of seriously injured persons).

Inspection of the numerical values clearly shows that the injury rate of those who had fastened their seat belts is lower than the rate of injury to those who had not, indicating the effectiveness of seat belts in preventing injury in the event of upsets. Moreover, it is considered that fastening seat belts is particularly effective in reducing the rate of serious injury.

Further, since there was an injury rate of 15% even to persons who had fastened their seat belts, it is considered possible that many of these injured had not properly fastened their seat belts or that their seat belts were loosened.

3.2.13.2 Injury of CA and situation of performing cabin services

Because of the nature on the duties of cabin attendants, that they are required to give services to passengers in the cabin and are responsible for cabin safety, it is considered that CAs do not take their seats and secure their harnesses except as the result of a Captain's instruction, as mentioned Japan Air Lines' OM.

At the time of the upset, because the CAs had commenced cabin services and were working at around the 2nd to 3rd seat rows from the front of each compartment, none of the CAs was in a position to secure their harnesses against the abrupt

aircraft descent.

Consequently, it is estimated that the situation in which all the CAs sustained injuries was the result of the fact that they were unable to prevent the galley carts from moving by pressing downwards, they rose from the floor together with the galley carts, and then dropped.

The degree that the CAs were thrown upwards and fell, while in the forward cabin CAs rose to the extent that they hit the ceiling panels and galley carts fell back to their original places and remained upright, in the aft cabins CAs struck the ceiling with sufficient force to break the panels, all of the carts toppled, and furthermore, one of CA and the galley cart she had been using broke through the ceiling panels and remained in the space above the ceiling. It is therefore considered that the degree of upset in the aft cabin was more severe than in the forward cabins.

Since it is the nature of CAs' that they are obliged move around the cabin, whether using galley carts or not, safety measures for CAs are considered necessary. In respect to this, it is considered that the fact that there were persons who managed to avoided injury despite not having their seat belts fastened by using arms or legs to absorb shock from impact or by grabbing the armrests of seats, will be a good reference.

Further, since the CAs, who were all working with galley carts at the time of the upset, responded reflexively to press down on the galley carts which would have been hazardous if thrown, it is also necessary to consider effective safety measures in relation to galley carts.

From these considerations, in addition to the safety measures for galley carts mentioning in section 3.2.15.4, it is necessary to examine that the provision of equipment such as hand grips that can be grabbed from the aisles, etc.

3.2.14 Rescue Activities

3.2.14.1 Rescue Activities in the cabin

Since when this accident occurred the flight crew could not give advance warning of the upset to the cabin crew, and since a situation occurred during which cooperation between the flight crew and cabin crew was not possible, it is considered that no preventative measures could have been taken prior to the start of the upset.

According to the statements of the CAs and passengers, the seat belt sign was not switched on after the accident occurred, but it is estimated that it was passengers securely fastened their seat belts as the result of a cabin announcement from the CP.

After the upset, the CAs checked the cabin to ascertain the situation of the injuries to passengers under a state of confusion, without time to regard their own

injuries, and rescue activities were conducted with the support of flight crewmembers who were engaged in operations activities. Rescue activities were concentrated within the areas of responsibility in the cabin of each CA by confirmation of the degree of injuries by calling out to passengers and first aid treatment to injured persons using first aid kits. Although there was no medical assistance from doctors, etc., it is considered that the crew had been able to respond, including to those seriously injured, because appropriate cooperation between crewmembers had been conducted.

However, it is considered that the summing up of the situations of the injured, the counting of the number of injured persons, etc. and the notification to the flight crew by CAs, carried out within a limited time and in conditions of confusion, was not completely satisfactory. Concerning this, it is considered that because CP and CAs had conducted the rescue activities in the cabin, it was difficult to grasp precisely the situation in the cabin.

According to the CVR tape recording, the report which the FO made between around 16:38:06 to 16:39:02 to Japan Air Lines' Tokyo Airport Branch on the company radio frequency concerning injuries to passengers and crewmembers noted that five passengers and one CA, a total of six persons, had been injured, and requested two ambulances. Also, a male voice was recorded at between 16:25:55 and 16:55:57, around the beginning of the remaining CVR recording, as saying "already requested ambulances".

3.2.14.2 Rescue Activities on the Ground

Japan Air Lines' Tokyo Airport Branch received information concerning the occurrence of the accident from Aircraft-A at around 16:19:00, around 25 min. before Aircraft-A's ETA (Estimate Time of Arrival) and 25 min. after the accident had occurred. The company log at that time indicated that numbers of injured persons was unknown. The said branch office made a 119 call to the emergency services and requested an ambulance to be dispatched immediately.

The Tokyo Fire Fighting Bureau received a report at around 16:24:00, and in response mobilized the Kamata Rescue Team, etc. based adjacent to Tokyo International Airport. After that, the ambulance arrived at the assigned place at the airport 10 min. before the arrival of Aircraft-A and stood by.

Regarding the dispatch of a single ambulance at first, the number of injured that the rescue team has been able to confirm just before the arrival of Aircraft-A at its spot was 6 persons. After that, the number of confirmed injured rose at the time of confirming injured persons and giving first aid treatment in the cabin, and again

when first aid treatment was being given in the rescue center established at the scene. Because the numbers of confirmed injured gradually increased at each stage, further assistance was requested each time. In total, 43 vehicles including ambulances for conveying the injured to hospital, and 155 rescue personnel were mobilized on that day.

As a result, first aid treatment of the injured after Aircraft-A had arrived at its spot took about 30 min. from 16:50, and the transfer of the injured to hospitals took about 1.5 hrs from 17:20.

Given these facts, as described in section 3.2.14.1 it is considered that it was difficult to grasp precisely the situation in the cabin within a limited time during the confusion after the accident occurrence, and re-examining the rescue activities on Aircraft-A and on the ground, the incorrect information was conveyed, and this affected the rapid rescue activities after Aircraft-A's arrival at the airport.

3.2.15 Damage of Cabin due to Galley Cart

3.2.15.1 Damage of Cabin

In this accident, ceiling panels in the cabin of Aircraft-A were damaged in several places. The position of the CAs and galley cart they had been using in carrying out cabin service duties and the positions of the damaged ceiling panels corresponded nearly. Consequently, it is estimated that ceiling panels had been damaged due to the impact of CAs and galley cart when they were thrown.

Some parts of floor panels in the cabin had also been damaged, and from the fact that many galley carts received damage to the lower part of cart where casters are attached, it is estimated that this damage was caused by the shock caused by the impact of galley carts dropping after being thrown.

3.2.15.2 The Throwing and Falling of Galley Carts

At the time that the accident occurred, the CAs were carrying out cabin service duties, serving beverages to passengers, and many galley carts were in use. It is estimated that all the galley carts in use were thrown, and one of the galley cart in use in the aft cabin pushed up the ceiling panel located over the aisle, entered the space above the ceiling panels, damaged adjacent air conditioning ducts and came to rest lying between air condition ducts and a supporting structure beam.

3.2.15.3 The Galley Cart above the Ceiling

There was a risk of the galley cart that had been emplaced above the ceiling falling back into the cabin or damaging the aircraft's flight control or other systems.

However, it was difficult to bring the galley cart down during flight. Therefore, passengers in the vicinity were relocated to a safe area, and the galley cart remained above the ceiling till landing. As the result of the examination after the accident occurred, after Aircraft-A had returned to Tokyo International Airport, it is considered that the galley cart would not have fallen back into the cabin at that time.

3.2.15.4 Safety Measures regarding Galley Carts

As described in section 2.12.1.2, some devices for securing galley cart had been installed on the floor adjacent to the exits, but in this accident, because the upset occurred abruptly without prior warning, it is estimated the fixtures could not have been used. In the case that an aircraft when descends abruptly or changes attitude abruptly due to turbulence etc., if galley carts are in use then there is the risk of them being thrown or toppling, resulting in possible injuries to passengers and crewmembers and also possibly causing damage to the aircraft's flight control and other systems. Because of this, it is necessary to examine new measures to strive to reduce the possibility of galley carts being thrown, by means of securing the galley carts during cabin services, etc.

4 PROBABLE CAUSE

It is considered that the accident was caused as follows:

A Conflict Alert (CNF) was issued at Tokyo ACC warning of the proximity of Japan Air Lines flight 907 (Aircraft-A), which was making a climbing left turn, and Japan Air Lines flight 958 (Aircraft-B), which was cruising in level flight. While responding to this conflict alert, Tokyo ACC mistook the flight number of Aircraft-B for that of Aircraft-A, and instructed Aircraft-A, which was climbing at the time, to descend.

Immediately after Aircraft-A initiated a descent in response to this instruction, its Traffic Alert and Collision Avoidance System (TCAS) issued a Resolution Advisory (RA) to climb, but Aircraft-A continued the descent in compliance with the ATC instruction. Both Aircraft-A and Aircraft-B which descended in response to its own TCAS RA, came to abnormal close proximity while maintaining mutual visual contact, and just before their closest point of mutual approach both aircraft made evasive maneuvers to avoid a collision based on visual judgment. Aircraft-A made an abrupt descent intending to pass under Aircraft-B just before their flight paths crossed, and as a result passengers and cabin attendants (CA) of Aircraft-A rose from the cabin floor or seats, floated, then dropped and sustained injuries.

It is considered that the following causal factors contributed to the accident:

- (1) Regarding Tokyo ACC's descent instruction which was mistakenly issued to Aircraft-A instead of Aircraft-B: When the conflict alert was issued, the ATC trainee who was controlling the heavily congested traffic of Kanto South C sector and his ATC watch supervisor were psychologically upset by the urgent situation, and the ATC trainee, mistaking the flight numbers, issued an instruction to descend not to Aircraft-B as he had intended but to Aircraft-A, and the ATC watch supervisor did not notice this mistaking of flight numbers. When Aircraft-A read back the ATC instruction, neither the ATC trainee nor ATC watch supervisor noticed that the flight number read back was different from the one intended.
- (2) Regarding the psychological upset of the ATC trainee and ATC watch supervisor when the conflict alert was issued: Both the ATC trainee and the ATC watch supervisor had forgotten the presence of Aircraft-B when the conflict alert was issued. The CNF conflict alert was issued not at the specified three minutes before standard separation would be

lost, but two and a half minutes later than that, at approximately one minute before the closest point of approach. At that time, the controllers felt that it had become very difficult to maintain standard separation with ATC instructions, so it was necessary to urgently issue instructions within the limited time available to avoid a collision.

- (3) Regarding the circumstances in which the ATC trainee had forgotten the presence of Aircraft-B: At the time of the radar hand off and establishment of radio contact with Aircraft-B, American Airlines flight 157 (Aircraft-C) was cruising at the same flight level approved for Aircraft-A and the aircraft were on converging flight paths. The ATC trainee therefore called Aircraft-C twice to issue an instruction to secure separation against Aircraft-A. However, he received no response from Aircraft-C because he had not established radio communication with it, so his attention was directed to Aircraft-C at that time. Also, just prior to establishing contact with Aircraft-B, the ATC trainee communicated with Aircraft-D (Japan Air Lines flight 952) which had the flight number similar to that of Aircraft-B, and that he continued communicating with another aircraft without pause immediately after. As a result of these events, the presence of Aircraft-B was not sufficiently kept in the ATC trainee's memory. Furthermore, while later receiving comments from the ATC watch supervisor on the ATC tasks performed up to that time, he did not reconfirm the traffic situation on the radar display and so remained unaware of Aircraft-B's presence.
- (4) Regarding the circumstances in which the ATC watch supervisor had forgotten the presence of Aircraft-B: The ATC watch supervisors' continuing unawareness of the presence of Aircraft-B was attributed to: her coordination with a neighboring sector on the separation of Aircraft-A and Aircraft-C; the subsequent direction of her attention to obtaining contact with Aircraft-C; then, at the time that priority should have been given to reconfirming the air traffic situation on the radar display, her giving comments to the ATC trainee on the ATC tasks performed up to that time and remaining in condition of forgetting. Further, the ATC watch supervisor had not received any education on appropriate training methods as training supervisors.
- (5) Regarding the circumstances in which the conflict alert was not issued at the specified time of three minutes before standard separation would be lost: The Air Route Radar Data Processing System did not have a function to predict the possibility of separation being lost taking into account turning flight path of aircraft.
- (6) Regarding the circumstances in which Aircraft-A did not comply with RA indicating a

climb, it was psychologically difficult for the Captain of Aircraft-A to change an action which he had already started, because he had already initiated a descent in accordance with the ATC instruction to descend when RA was issued, he thought the air traffic controller had issued the instruction in order to secure separation based on a complete information of all aircraft in the airspace; he was maintaining constant visual contact with Aircraft-B and he judged that rather than climb again it was better to continue the descent because he was not confident about the aircraft's climb performance at that altitude. The Captain was also not sufficiently aware of the risks of maneuvering contrary to an RA instruction.

- (7) Regarding the circumstances in which Aircraft-A continued descending: It was difficult for the flight crew of Aircraft-A to grasp precisely the vertical separation between their own aircraft and the descending Aircraft-B and the movement of Aircraft-B by visual observation; they were not sufficiently aware about the dangers of maneuvering contrary to the RA indication; their situation awareness from displayed TCAS information was insufficient; and the flight crewmembers other than the Captain did not give proper advise to the Captain that he should comply with the RA.
- (8) Regarding the circumstances in which the Captain of Aircraft-A was not sufficiently aware of the potential dangers of maneuvering contrary to an RA indication: the flight crewmembers other than the Captain did not give proper advice to the Captain that he should comply with the RA; the expressions in manuals relating to flight operations did not sufficiently instill in the flight crew recognition of the dangers of maneuvering contrary to an RA; the flight crew's training regarding TCAS had been insufficient; and there had been nothing in the Cockpit Resource Management (CRM) training regarding the division of tasks related to TCAS.
- (9) Regarding the insufficiency of expressions in manuals relating to flight operations to allow flight crews to recognize the dangers of maneuvering contrary to an RA: the Aeronautical Information Circular (AIC) issued by the Civil Aviation Bureau, and ICAO documents for aircraft operation did not explain that RAs should be complied with and the dangers of maneuvering contrary to an RA. In particular, it was not explained that the RA should be complied with when an ATC instruction and an RA are received at the same time and conflict each other.
- (10) Regarding the injuries to the passengers: There were many passengers who had not fastened their seat belts, and many of them rose and then dropped due to the motions of

the aircraft, since the accident occurred at the time when the seat belt signs were turned off and the cabin service had just begun. Regarding injured passengers who had fastened their seat belts, in the main their seat belts had not been properly fastened, and one of the injured was struck by a falling person who had raised due to aircraft motions.

- (11) Regarding the injuries to cabin attendants: The cabin attendants were performing cabin service duties at the time of the accident, and since they did not have time to put the galley carts back to the galley or to secure themselves with seatbelts because of the aircraft's abrupt maneuvering, they could not keep the galley carts under control and rose together with them from the cabin floor, floated and fell.

5 MATTERS FOR REFERENCE

5.1 Measures taken by the Civil Aviation Bureau of the Ministry of Land, Infrastructure and Transport in response to the proposals contained in the interim report of this accident investigation

Responding to the proposals made by the then Aircraft Accident Investigation Commission in the progress report relating to this accident published on June 22, 2001, the Civil Aviation Bureau of the Ministry of Land, Infrastructure and Transport replied to the following effect on September 21, 2001. (See Attachment 6.)

5.1.1 Improvement of mutual awareness between air traffic control and aircraft

In order for air traffic controllers to recognize appropriately the issuance of RAs and the avoidance maneuvers by pilots, it is planned to establish means and ways of communication between air traffic control facilities and aircraft that will enable rapid and certain mutual awareness by, in the case that an RA is issued by an aircraft's TCAS during flight, indicating RA information on radar displays concerning the content (upward or downward avoiding direction) of the RA and the ending of the RA to provide this information to air traffic controllers.

5.1.2 Improvement of training of air traffic controllers to promote cooperation between air traffic control and aircraft

Comprehensive training is planned to promote cooperation between air traffic control and aircraft, by implementing training utilizing radar simulators with RA indication functions that display the commanded evasive maneuvers so that air traffic controllers can deal appropriately with cases in which RAs are issued, and by increasing opportunities to conduct familiarization training on aircraft (e.g. air traffic controllers observe operations in the aircraft cockpit to deepen their understanding of the situation on the pilot side, etc.).

5.1.3 Investigation and analysis of actual circumstances corresponding to issuance of TCAS RA

It is planned to conduct investigation and analysis of actual circumstances in which TCAS RAs have been issued, and to examine measures for improvement as necessary, with an examination committee consisting of academics and persons of experience: former air traffic controllers, pilots, TCAS researchers, the Civil Aviation Bureau, etc.

5.2 Safety measures for prevention of recurrence of this accident taken by the Civil Aviation Bureau of the Ministry of Land, Infrastructure and Transport

On June 27, 2001, the Civil Aviation Bureau of the Ministry of Land Infrastructure and Transport prepared safety measures containing the items enumerated in paragraphs 5.2.1 through 5.2.7 below in order to prevent recurrence of this accident. Measures corresponding to the proposals mentioned in paragraph 5.1 above were also contained in the safety measures. In addition, measures described in paragraph 5.2.8 were taken by the Civil Aviation Bureau.

5.2.1 Strengthen the training system

- (1) Strengthen the organization of the training facilities
- (2) Strengthen the system of training instructors
- (3) Strengthen the system of training supervisors
- (4) Establish a training system for improving ATC skills
- (5) Introduce comprehensive training regarding human relationships (Introduction of TRM training)
- (6) Improve training equipment
- (7) Implement measures to cope with insufficiency of performance during training, etc.

5.2.2 Strengthen aptitude assessment, etc.

- (1) Review the entrance examination to the Aeronautical Safety College with respect to aptitude assessment
- (2) Review the basic training course at the Aeronautical Safety College
- (3) Introduce a system for periodical examination for air traffic controllers
- (4) Establish measures in regard to air traffic controllers who are determined to have difficulty in performing their duties

5.2.3 Improve the working environment, etc.

- (1) Clarify the assigned roles of each operating position
- (2) Clarify of duration of time at a position
- (3) Introduce a system of promotion corresponding to ability
- (4) Improve labor conditions corresponding to duties, and pressure of work and difficulty of each position
- (5) Review the safety reporting system

5.2.4 Substantiate interchange with pilots, etc.

- (1) Substantiation of aircraft on board familiarization training
- (2) Systematization of interchange meetings with pilots
- (3) Substantiation of cross training

5.2.5 Development of ATC supporting systems, etc.

- (1) Reinforce the conflict alert function
- (2) Indicate TCAS RA information on radar displays
- (3) Introduce an advanced ATC sector console that adds aircraft sequencing function, etc.
- (4) Graphic display of aeronautical information, meteorological information, etc.

5.2.6 Drastic rearrangement of air space and air routes

- (1) Promote double track and one-way air routes utilizing area navigation (RNAV)
- (2) Reorganize the controlled air space of area control centers
- (3) Develop of wide area radar approach control services
- (4) Reorganize air space of major air terminals
- (5) Unify control of air space, etc.
- (6) Reinforce the air traffic flow and air space management system

5.2.7 Clarify identification of aircraft flight numbers

5.2.8 Addition of altitude restrictions to standard instrument departure routes

On March 22, 2001, altitude restrictions were added to the OCEAN transition of the standard instrument departure routes of Tokyo International Airport.

5.3 Development plan of air traffic control equipment and personnel assignment plan for air traffic controllers in the Civil Aviation Bureau, etc.

In response to this accident, the Ministry of Land Infrastructure and Transport Civil Aviation Bureau, etc. prepared a development plan of air traffic control equipment and a personnel assignment plan for air traffic controllers. The followings are the contents of the plans, including items already carried out.

- (1) Improvement of the conflict alert function
FY (Fiscal year) 2001: Modification of RDP program
- (2) Indication of RA information on radar displays
Modification of display control unit

FY 2003: Sapporo, Tokyo, Fukuoka and Naha ACC

Renewal of radar sites (corresponding to Mode S)

FY 2002: Yamada (Chiba)

FY 2003: Iwaki (Fukushima), Mikuniyama (Osaka)

Thereafter, approximately two sites will be renewed every year. Renewal of all sites will be completed in approximately ten years.

(3) Substantiation of the education and training of air traffic controllers

- ① Radar simulators for recurrent training (Sapporo, Tokyo, Fukuoka and Naha ACCs, Iwanuma Training Center, Hakodate Airport and 16 other airports)

FY 2002: System design

FY 2002–2003 : Purchase of equipment

FY 2003: Installation work

End of FY 2003: Start of operation

- ② New allocation of training instructors

FY 2002: 15 instructors

Kushiro, Sendai, Chofu, Niigata, Yao, Hiroshima, Takamatsu, Matsuyama, Kochi, Oita, Shimojishima, Obihiro, Okayama and Ishigaki Airports, AirTraffic Flow Control Center

FY 2003: 12 instructors

New-Tokyo, Kansai, Fukuoka, Miyazaki, Kagoshima, Aomori and Miyako Airports, Sapporo, Tokyo, Fukuoka and Naha ACC

5.4 Measures for prevention of recurrence of this accident taken by Japan Airlines

Measures for prevention of recurrence which were taken by Japan Airlines after the accident were as follows:

- (1) On February 1, 2001, this accident was promptly introduced as a report in Operations News.
- (2) On February 2, 2001, the Senior Vice President, Flight Operations Division instructed to thoroughly implement preventive measures of near midair collisions in order to ensure the safe operation of aircraft.
- (3) On March 5, 2001, Operations Order GENE-94 was issued with respect to operation of TCAS.
- (4) On March 12, 2001, Operations News published regulations and information related to prevention of near midair collision that should be reconfirmed.
- (5) On May 14, 2001, Operations Information 5 was issued to provide supplemental explanation about TCAS.

The contents included description of the principle of detect threatening aircraft by

TCAS, the TCAS coordination function, and possibility to climb even at high altitude by exchanging excess thrust and speed energy for climb rate.

(6) On September 14, 2001, Operations Order GENE-100 providing operational guidance was issued. The main contents were as follows:

Pay attention to prevention of collision based on right of way, etc. when a TA is issued. Comply with RAs immediately after they are issued. In case that the Captain judges that the collisions risk has increased even though evasive maneuvers have been carried out in accordance with the RA, try to avoid other maneuvers. Even in these cases, maneuvers contrary to the RA may remarkably reduce the separation between aircraft.

Notify air traffic control as soon as possible after commencement of evasive maneuvers.

6 RECOMMENDATIONS AND PROPOSALS TO MINISTER FOR LAND, INFRASTRUCTURE AND TRANSPORT

Based on the result of the investigation of this accident, in addition to the proposals in the interim report submitted regarding the investigation of this accident on June 22, 2001, the Aircraft and Railway Accident Investigation Commission (ARAIC) makes the following recommendations that are considered particularly necessary for the prevention of aircraft accidents. Also, ARAIC makes proposals below that are considered necessary to ensure aviation safety and to allow the smooth and accurate investigation of accidents.

I. RECOMMENDATIONS

[1] The reliable operation of air traffic control services

The following measures related to improvement of air traffic control (ATC) equipment and air traffic controllers training are necessary to secure reliable operation of air traffic control services and ensure aviation safety.

(1) The improvement of the issuing time of CNF

Due to the turning flight of Aircraft-A (Japan Airlines flight 907) in this accident, the CNF (Conflict Alert) did not appear on the air traffic control radar display used by the air traffic controllers at Tokyo Area Control Center at the specified time of 3 minutes before the prescribed ATC separation between Aircraft-A and Aircraft-B (Japan Airlines flight 958) would be lost, but was issued after a delay of approximately 2 minutes 30 seconds. When CNF was issued, it was between thirty and forty seconds before the anticipated loss of ATC separation, at a time when it would have been extremely difficult situation to maintain ATC separation between the aircraft by ATC instructions. To allow air traffic controllers to properly perform their duties, it is necessary that they should grasp the possibility of close proximity of aircraft under their control with a sufficient time margin, and the CNF should be issued at a time when it is still possible to ensure separation through ATC instructions.

Therefore, the operation of CNF should be augmented such that a CNF alert is issued while it is still possible to maintain ATC separation by issuing ATC instructions, even in cases that aircraft become close as a result not only of continuing in straight flight but also by changing heading.

(2) Indication of RA information on the air route ATC radar display

In this accident, the reports from the aircraft to air traffic control concerning the TCAS (Traffic Alert and Collision Avoidance System) RAs (Resolution Advisories) were made after the aircraft had passed their closest point of approach, when the danger of collision had been averted. To be able to deal appropriately with RAs issued on aircraft, it is necessary that ATC obtain information on the issuance of RAs as early as possible. Therefore, in addition to the report by a flight crew member to air traffic control through radio communication as described in paragraph 2 (2) below, the air route radar display used by air traffic controllers should indicate RA information issued by TCAS on aircraft such that the air traffic controllers can grasp the state of aircraft on-board TCAS operation, rapidly, positively and easily.

(3) Air traffic controller training

In this accident, it is thought in the background to the instruction to descend by Tokyo Area Control Center mistakenly being issued to Aircraft-A by saying the wrong flight number was the inappropriate method used by the ATC watch supervisor of administering OJT (on-the-job-training) to the ATC trainee.

Also, for future accident prevention, it is necessary to strengthen the cooperative working among air traffic controllers when they perform air traffic control duties, and to conduct training of air traffic controllers regarding TCAS.

Therefore, the following measures are recommended to substantially reinforce the training to air traffic controllers.

(i) Review of the method of OJT for air traffic control duties

Review the method of OJT for air traffic control duties, and take all possible measures to ensure the proper execution of air traffic control duties during OJT. In particular, prescribe a method for ATC watch supervisors to explain to ATC trainees using intervals while carrying out duties about tasks previously carried out, such that the explanation does not interfere with the recognition of the air traffic situation during their duties.

(ii) Required qualifications etc. for ATC watch supervisors conducting OJT in air traffic control duties

Clarify required qualifications for ATC watch supervisors, train ATC watch supervisors in methods of OJT instruction, and confirm that ATC watch supervisors have acquired the necessary knowledge and skills.

(iii) Training regarding cooperative working between air traffic controllers

In order to ensure the cooperative working of controllers within a team operating a sector and between adjacent sectors, train air traffic controllers in mutual cooperation under circumstances simulating actual conditions by using similar methods to Crew

Resource Management (CRM) or Line-Oriented Flight Training (LOFT) which are utilized for flight crew training.

(iv) Training of air traffic controllers regarding TCAS etc.

Plan comprehensive training for air traffic controllers regarding knowledge of TCAS and responses to receiving information about an RA. Also plan comprehensive training regarding knowledge about the conditions of CNF operation and the relationship between the trajectory of the aircraft and the warning time provided by CNF, and the response to CNF alerts, particularly in cases where the alert is issued unexpectedly.

(v) Regular training of air traffic controllers

Implement periodic training of air traffic controllers, starting with knowledge about TCAS and measures to be taken in response to TCAS, such that they may be enabled to always carry out air traffic control duties based on the latest knowledge. Also, plan training such that air traffic controllers can periodically refresh their knowledge about TCAS, and have them experience simulated scenarios that would rarely occur in their normal daily duties, such as loss of separation between aircraft or an RA issued on an aircraft, to maintain and improve their ability to cope with emergency situations.

[2] Measures relating to issuance of RA in aircraft operation

To secure flight safety, the following measures are necessary such that when a TCAS RA is issued during aircraft operation, the flight crew may take appropriate measures and report information promptly to ATC.

(1) Response to TCAS evasive directions in aircraft

In this accident, Aircraft-A descended in accordance with an instruction from ATC despite a TCAS RA advising a climb, while Aircraft-B descended in accordance with an RA that advised to descend, and as a result both aircraft descended and ended up in abnormally close proximity. In June 2001, then Aircraft Accident Investigation Commission proposed to conduct a survey of actual cases of RAs being issued and to examine measures for improvement. According to the subsequent examination by this Commission, it was considered that to prevent aircraft accidents, when proximity with another aircraft is anticipated, it is necessary that aircraft carry out evasive maneuvers under the principle that they must comply with the RA's evasive instruction without fail. Therefore, the following measures are recommended based on the survey proposed in June 2001 and the result of the examination, in particular the examination of whether the cases in which it is not appropriate to comply with RA should be limited.

- (i) Clarify the measures to be taken by the flight crew in response to an RA, paying attention to the following points.
 - (a) The RA must always be complied with, except for a few exceptional cases corresponding to (c) or (d) below.
 - (b) The danger of conducting maneuvers contrary to the RA must be clearly explained.
 - (c) If it is considered that there are any situations in which it is not appropriate to comply with the RA, it must be explained concretely and as clearly as possible what kind of situations exist.
 - (d) When the flight crew receives conflicting instructions from ATC and RA simultaneously, they are to comply with the RA as a matter of principal. If there are any exceptional circumstances under which the ATC instruction must be followed, these should be explained concretely and as clearly as possible.
- (ii) Persons concerned should be informed thoroughly about measures resulting from the above, by prescribing them in the AIC issued by Civil Aviation Bureau, aircraft operations manuals and by other effective means.

(2) Report regarding to TCAS RAs to the air traffic control

In this accident, although Aircraft-B conducted evasive maneuvers in accordance with the RA, the report to this effect to air traffic control was made after point of nearest had been passed and the danger of collision alleviated. This report by Aircraft-B was made in accordance with the company rules of the aircraft operator. In June 2001, the then Aircraft Accident Investigation Commission made a proposal to examine the means and manner of radio communications to obtain prompt and certain understanding between air traffic control and aircraft. According to the subsequent study by our Commission, the measures listed below are considered to be particularly necessary.

In order that air traffic control is informed of the issuance of RAs on aircraft, to allow air traffic controllers to handle such situations appropriately, it is necessary to implement the following measures and to inform persons concerned about them thoroughly.

- (i) In case that the flight crew performs an evasive maneuver in accordance with an RA, air traffic control should promptly be notified to this effect, at the earliest opportunity before the risk of collision is averted unless it is difficult to do so due to the execution of avoiding maneuvers, etc.

- (ii) Persons concerned should be informed thoroughly about measures resulting from the above, by prescribing them in the AIC issued by Civil Aviation Bureau, aircraft operations manuals and by other effective means.

(3) Request to the International Civil Aviation Organization regarding TCAS

Concerning the items mentioned in the above paragraphs (1) and (2), it is considered that the measures taken in our country when the accident occurred were based on the regulations related to TCAS provided by the International Civil Aviation Organization (ICAO). Therefore, at the opportunity of occurrence of this accident, the following requests are made to ICAO to amend the related regulations for the effective operation of TCAS as follows:

- (i) Amend ICAO Annex 6 or PANS-OPS to state explicitly that pilots should always comply with an RA with a few limited exceptions. In particular, it should be described that when pilots receive simultaneously contrary instructions to maneuver from ATC and an RA, they must comply with the RA.
- (ii) Revise PANS-OPS to describe the danger of maneuvering in contrary to the indication given by the RA. Such material has already been included in the Guidance Material to ICAO Annex 10 Volume 4 Chapter 4 Appendix A.
- (iii) Revise PANS-OPS to state explicitly that, in the case that a pilot carries out evasive maneuvers in response to an RA, ATC shall be notified as soon as possible before the danger of collision is averted, unless it is difficult to do due to the execution of evasive maneuvers etc.

(4) Flight Crew Training

In this accident, it is considered that the Captain of Aircraft-A descended not in compliance with the RA's direction to climb but in accordance with the instructions of air traffic control to descend, and the other flight crewmembers did not advise the Captain that a climb RA had been issued and that he should follow RA. Furthermore, the Captain of Aircraft-A mentions that anxiety about the climb performance of the aircraft at high altitude was one of the reasons why he judged to descend. To enable flight crewmembers to respond appropriately to an RA, it is necessary to comprehensively strengthen flight crew training regarding TCAS paying attention to the following factors and taking into consideration the matters pointed out in (1) and (2) above, and guidance should be given to aircraft operators to this effect.

- (i) For training regarding TCAS, emphasis should be put not only the method of maneuvering to comply with an RA, but also on the principle that an RA should always be complied with except in a few exceptional cases, and on the means of distinguishing

cases where an RA should be complied with from cases where it should not. In particular, training should be provided on how to respond when ATC instructions and the RA contradict each other, the principle that RA should be complied with except in a few exceptional cases, in what kind of exceptional cases ATC instructions should be complied with instead, and the reporting to air traffic control when following an RA.

- (ii) Sufficient classroom training should be given about the coordination of RA commands between TCAS-equipped aircraft, the dangers of maneuvering contrary to an RA, the way the PF and PNF should utilize TCAS displayed information, aircraft performance when an RA is issued at high altitude, reporting to air traffic control regarding an RA, etc.
- (iii) For practical skills training regarding RAs, realistic training exercises should be conducted, as far as possible using flight simulators, with various scenarios that may be encountered in operations, for example the situation experienced in this accident that an ATC instruction and RA are in contradiction. Training should also be conducted on the avoidance maneuvers in response to an RA, the roles and responsibilities of the PF and PNF, the notification to ATC, and cooperative work among the flight crew utilizing CRM and LOFT methods.

[3] Fastening of seat belts by aircraft passengers

Examination of the injury rates to passengers from the viewpoint of fastening or not fastening of seat belts in this accident found that the injury rate to passengers who did not fasten their seat belts was clearly higher than to those who had fastened their seat belts. In particular, there is a conspicuous difference in the rates of serious injury between fastening and not fastening seat belts.

It is essential for the safety of passengers that seat belts be fastened during in-flight upsets. Although on March 5, 1999, the then Aircraft Accident Investigation Commission made “a proposal to promote fastening of seat belts at all times during aircraft operation”, it is also recommended hereafter that aircraft operators should take further measures to drive home the importance of passengers fastening seat belts at all times during flight.

II. PROPOSALS

[1] Improvement of air traffic control operational methods

To ensure the safety of flight, it is necessary to examine the following items and to take appropriate measures with respect to air traffic control operational methods, improvement of air traffic control equipment, and the training of air traffic controllers.

(1) The positive conduct of radar hand off and establishment of communication

In this accident, it is considered that the presence of Aircraft-B was not fixed sufficiently in the consciousness of the ATC trainee at the time of radar hand off and establishment of communication with it. It is considered that in order to avoid losing awareness of the existence of an aircraft, it is a basic air traffic control operation principle that the existence of the aircraft be positively recognized at the time of radar hand off and establishment of communication.

Therefore, it is necessary to examine whether there are any further measures that may be taken to ensure the fixation in memory of the existence of aircraft at the time of radar hand off and establishment of communication, and to secure the positive operation of ATC communications, and to take appropriate measures as necessary.

(2) Utilization of video recording for OJT for air traffic control duties

In this accident, as part of the on-the-job training for air traffic control duties, the ATC watch supervisor conducted an explanation to the ATC trainee regarding tasks carried out, while he was on duty. Although the explanation of tasks already carried out is more effective if it is conducted while they are still fresh in memory, if such explanation is conducted while the trainee is on duty and if the trainee becomes absorbed in it there is a risk that his or her situational awareness of the aircraft on the radar display may become insufficient.

Therefore, during OJT for air traffic control duties, videotape recordings of the radar display and recordings of ATC communication, additional to the normal recordings, should be made for the purposes of training, and the explanation about tasks carried out should be conducted after the end of the duty period utilizing these image and sound recordings. The feasibility of this method should be examined, and appropriate measures taken as necessary.

(3) Situational awareness of air traffic while performing air traffic control duties

In this accident, the ATC trainee and his ATC watch supervisor had forgotten about the presence of Aircraft-B until the CNF was issued. It is necessary to take measures

mentioned in the above paragraphs (1) and (2) in order to prevent air traffic controllers from forgetting about the presence of aircraft that they are handling while on duty. Furthermore, it is necessary to take all possible measures to counter this problem, since it is a matter of human errors that may occur at any time.

Therefore, appropriate measures in addition to the items pointed out in the above paragraphs (1) and (2) should be examined and implemented as necessary.

(4) Communications between aircraft and air traffic control

ARAIC made a proposal related to this accident in June 2001 to examine methods and means of communication to obtain mutual awareness between air traffic control and aircraft regarding TCAS RAs. Subsequent examination by this Commission found that the reliability of communications between aircraft and air traffic control clearly decreases under urgent situations, such as the close approach of Aircraft-A and Aircraft-B in this accident. Therefore, in order to secure the positive execution of essential communications in urgent situations and to minimize the occurrence of abnormally close proximity, the Commission examined what measures should be taken to effectively prevent the same sort of situation from recurring.

From the viewpoint of avoiding abnormally close proximity much as possible, in the case that aircraft are conducting evasive maneuvers following an RA, it is recommended to examine concrete methods for receiving information from the aircraft regarding the issuance of the RA at air traffic control facilities, to provide information about the aircraft involved, etc. and to implement appropriate measures as necessary.

(5) Comprehensiveness of the safety reporting system

To contribute to flight safety, a safety reporting system is operating under which information on unsafe instances experienced during daily air traffic duties are collected and distributed to persons concerned. In order to increase the filing of reports in response to unsafe instances and to make positive use of them, it is recommended to review the safety reporting system for its vitalization, including how to ensure the neutrality of the administrator of the system, how to protect the confidentiality of the information providers, etc., and to take appropriate measures as necessary.

[2] Circulation of information regarding the operation of TCAS

In order to circulate information regarding salient points about TCAS operation, example cases where RAs have been issued, etc. to flight crews, air traffic controllers, and other concerned persons, and to enhance the appropriate operation of TCAS, it is necessary to examine the following items and to take appropriate measures.

(1) Preparation of guidance materials regarding TCAS operation

In order that flight crews, air traffic controllers, and other concerned persons, should understand correctly about TCAS and so that TCAS is operated properly, the unified procedures for TCAS operation should be indicated concretely and clearly by means of preparing guidance material on TCAS operation with content equivalent to material such as the Advisory Circulars of the United States (AC-121-55A or its revisions) and Guidance Material of the United Kingdom (CAP579), or enhancing the content of the AIC issued by the Civil Aviation Bureau.

(2) Effective utilization of the RA reporting system

RAs experienced by flight crews during aircraft operations are reported to the Civil Aviation Bureau as RA reports. Information such as the concrete contents of those reported cases that are considered important to improving aviation safety, statistical data, results of evaluation of all reported instances, etc. should be compiled and distributed to flight crewmembers, air traffic controllers and other concerned persons, while paying attention to the confidentiality of the information providers, and utilized effectively to improve the safe operation of aircraft.

[3] Prevention of injuries to passengers and cabin crew, and the administering of first aid

In order to prevent injuries to passengers and cabin crew in the case of in-flight upsets, and to administer first aid to injured persons smoothly, in addition to the thorough promotion of fastening seat belts for passengers as mentioned paragraph 3 of the Safety Recommendations above, it is necessary to examine the following items and to take appropriate measures.

(1) Aircraft cabin safety measures

Many passengers sustained injury in this accident. Also, all twelve CAs were injured, two sustaining serious injuries. At the time of the accident, all of the CAs was engaged in the cabin services. They and their galley carts rose from the cabin floor together and then dropped, resulting in injury. In particular, one cabin attendant was projected above the cabin ceiling with the galley cart which she had been using.

Considering these facts, in order to secure the safety of passengers and cabin crew during aircraft operation and to eliminate the risk of damage to aircraft control systems, etc. by projected galley carts, examine the feasibility of the following safety measures for aircraft cabins, and then take appropriate measures as necessary.

(i) Reduce the possibility that galley carts are projected by means of securing galley carts

being used for cabin services or by any other effective methods.

- (ii) As safety measures for passengers and CAs when they walk about the cabin, install hand grips or other equivalent equipment which are easy to grab from the aisles.

(2) Reporting about injured persons to ground facilities after an accident

In this accident, compared with the number of injured reported by Aircraft-A before its arrival at the airport, the number of injured confirmed after its arrival increased as time went by, and the dispatch of additional ambulances as requested every time the number of confirmed injured increased. It is considered that it was difficult to accurately grasp the situation inside the cabin of Aircraft-A in the confusion after the accident within the limited time between the occurrence of the accident and landing. Even under such circumstances, it is considered that reporting the status of injured persons in the cabin as accurately as possible will be effective for enabling prompt rescue operations after arrival at the airport.

It is considered to be an effective method for rapid reporting that cabin crewmembers report directly to the ground facilities about the situation in the cabin after the occurrence of an accident, by using satellite telephones furnished in the cabin or by any other available means, without unnecessarily disturbing flight crewmembers who are busy with aircraft operation. The feasibility of such methods of reporting should be examined, and appropriate measures implemented as necessary.

[4] The recording of data for accident investigations

The DFDR (Digital Flight Data Recorder) and CVR (Cockpit Voice Recorder) are extremely important to precede the aircraft accident investigation process smoothly and that accurate findings may be obtained. It is therefore necessary to take the following measures with respect to DFDR and CVR.

(1) Addition of TCAS data to DFDR recorded data

After the accident occurred, both aircraft had no further disruption to their operations. Therefore, after Aircraft-A and Aircraft-B had landed, the DFDR recordings and TCAS data recorded on separate recording devices could be downloaded after those devices had been removed from the aircraft. However, in the event of a mid-air collision, it is considered that it would impossible to obtain TCAS data unless such data are recorded on the DFDR, which is designed to withstand impact and fire, instead of on other non-crashworthy recorders. In this case, the task of the subsequent accident investigation to analyze the situation of both aircraft at around the time of the collision would be considerable more difficult.

ICAO Annex 6 specifies as an international standard the installation of Type 1A Flight Data Recorders (FDRs) on all aircraft with a maximum take off weight exceeding 5,700 kg and of which first airworthiness certificate will be issued after January 1, 2005. It is required that the Type 1A FDR record TCAS data if such data are used by aircraft systems or the flight crew.

For these reasons, that TCAS parameters that are necessary for accident investigation should be added to the parameters be recorded on the DFDR, and Japan should implement domestically the above-mentioned stipulation of ICAO Annex 6.

(2) Extension of the recording time of CVR

It is useful for accident investigation to obtain information about the flight crewmembers' responses to the accident, instructions and comments exchanged between the flight crewmembers, warning sounds in cockpit, etc. from the voices and sounds recorded by the cockpit voice recorder around the time of accident occurrence. In this accident, however, Aircraft-A landed 50 minutes after the accident occurrence and Aircraft-B landed at 37 minutes after the accident occurrence, and because the CVRs recorded only the last 30 minutes up to the time when the aircraft parked at their spots after landing, voice and sound recordings from at or before the time of the accident were not retained.

ICAO Annex 6 specifies as an international standard the installation of a CVR of which the recording time is longer than two hours on aircraft with a maximum take off weight of exceeding 5,700 kg for which first airworthiness certificate will be issued after January 1, 2003, and it also recommends the installation of a CVR of which the recording time is longer than two hours on airplanes with maximum take off weight of exceeding 5,700 kg for which first airworthiness certificate was issued after January 1, 1990.

For these reasons, Japan should extend the mandated recording times of CVRs to a period longer than 30 minutes, and implement domestically the above-mentioned contents of ICAO Annex 6 in accordance with the ICAO standards and recommended practices to facilitate the smooth and accurate process of accident investigation.

7 SAFETY RECOMMENDATIONS TO ICAO

In this accident, just after Aircraft-A had started to descend following an ATC instruction, its flight crew received a TCAS RA instructing a climb, but it continued descending. Meanwhile, Aircraft-B descended in accordance with its own TCAS RA. As a result of both aircraft descending, they approached to an abnormally close proximity. After the danger of collision had passed, the pilots of Aircraft-B notified ATC that they had made evasive maneuvers in response to an RA.

The Aircraft and Railway Accidents Investigation Commission (ARAIC) of Japan believes descriptions in ICAO regulations related to ACAS operation influenced the actions of the flight crews in this accident. This Commission therefore recommends that, in order to better ensure flight safety and prevent recurrence of similar accidents and the occurrence of midair collisions, ICAO amend these regulations as follows:

1. Amendment of PANS-OPS to specify explicitly compliance with an RA and the dangers of maneuvers contrary to an RA.

In order to prevent aircraft accidents, when two aircraft are expected to approach with close proximity, pilots should execute evasive maneuvers under the principle that resolution advisories should always be complied with. Learning from the experience of this accident in Japan, ICAO should amend its regulations related to ACAS operation as follows in order that ACAS be operated effectively worldwide.

- (1) Amend ICAO Annex 6 or PANS-OPS Volume Part VIII Chapter 3 “Operation of ACAS Equipment” to express explicitly that pilots should always comply with a resolution advisory, except in a few limited circumstances. In particular, when pilots simultaneously receive conflicting instructions to maneuver from air traffic control and a resolution advisory, pilots should comply with the resolution advisory.
- (2) Describe in PANS-OPS Volume Part VIII Chapter 3 “Operation of ACAS Equipment” the dangers of maneuvering contrary to the indication of a resolution advisory. Such has already been included in paragraph 3.5.8.10.3 of the Guidance Material to ICAO Annex 10 Volume IV Chapter 4 Appendix A.

2. Amendment of PANS-OPS to specify when pilots should inform air traffic control of deviation from an air traffic control instruction or clearance.

It is necessary that pilots notify air traffic control of the activation of a resolution advisory at the earliest time before the conflict is resolved, in order that air traffic

controllers are aware of the activation of the resolution advisory and can respond appropriately to such situations. Therefore, ICAO should amend its regulations related to ACAS as follows:

The current PANS-OPS Volume Part VIII Chapter 3 states in “Operation of ACAS Equipment” paragraph 3.2 d) that “pilots who deviate from an air traffic control instruction or clearance in response to a resolution advisory shall promptly return to the terms of that instruction or clearance when the conflict is resolved and shall notify the appropriate ATC unit as soon as practicable, of the deviation, including its direction and when the deviation has ended.” It is possible to interpret this sentence as that pilots may notify air traffic control after the conflict is resolved. It is therefore necessary to specify explicitly that, in case that a pilot executes evasive maneuvers in response to a resolution advisory, the notification of the deviation to ATC shall be made promptly before the conflict is resolved, unless it is difficult to do due to the execution of the evasive maneuvers.

8 FINDINGS

Besides the recommendations and proposals to the Minister for Land, Infrastructure and Transportation mentioned in Chapter 6 and the safety recommendations to International Civil Aviation Organization mentioned in Chapter 7, the following items are considered as those which, for the prevention of aircraft accidents and for future aviation safety, must be more concrete or which require further examination regarding their feasibility.

1. OJT for air traffic control duties

- (1) ATC watch supervisors should always be aware of the air traffic situation, and while maintaining a condition under which it is possible to supervise the ATC trainee, should concentrate on the air traffic duties conducted by the ATC trainee and his or her supervision.
- (2) For ensuring future air traffic safety, it is necessary that air traffic control facilities prepare a working environment in which, when the air traffic situation becomes beyond the ATC trainee's ability and he or she feels limitations and burdens during OJT for air traffic control duties, the ATC watch supervisor can override the ATC trainee and carry out for air traffic duties in stead, or the ATC trainee can declare his or her situation without hesitation.

2. Cooperation between air traffic controllers

- (1) For cooperation within a sector, it is necessary to prepare a working environment in which each air traffic controller mutually understands the other air traffic controllers' situations properly, and can advise and help them easily.
- (2) For coordination between sectors, it is necessary to study measures to enable each air traffic controller to understand properly the situation of the air traffic controllers in neighboring sectors and to communicate positively to them his or her intention.

3. Cooperation between flight crew and air traffic controllers

For smooth and appropriate communication between aircraft and air traffic control facilities, it is desirable for flight crews and air traffic controllers, who usually have a chance to contact each other only through ATC communications, to lay the foundation for mutual understanding, with promotion of appreciation of each other's working situation through regular activities and through exchange of information and views. Therefore, it is desirable to create opportunities for mutual intercourse and mutual visits to working places between as many flight crewmembers and air traffic controllers

as possible.

4. Improvement of ATC equipment

- (1) In the development of ATC equipment, it is necessary to examine measures to utilize data communication in addition to voice communication in order to prevent the deterioration of the reliability of ATC communication under pressing conditions such as the issue of an RA, based on the state of technological development.
- (2) It is desirable to examine the addition of a function by which the data block on the ATC radar display of the aircraft that is the target of communication is emphasized, for example by blinking etc., so that air traffic controllers can grasp clearly the aircraft with which they are communicating, based on the state of technological development.
- (3) In cases where there are known limitations in the performance of ATC equipment such that it is possible that it may not function as specified under some circumstances, like the CNF function in this accident, it is necessary to inform the air traffic controllers who are the users of such equipment in advance of their use.
- (4) For the improvement of ATC equipment, it is necessary to consider the information handling capability of air traffic controllers, etc. who use the equipment in performing their duties, and to pay attention to ease of use and to comprehensibility.

5. Other measures for ATC duties

- (1) In order that air traffic controllers can execute radar point out appropriately and positively recognize the target aircraft, it is necessary to clarify the requirements for executing radar point out and the handling of targets for which radar point out has been executed, for example by preparing regulations.
- (2) Regarding the CNF indication on air route traffic control radar displays, it is desirable to issue CNF alerts from an early stage when there still remains ample time before the prescribed ATC separation will be lost, and in order that air traffic controllers can easily recognize the level of urgency, to augment the CNF indication to indicate, for example by color, the interval of time remaining before the prescribed ATC separation will be lost.

6. Flight crew training regarding TCAS

- (1) It is necessary to provide training such that flight crews are sufficiently aware that it is possible to avoid aircraft with which there is a risk of collision by maneuvering in accordance with an RA without rapid maneuvers, and that there is the possibility of causing injuries to persons on board if rapid maneuvers are carried out.

- (2) It is necessary to provide knowledge and to conduct flight training about the relationship between evasive maneuvers carried out in accordance with RAs and aircraft performance when an RA is issued at high altitude. Such flight training should also address situations in which buffeting occurs during evasive maneuvers in accordance with an RA.
- (3) In the TCAS training, it is necessary to provide knowledge about the difficulty of visually assessing the vertical separation with other aircraft..
- (4) It is necessary to conduct training such that flight crewmembers appropriately utilize the TCAS display to assess the movement of other aircraft by checking the arrow indication beside the corresponding target on the display showing its climb or descent.

7. Cooperation among flight crewmembers

- (1) In order that flight crews respond appropriately to TAs and RAs when these advisories are issued and also to ensure the safety of aircraft operation, it is necessary to examine the cooperation among flight crewmembers, including the role assigned to each flight crew member and how they should advise each other.
- (2) When a trainee carries out the duties of first officer while occupying the first officer's seat as PNF, the regular first officer on board occupies an observer's seat. It is necessary to make investigations and consider regulations, rules etc., such that if a situation arises in flight that is beyond the trainee's ability to cope with, the first officer may override the trainee with respect to PNF duties as much as possible, and give advice to the Captain appropriately as necessary.

8. Notification from aircraft to air traffic control about TCAS

- (1) It is desirable for flight crews to communicate positively with air traffic control, for example to confirm ATC instructions, to notify regarding the issuance of RAs and the flight condition of the aircraft, and to request information.
- (2) It is desirable for flight crews to inform air traffic control of the issuance of RAs as much as possible, even if they cannot comply with RA for some reason.

9. Preparation of intelligible, usable and systematic manuals

It is necessary that aircraft operators review their manuals related to TCAS from the point of view of ease of use and comprehensibility, and to examine the preparation of manuals, including their amendments as necessary, in order that flight crewmembers can understand easily and systematically the requirements and the notices related to maneuvers during flight operations in relation to TCAS.

Also, concerning operation manuals which apply uniformly to all aircraft types and

aircraft operation manuals which are applied to each type of aircraft, it is necessary that characteristics of each manual are systematic.

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Figure 1 Presumed flight route

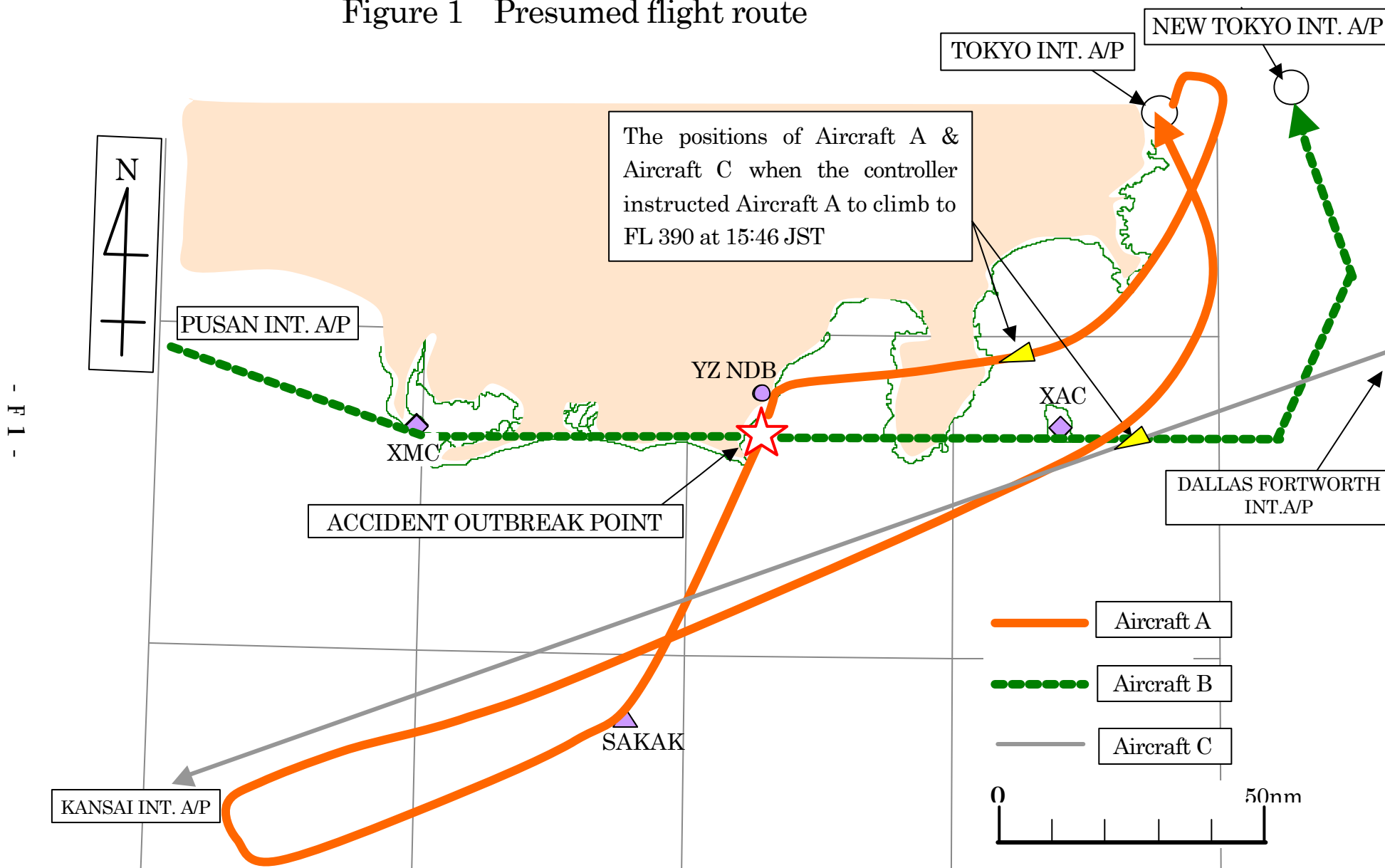


Figure 2 Outline of KANTO SOUTH C Sector, TOKYO ACC

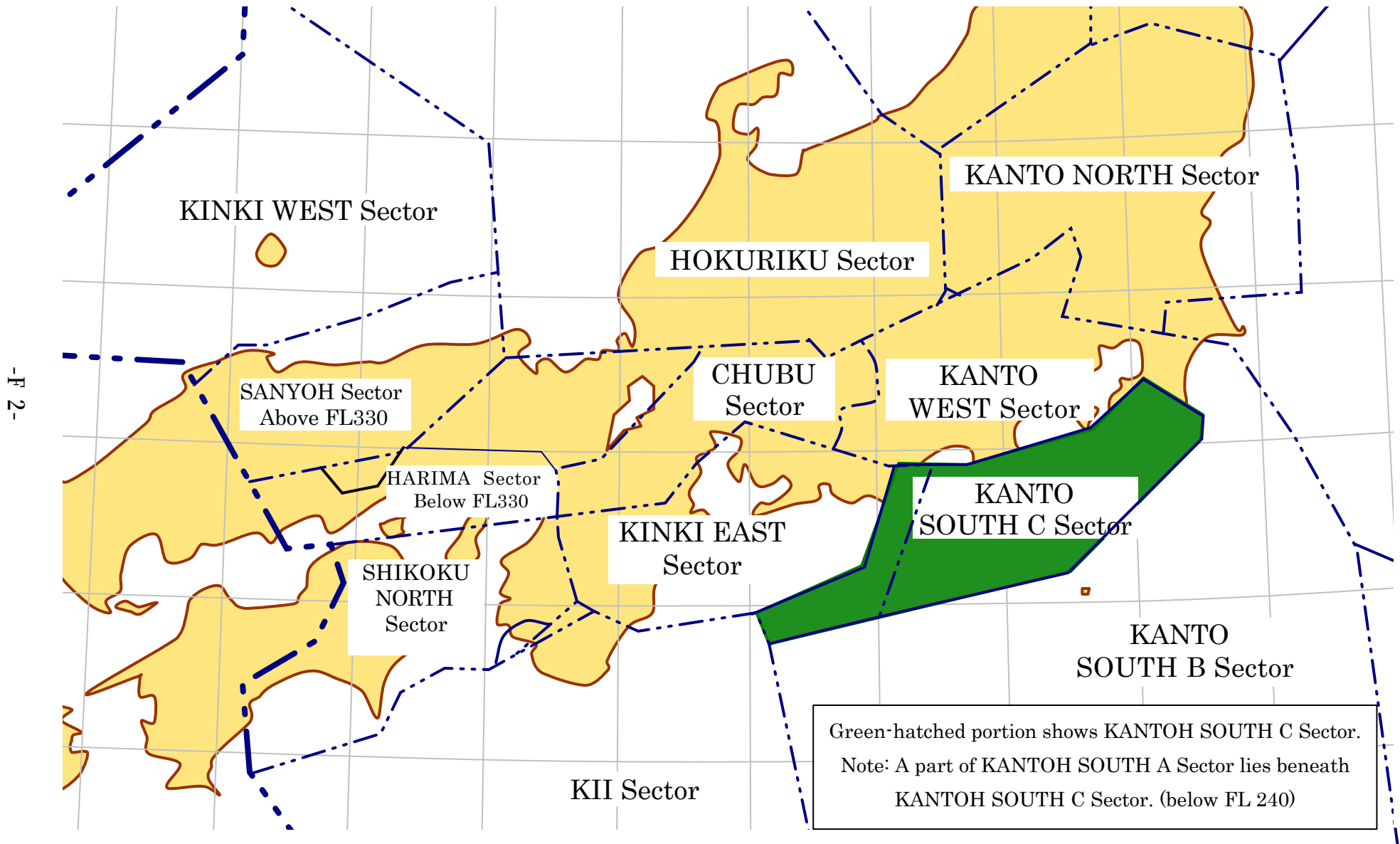


Figure 3 ATC console

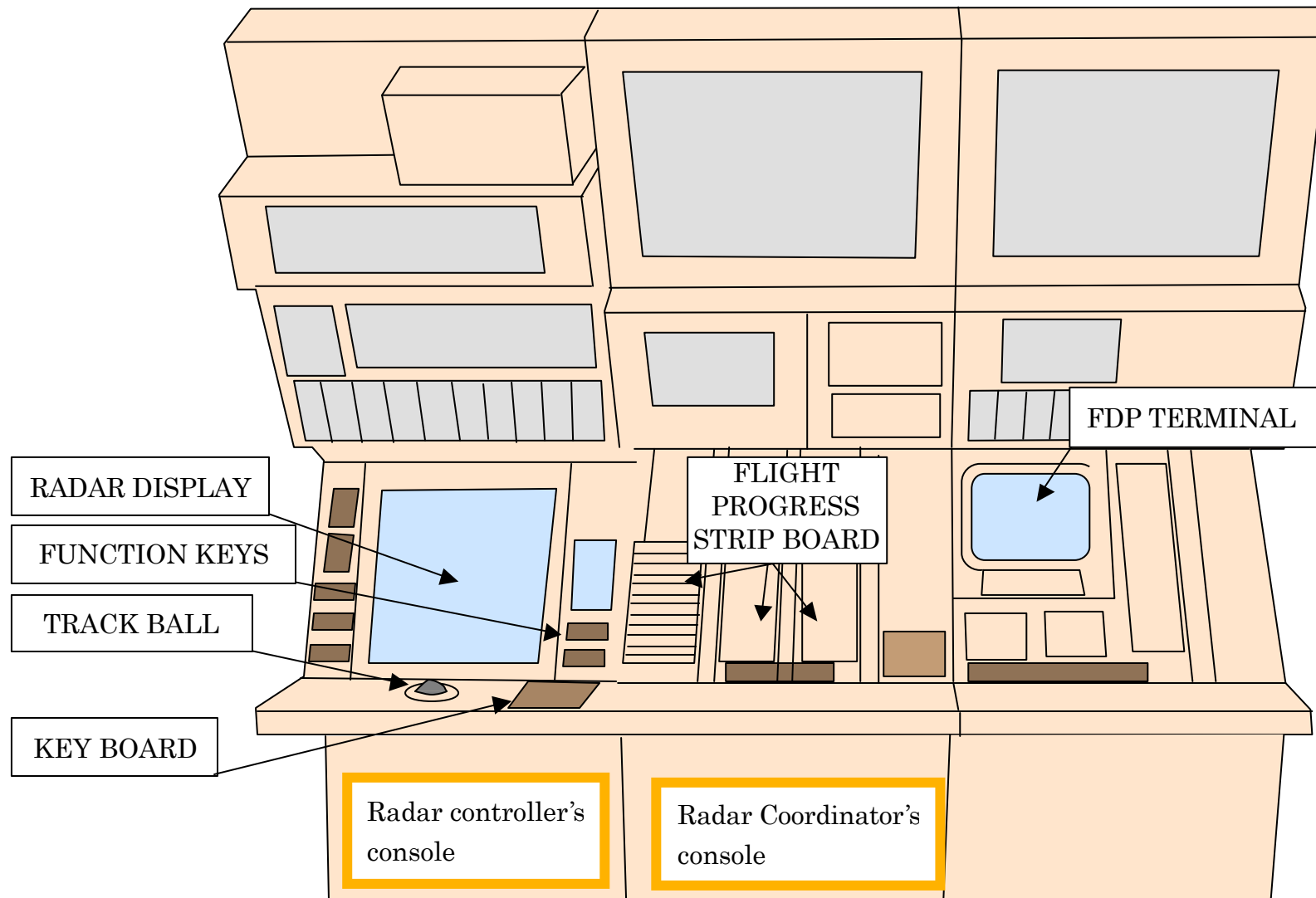
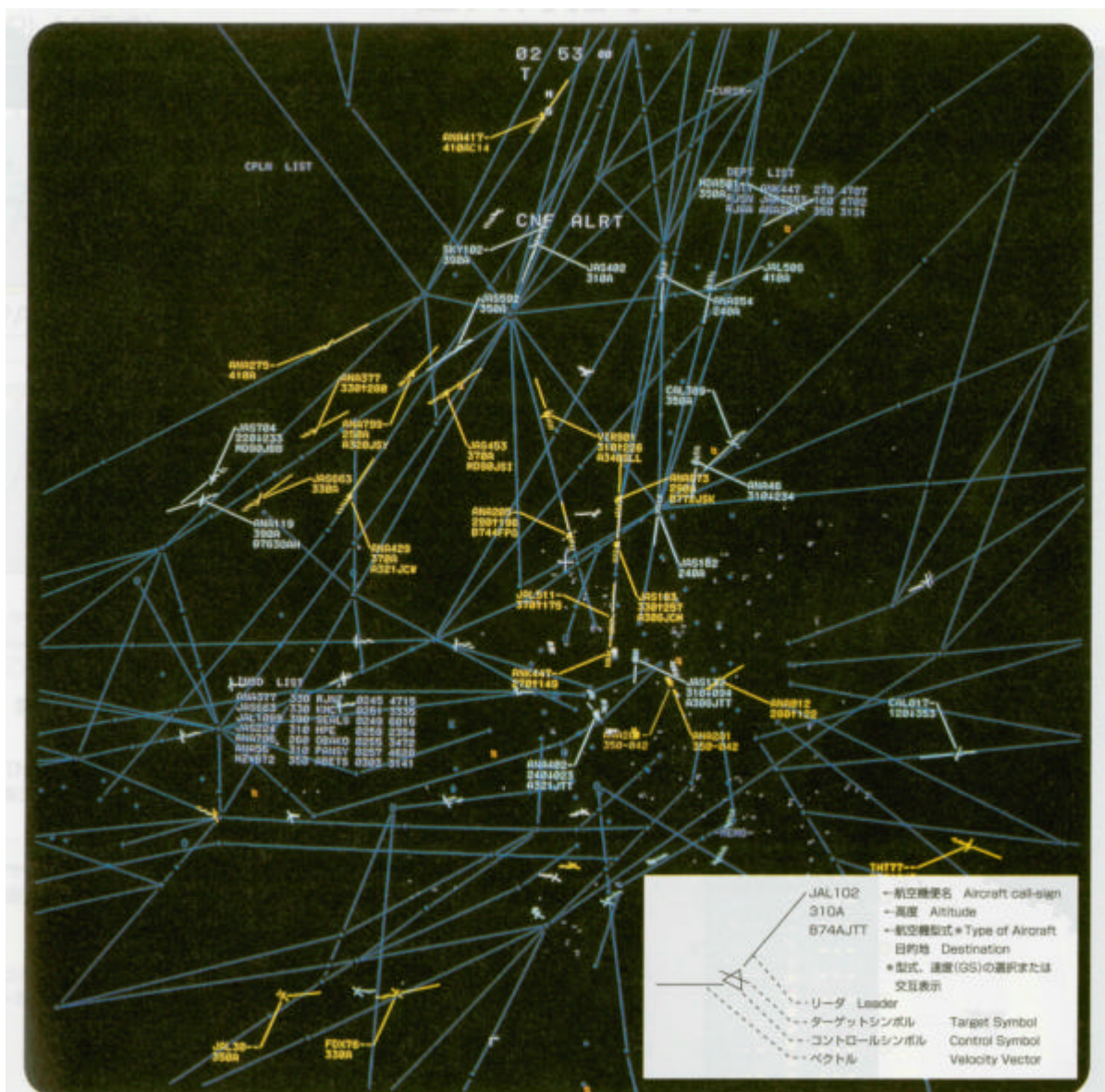


Figure 4 RADAR Display and Data block



AIM-J (RDP RADAR SCOPE)

Radar Handoff

CNF

INITIATE JAL102
310A
B74AHND

ACCEPT JAL102
310A
B74AQVR

JAL102
310A
B74ACNF

Note: Alphanumeric portion is called "Data block". When "Hand over" and "CNF" takes place, underlined portion blinks.

Figure 5 Three angle view of BOEING 747-400D

(Aircraft A)

Unit: m

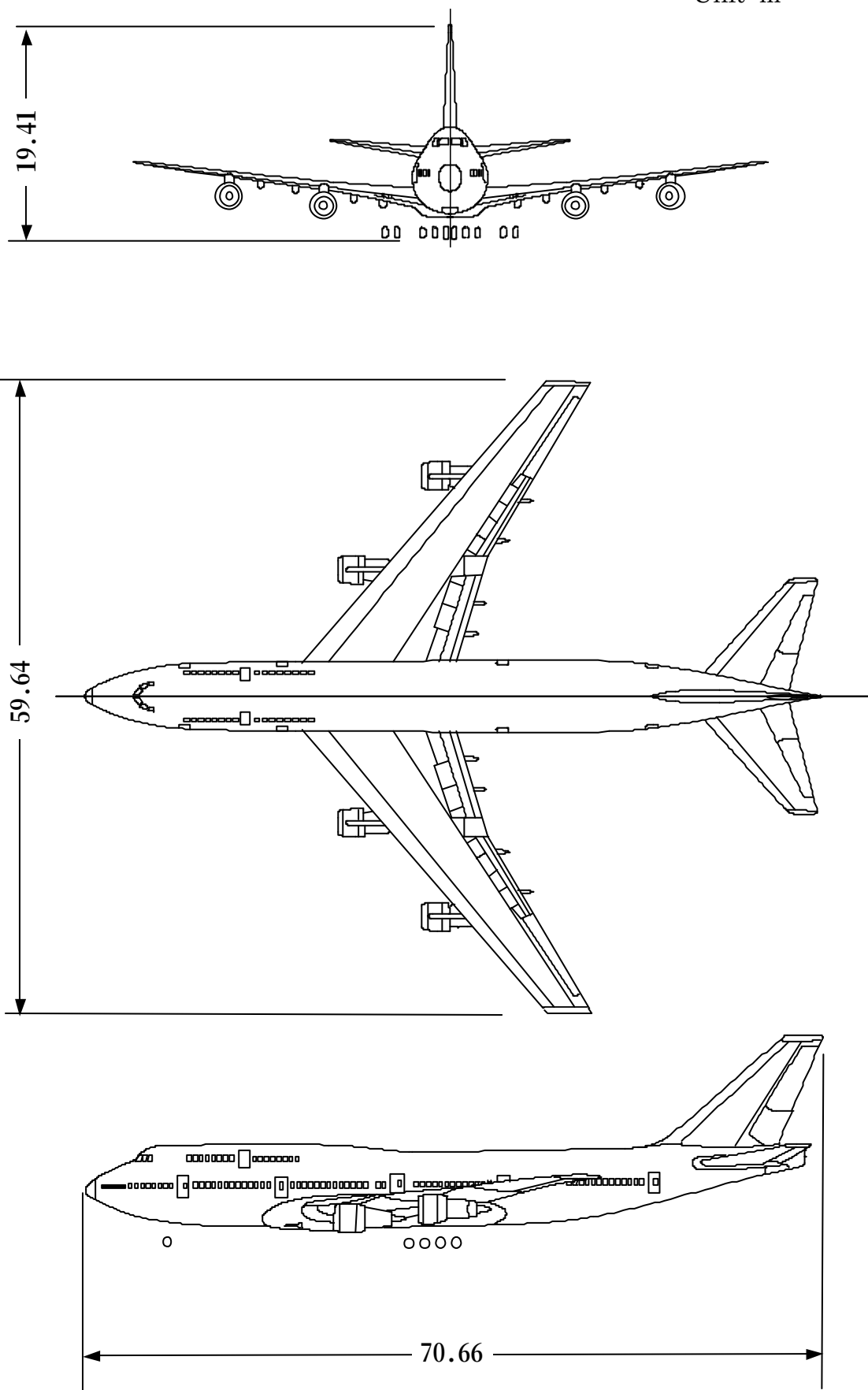


Figure 6 TCAS Antenna layout and TCAS Display (Aircraft A)

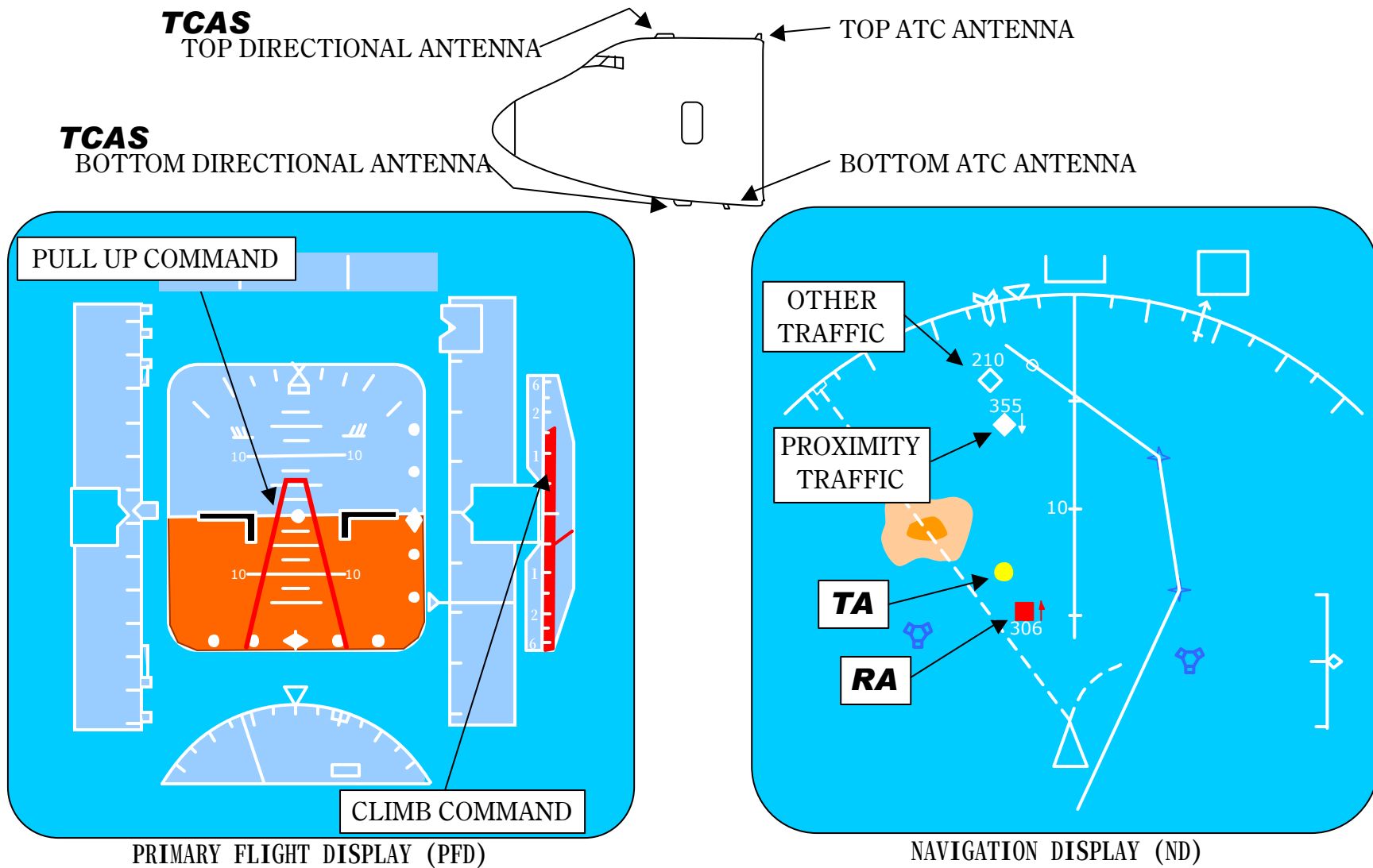


Figure 7 Three angle view of DOUGLAS DC-10-40
(Aircraft B)

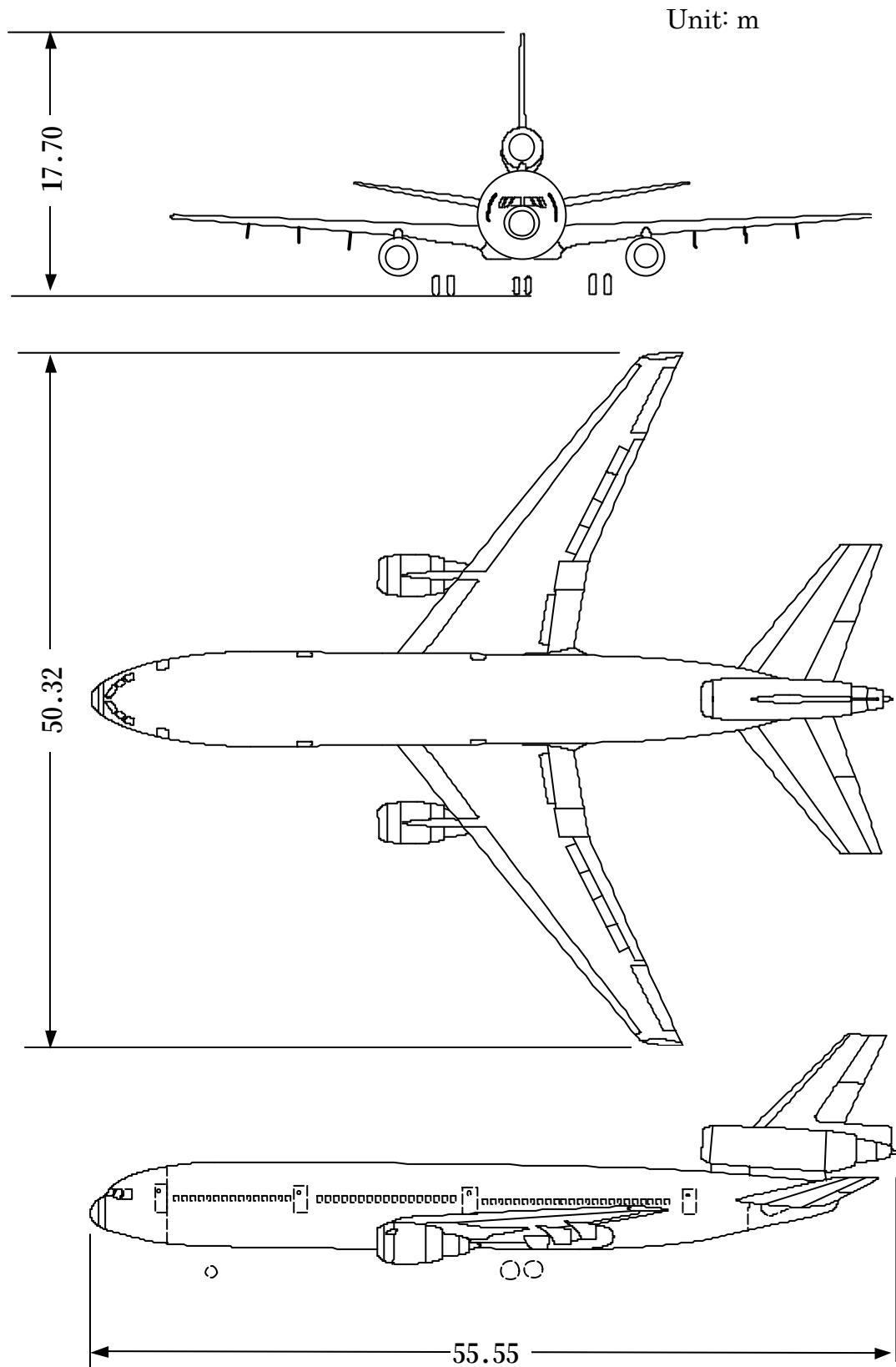


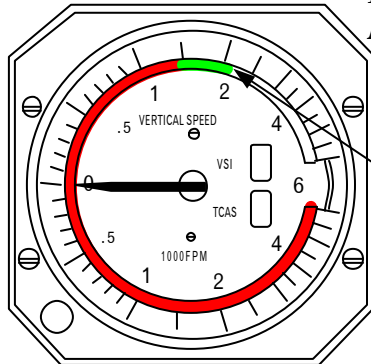
Figure 8 TCAS Antenna layout and TCAS Display (Aircraft B)

TCAS
TOP DIRECTIONAL
ANTENNA

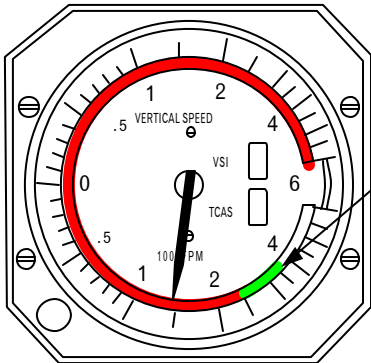
TOP ATC
ANTENNA

TCAS
BOTTOM DIRECTIONAL
ANTENNA

BOTTOM ATC
ANTENNA

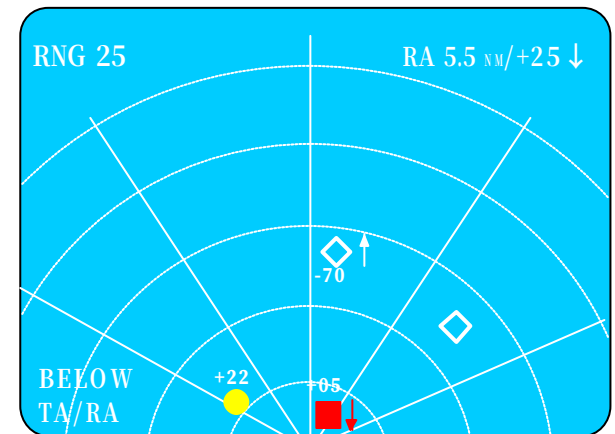
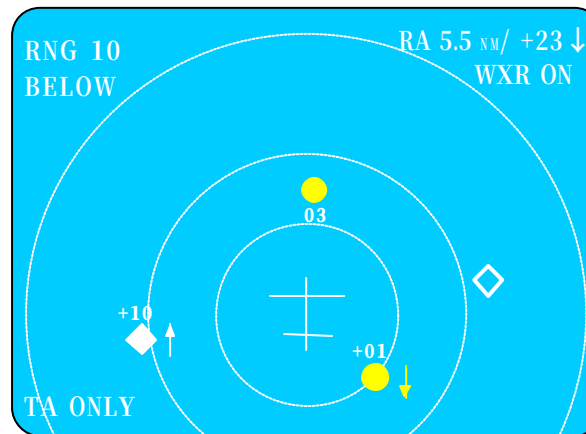
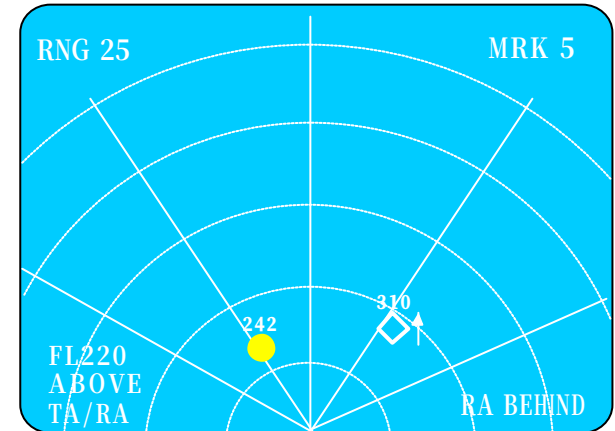
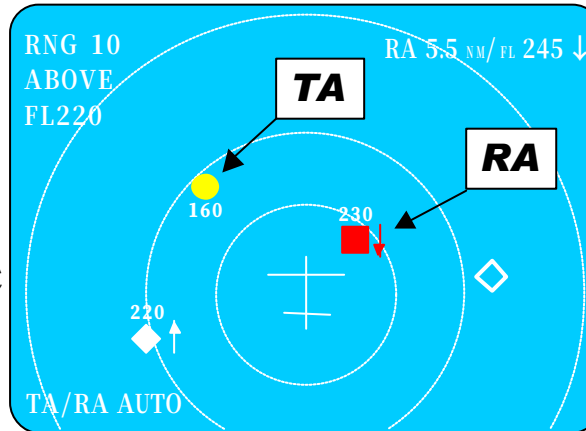


Climb



Increase
Descent

RA / VSI Indicator



TCAS Only display mode

WXR/TCAS Overlay
Display mode

Traffic / Weather Radar(WXR) Indicator

Figure 9 Flight pass around location of accident

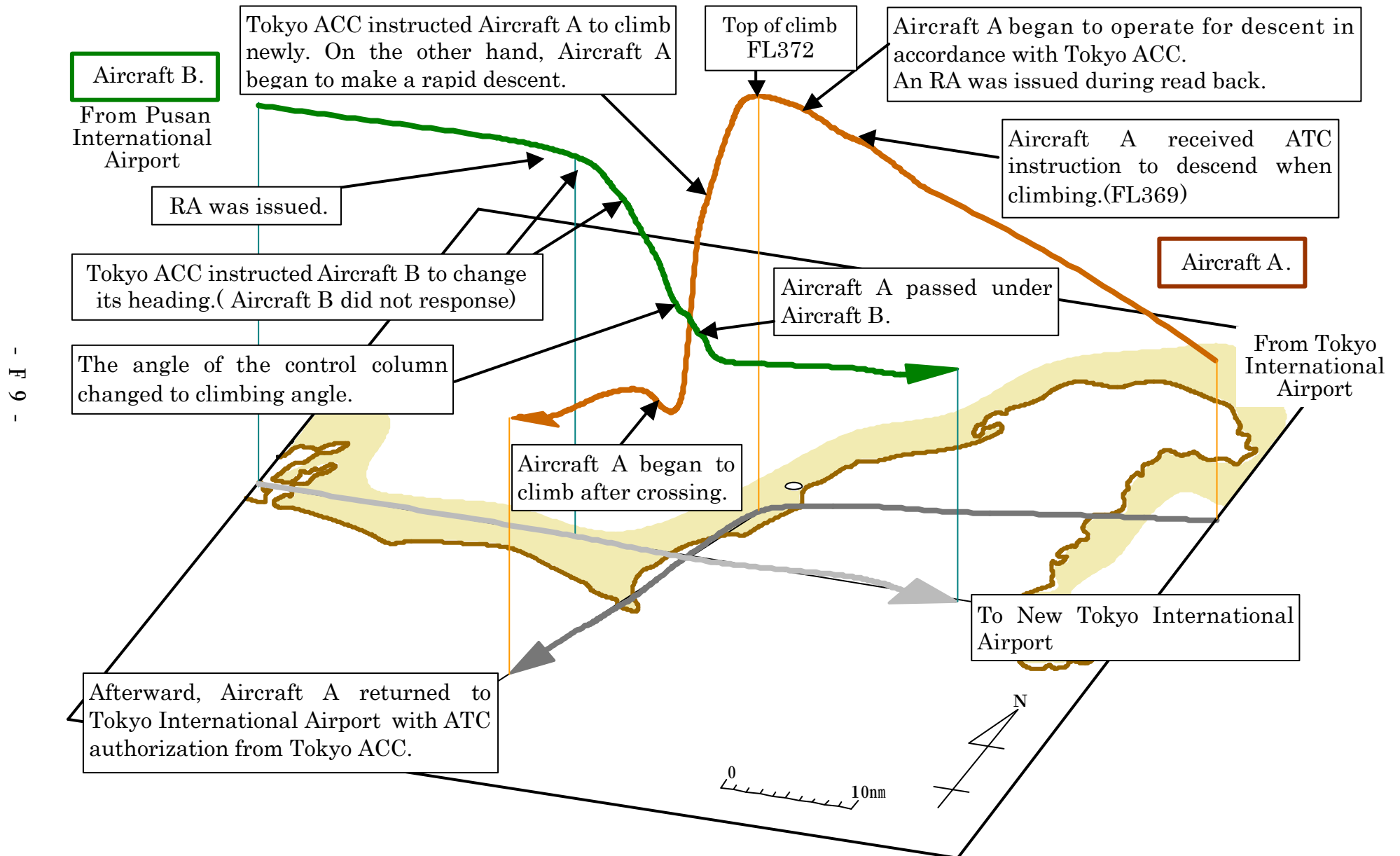
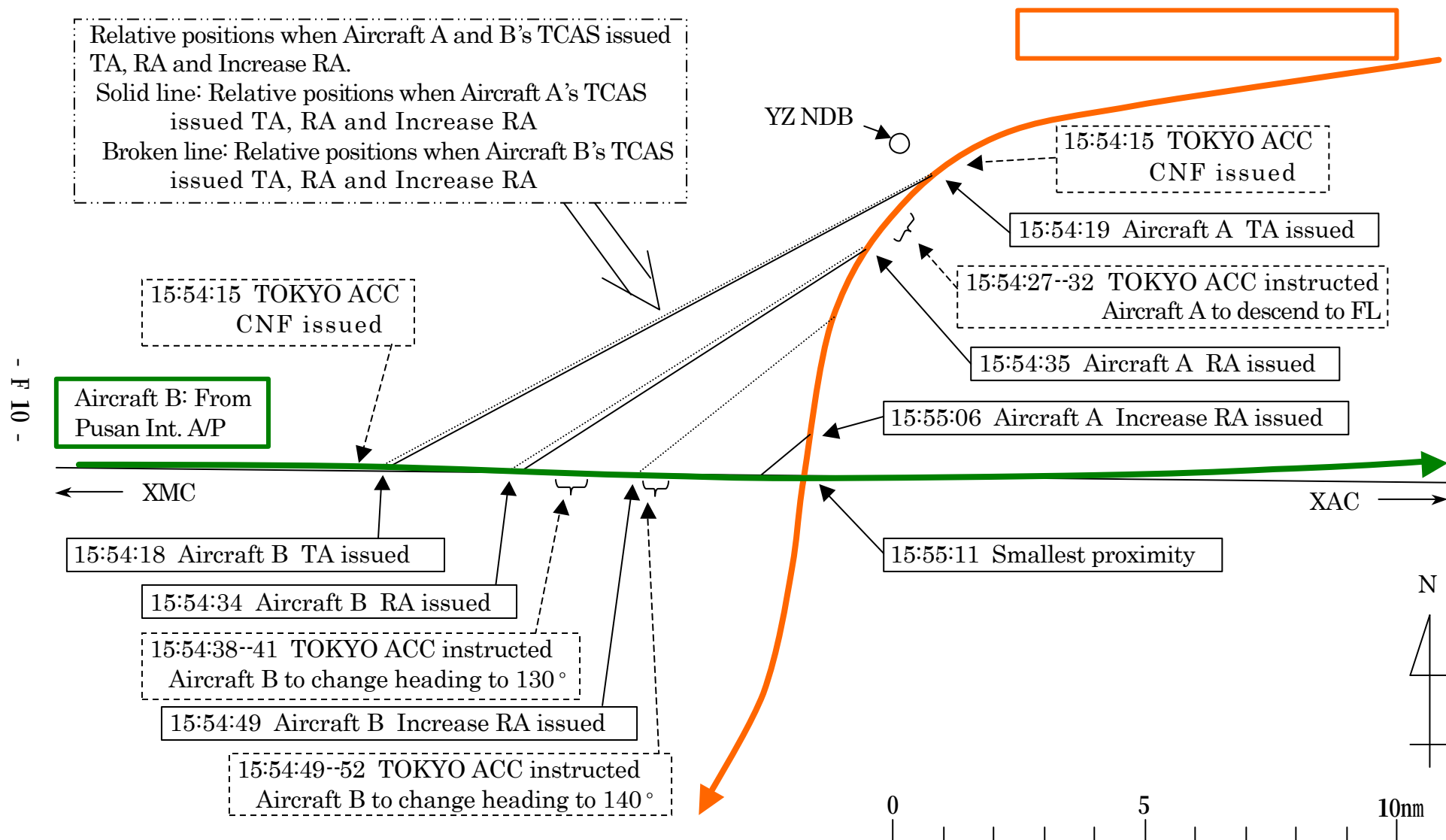


Figure 10 Proximity situation (Plane geometry)



- F I I -

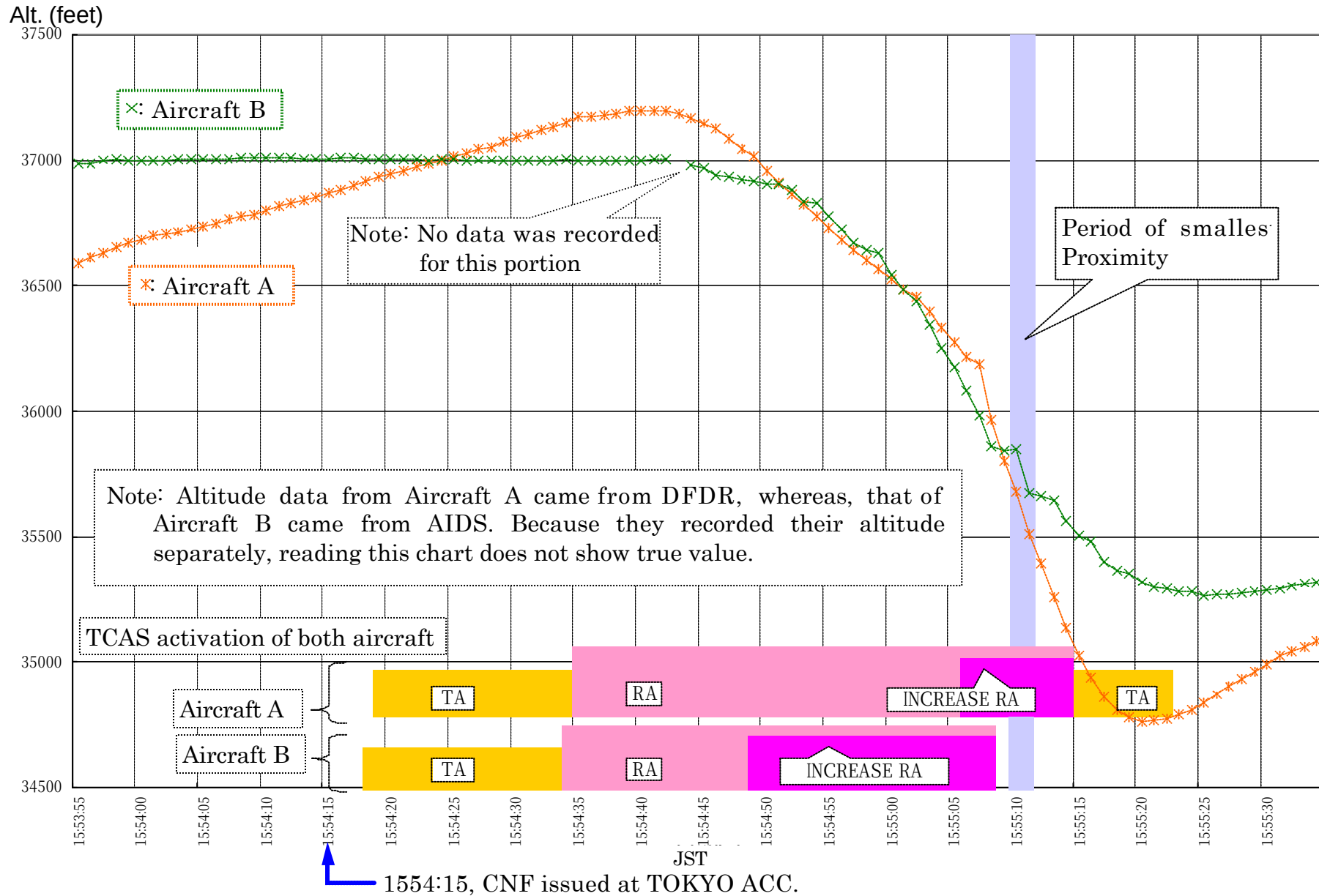


Figure 12 DFDR data, Aircraft A

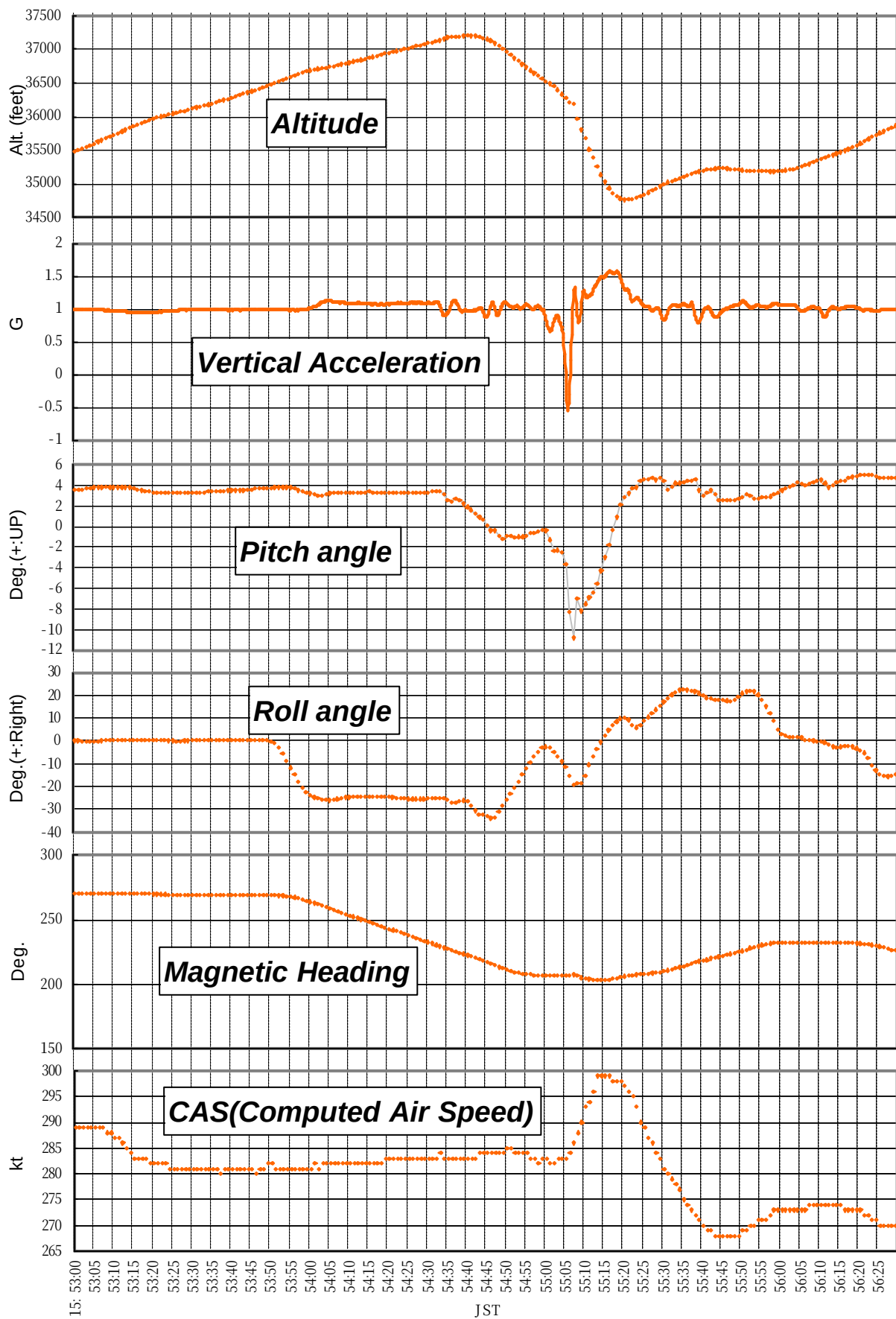


Figure 13 DFDR data, Aircraft B

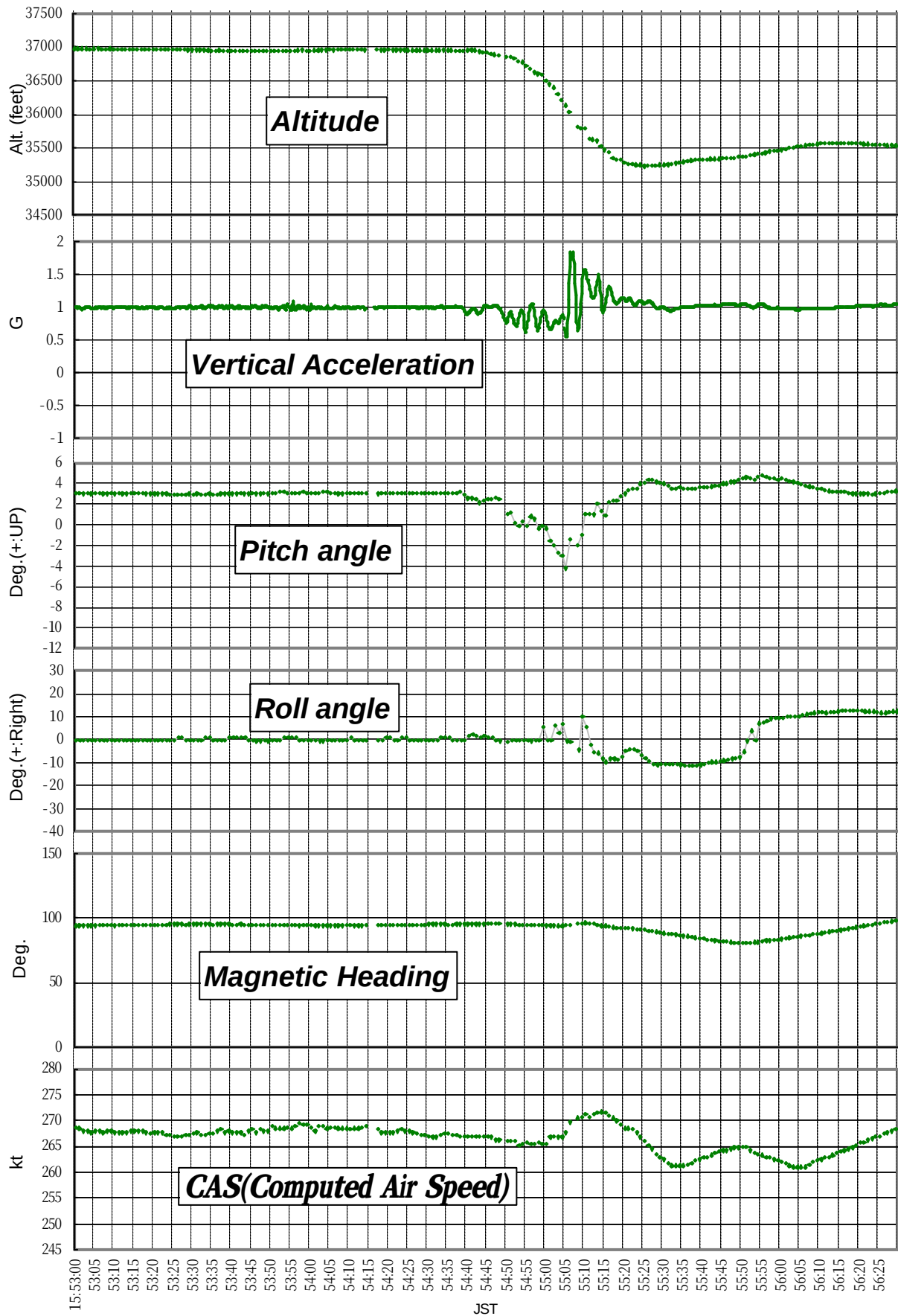


Figure 14 Injuries layout, Aircraft A

State of injury	Passengers	Crew
Serious	●	◆
Minor	●	◆

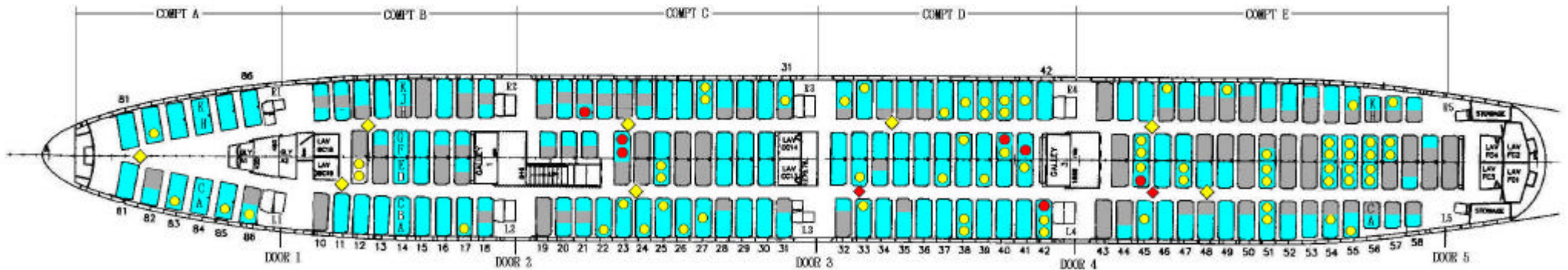
OCCUPIED
 VACANCY

SEAT CONFIGURATION
(B747-400D)



UPPER DECK-86 ECONOMY

Persons on board					Injuries													
					Serious				Minor				Total					
		SEATS	VACANCY	OCCUPIED	Seat belt			Total	Seat belt			Total	Seat belt					
					fasten	unfasten	unknown		fasten	unfasten	unknown		fasten	unfasten	unknown			
Passengers	FORWARD		A	24	2	22	0	0	0	0	2	3	0	5	2	3	0	5
			B	78	24	54	0	0	0	0	3	1	0	4	3	1	0	4
			C	116	35	81	2	0	1	3	3	8	0	11	5	8	1	14
	AFT.		D	106	8	98	2	1	0	3	3	18	0	21	5	19	0	24
			E	158	68	90	0	1	0	1	1	18	13	32	1	19	13	33
	UPPER DECK		U	86	20	66	0	0	0	0	2	3	0	5	2	3	0	5
	Seat position unknown					(3)	0	0	0	0	0	0	3	3	0	0	3	3
Total of Passengers		568	157	411	4	2	1	7	14	51	16	81	18	53	17	88		
Crew			Pilot 4	CA 12	16	2	-	0	2	10	-	0	10	12	-	0	12	
Total					427	6	2	1	9	24	51	16	91	30	53	17	100	



MAIN DECK-24 SUPER/458 ECONOMY

Figure 15 Damages to Aircraft A

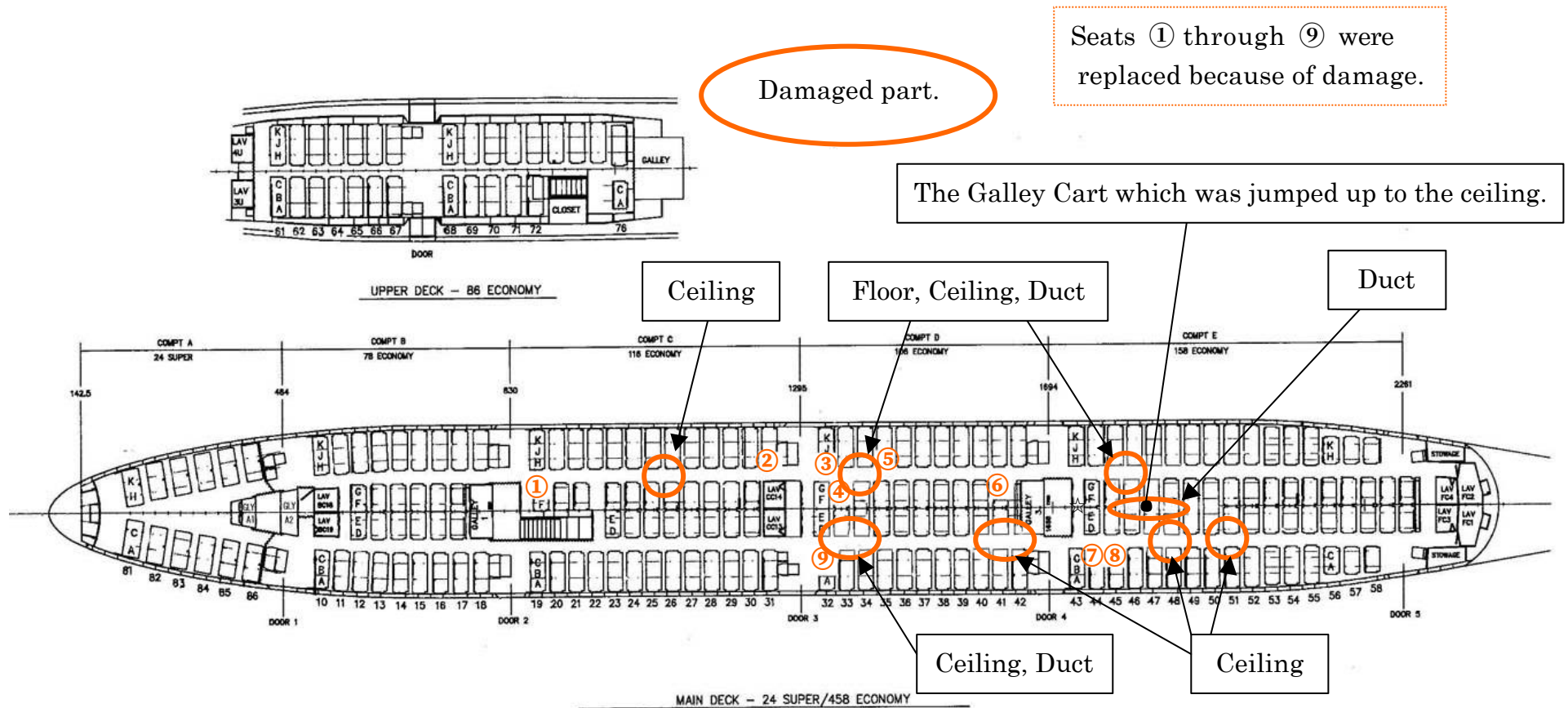


Figure 16 Cloud Information Chart

2001. JAN 31. 1500(JST)

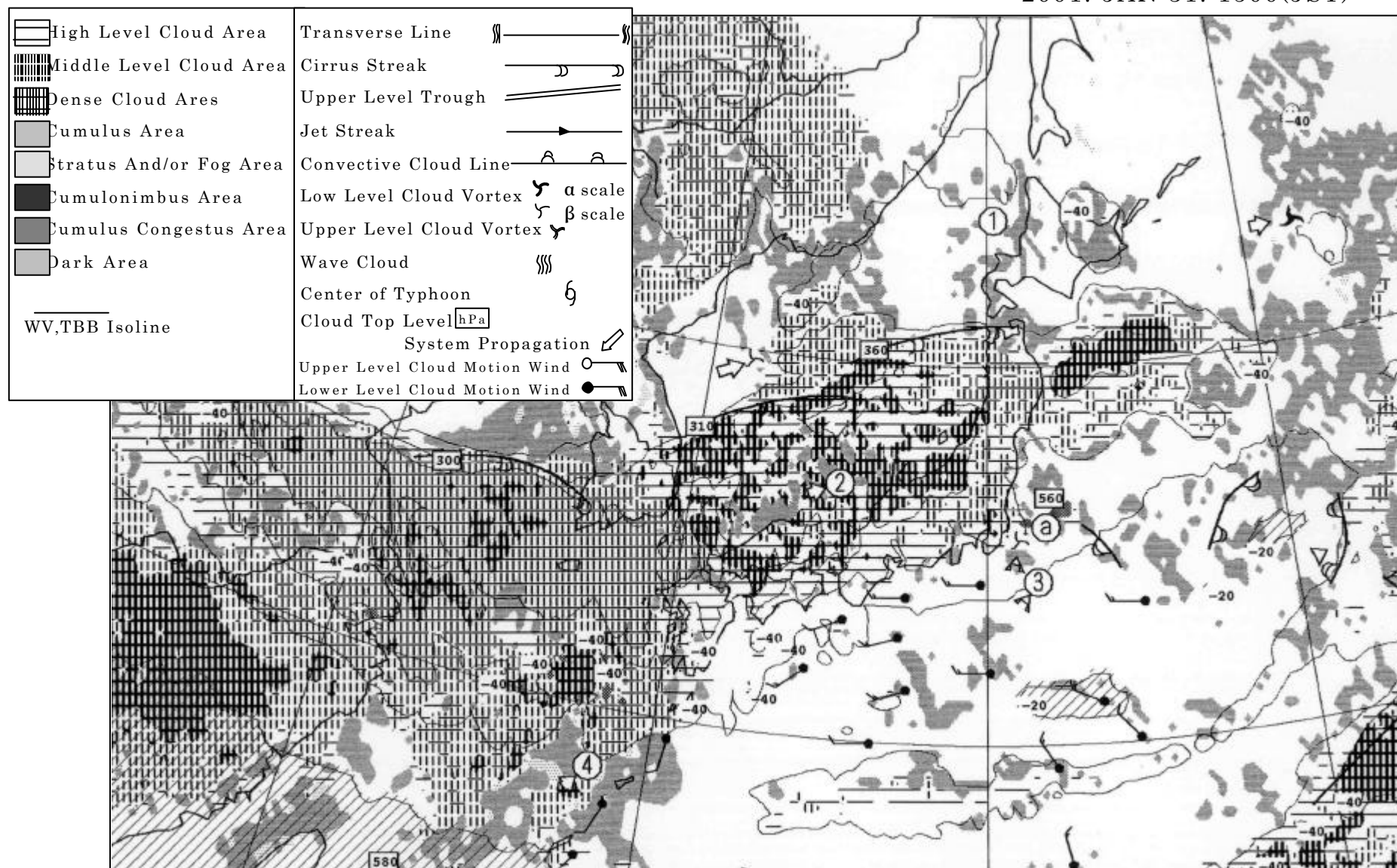


Figure 17 250hPa Isobar Weather Chart

2001. JAN 31. 2100(JST)

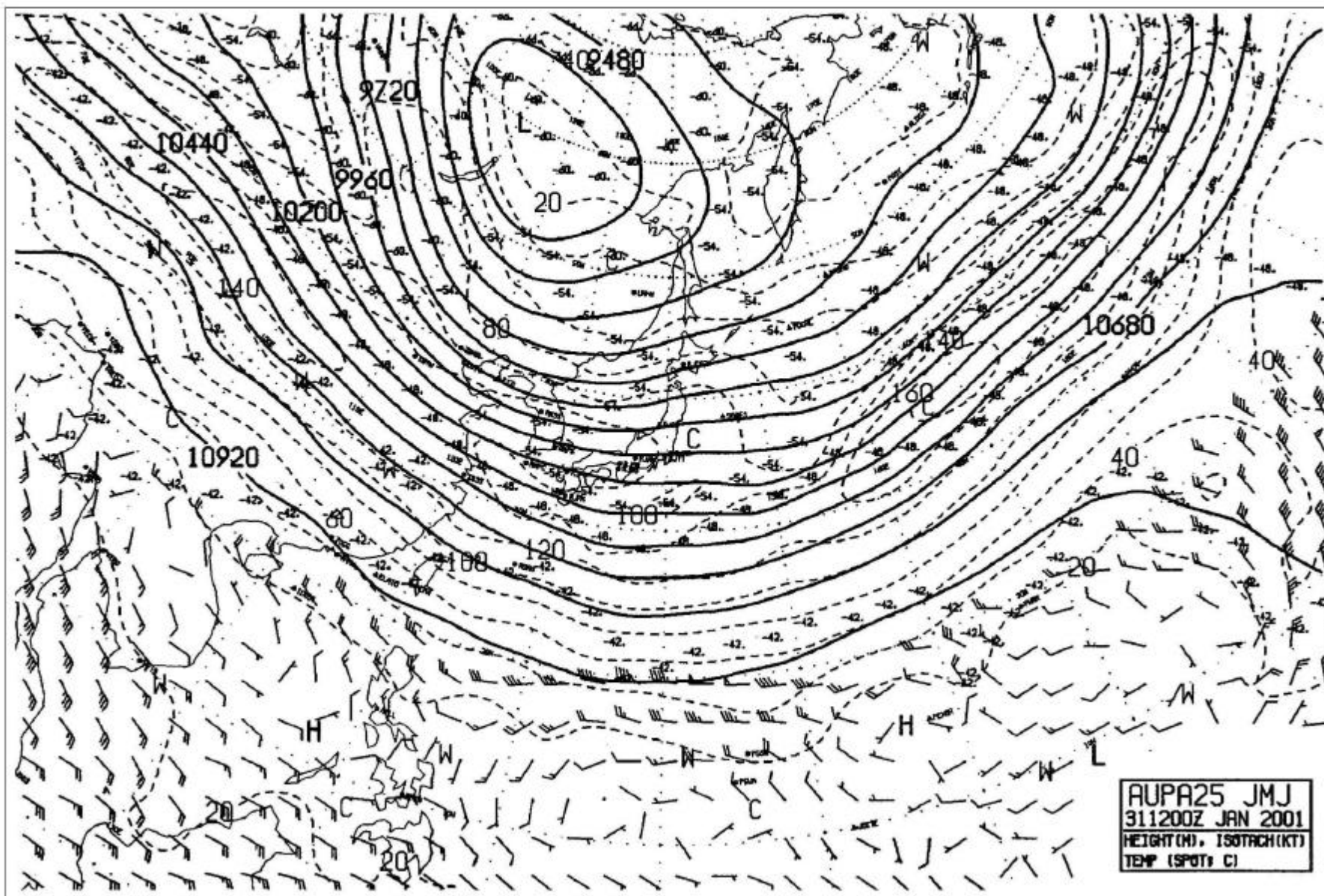


Figure 18 Aircraft A 's altitude simulation

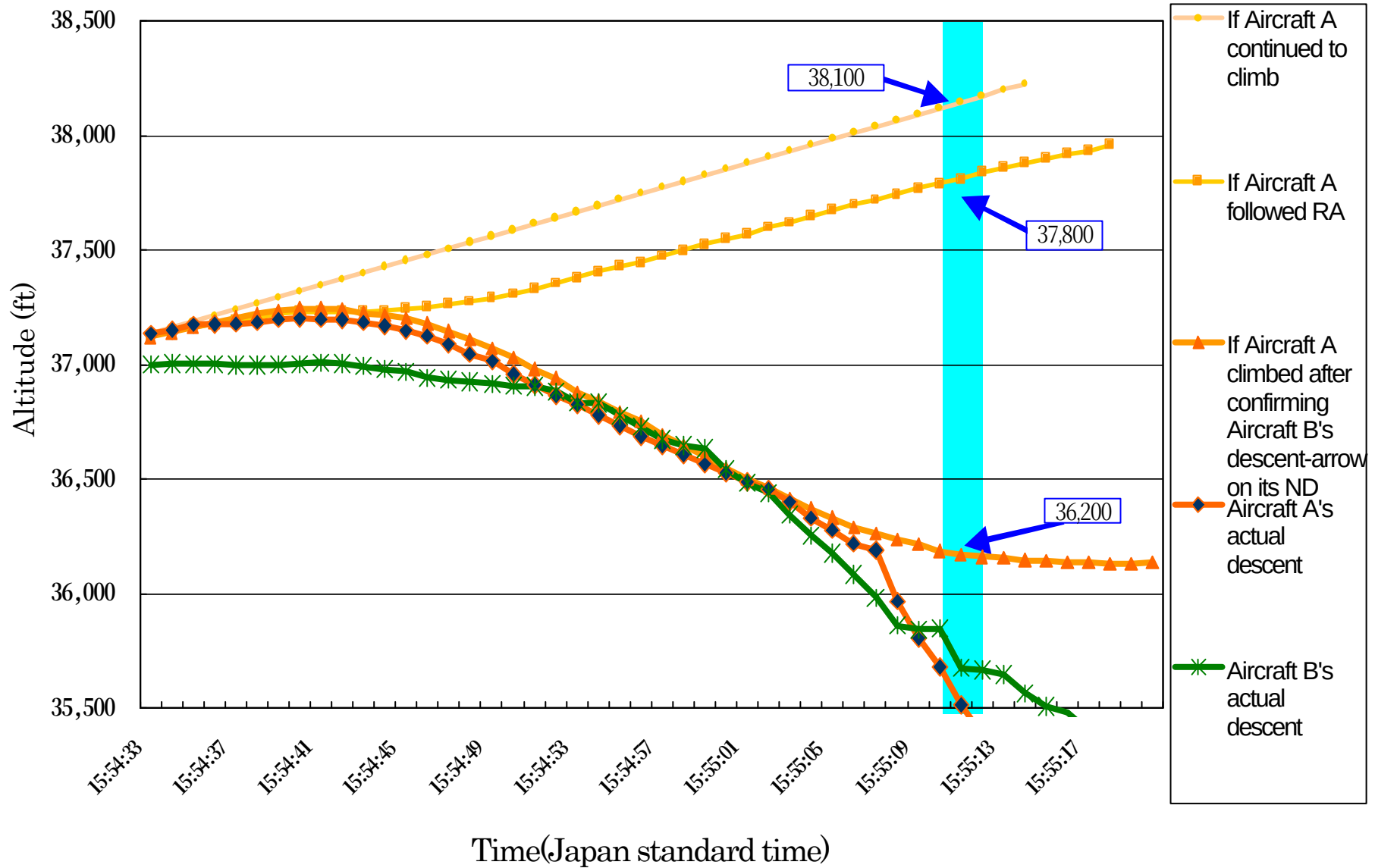


Figure 19 Throttle angle and its corresponding N1 and N2, Aircraft A

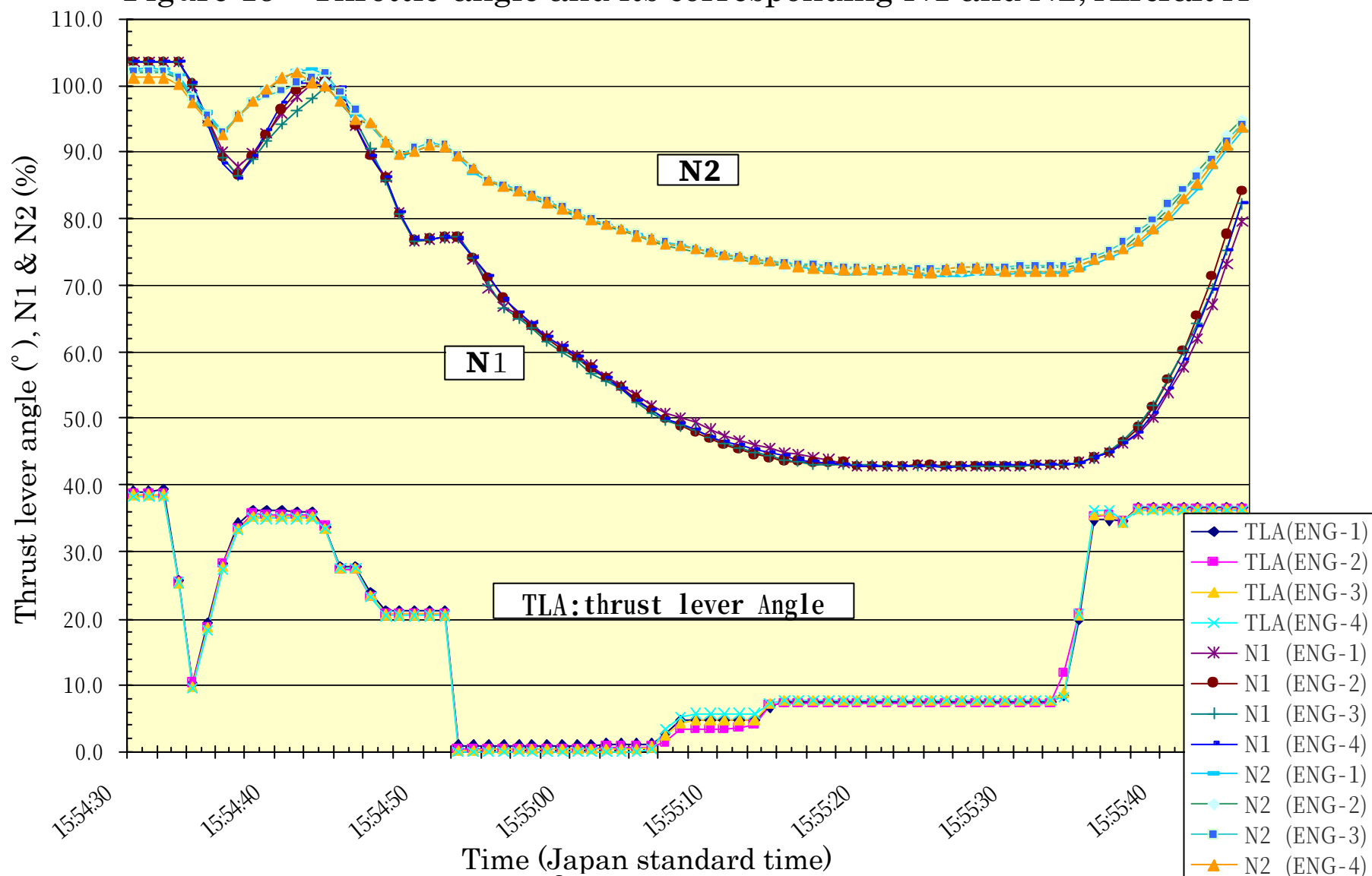


Figure 20 Air traffic controller's Qualification process

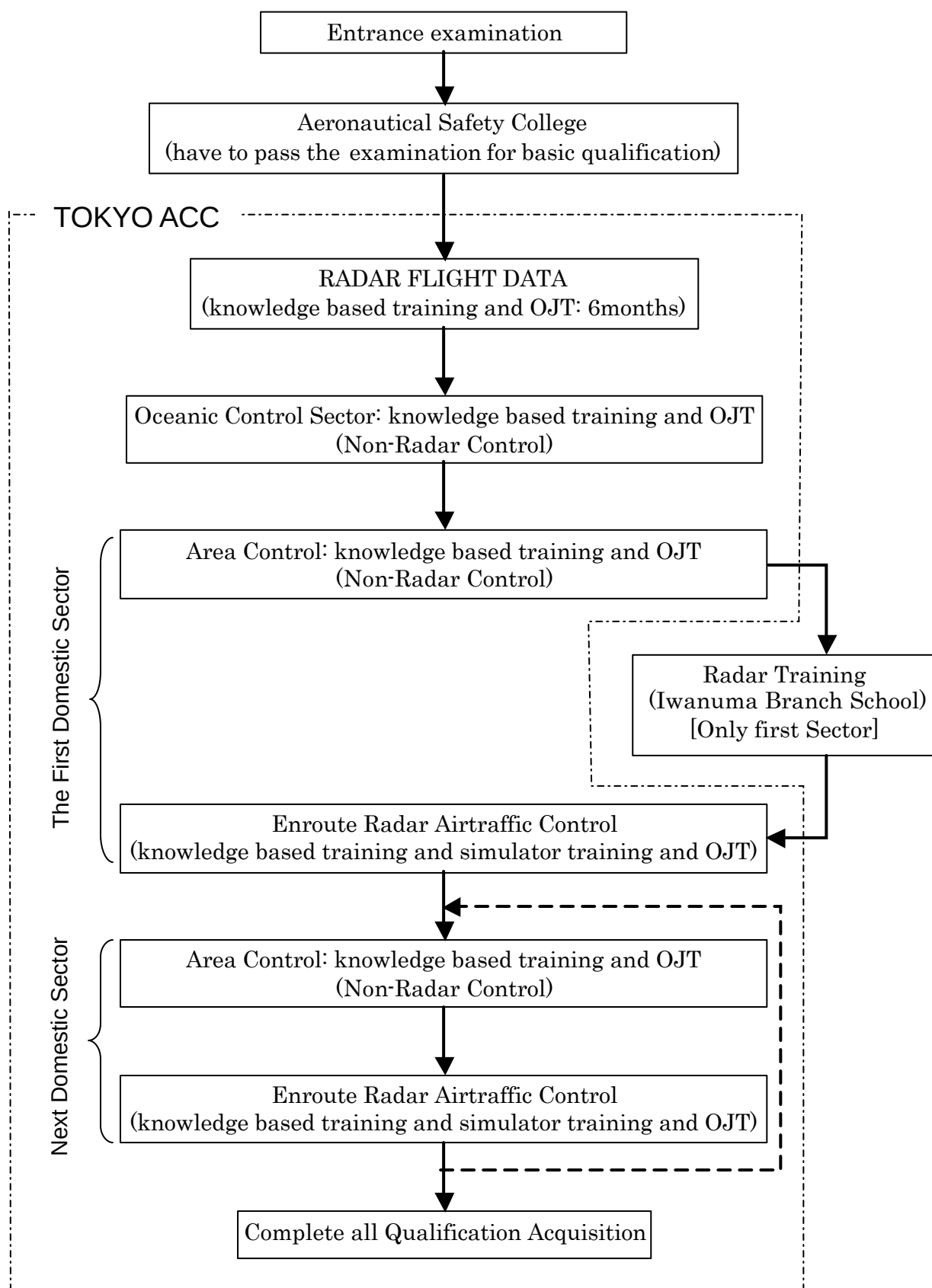
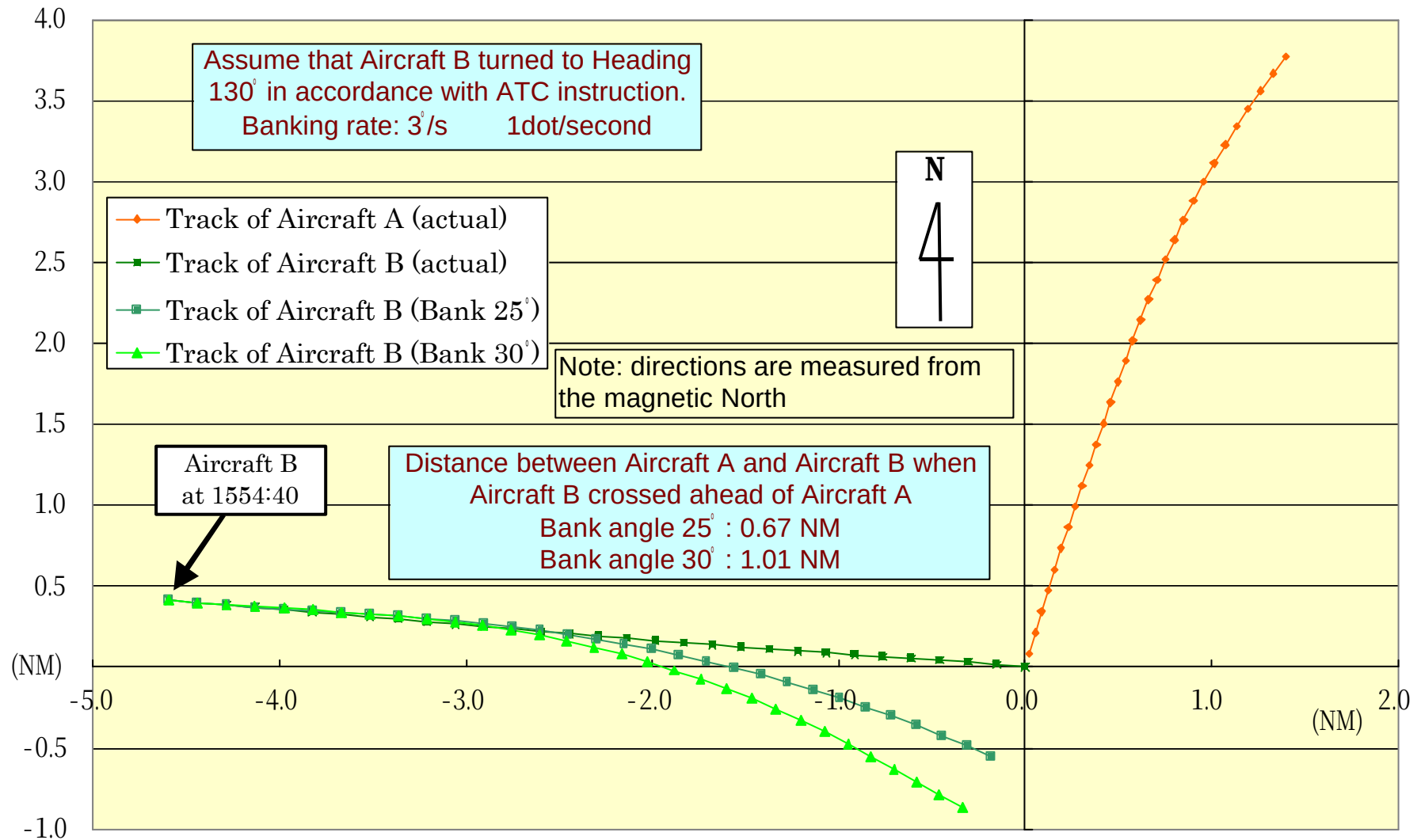
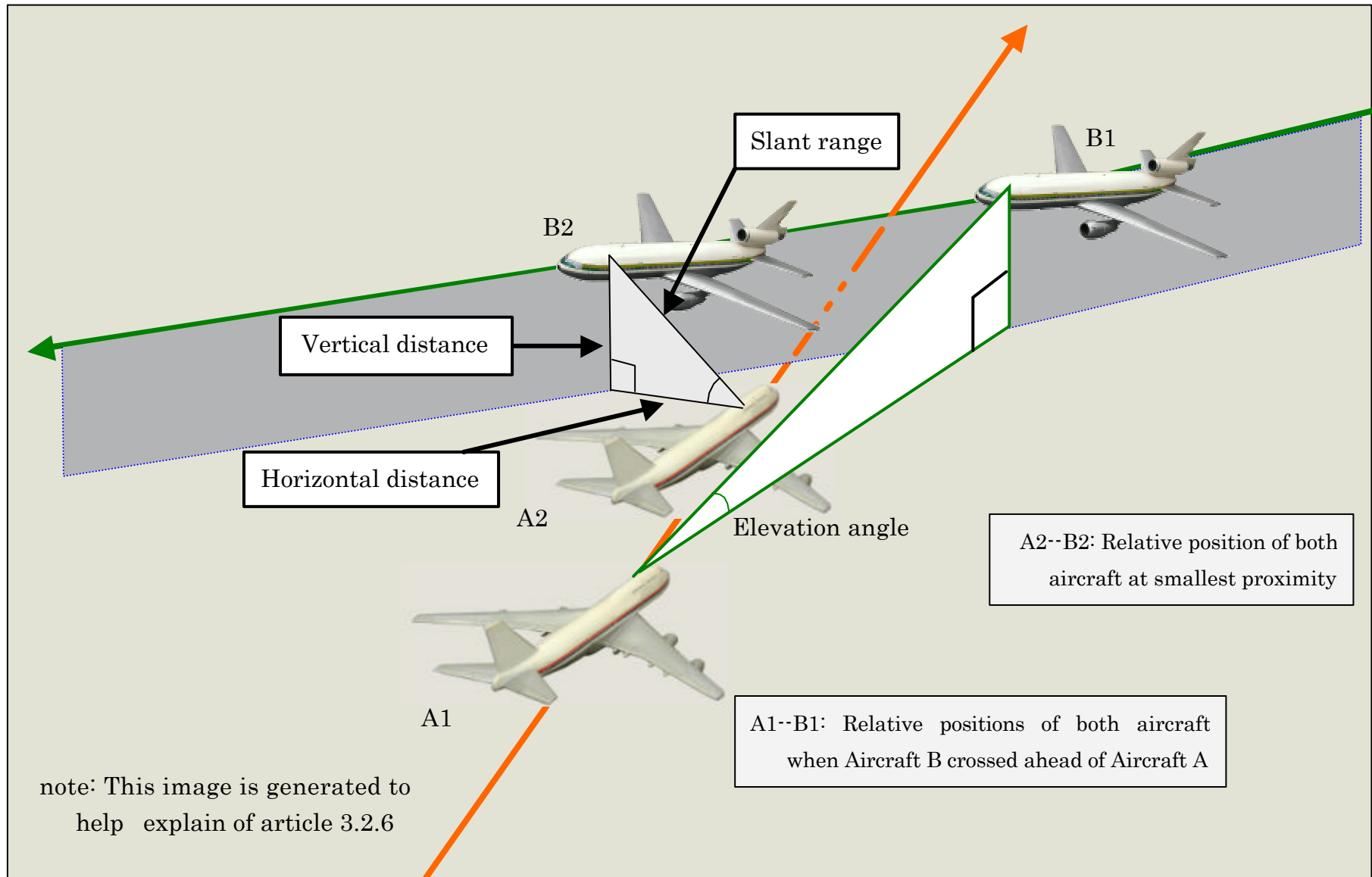


Figure 21 An assumed case that Aircraft B turned to 130°



The datum point is placed on the point of smallest proximity of both aircraft

Figure 22 Explanation of closest distance

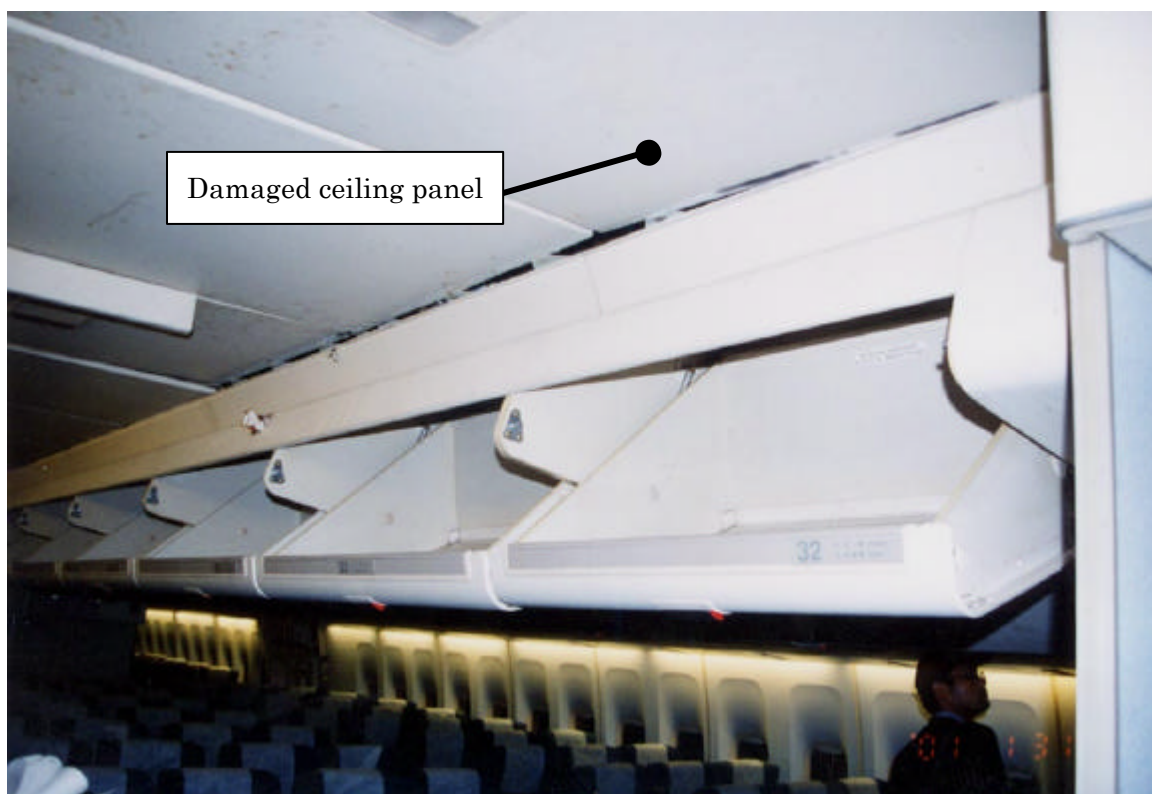


Photograph 1 Damage of the ceiling panel (Aircraft A) 1



The damage of ceiling panel over right side pass way seat No. 26(view from backward)

Photograph 2 Damage of the ceiling panel (Aircraft A) 2



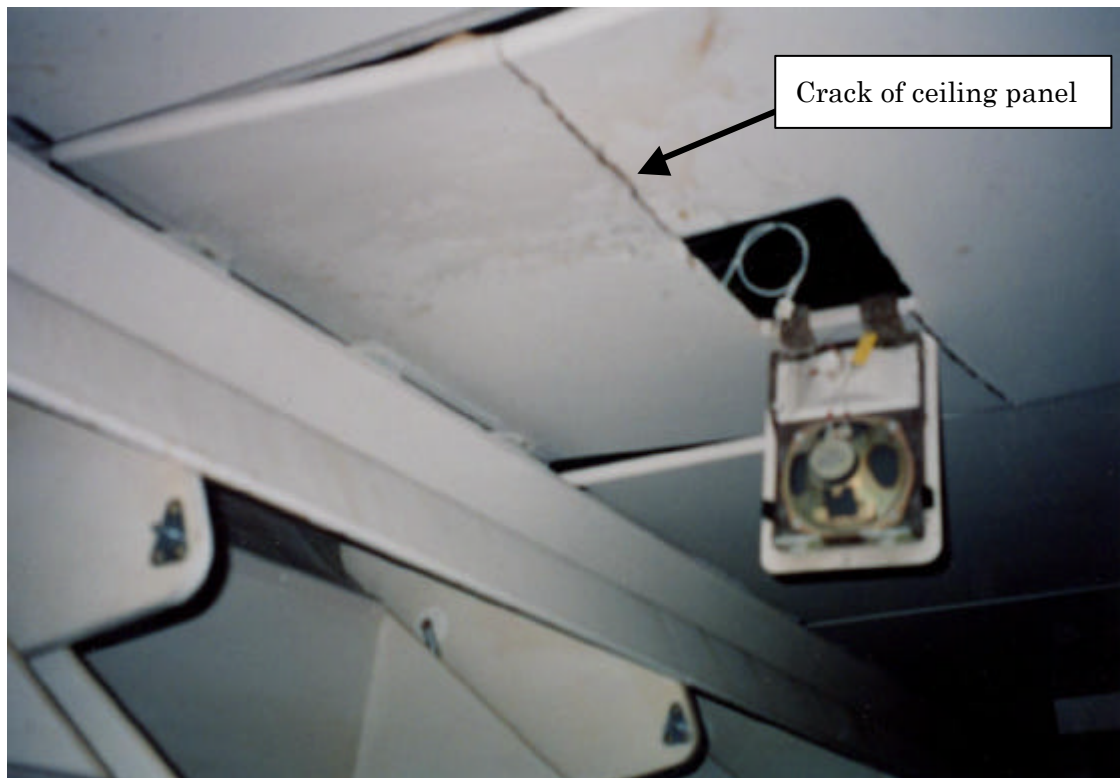
The damage of ceiling panel over right side pass way seat No. 32(view from front)

Photograph 3 Damage of the ceiling panel (Aircraft A) 3



The damage of ceiling panel over left side pass way seat No. 41(view from front)

Photograph 4 Damage of the ceiling panel (Aircraft A) 4



The damage of ceiling panel over left side pass way seat No. 48(view from front)

Photograph 5 Situation of the galley cart that was jumped up to the ceiling of Aircraft A 1



Rear view from the ceiling of right side pass way of seat No. 45

Photograph 6 Situation of the galley cart that was jumped up to the ceiling of Aircraft A 2



Rear view from the ceiling of left side pass way of seat No. 46

Photograph 7 Damage of seats (Aircraft A) 1



Damage of seat armrest of right side pass way seat No. 33

Photograph 8 Damage of seats (Aircraft A) 2



Damage of seat armrest of right side pass way seat No. 35

Attachment 1

ATC Transcription

- (1) This transcription recorded only the communication between the Air Traffic Controller of Tokyo ACC and Japan Air Lines 907 (Aircraft A), Japan Air Lines 958 (Aircraft B). But, from 1547:02 to 1556:28, describes all ATC Transcription.
- (2) JAL = Japan AirLines, ANA = All Nippon Airways, JAS = Japan Air System
 SKY = Sky Mark Airlines, AAL = American AirLine, VV = U.S.NAVY
 ATCt = ATC trainee, ATCs = ATCwatch supervisor,
 ATC = Air Traffic Controller who worked in shift, ? = Transmitter unknown,
 ... = unutterance part

Japan Standard Time

<i>(hh:mm:ss)</i>	<i>Utterance person</i>	<i>Contents</i>
15:42:12~16	ATCt	Japan air niner zero seven, fly heading two four zero for vector to Yaizu.
15:42:17~20	JAL907	Japan air niner zero seven, heading two four zero.
15:44:33~35	ATCt	Japan air niner zero seven, proceed directYaizu.
15:44:37~39	JAL907	Japan air niner zero seven, direct Yaizu.
15:45:25~30	ATCt	Japan air niner zero seven, maintain flightlevelthree five zero until further advised.
15:45:31~34	JAL907	Japan air niner zero seven, comfirm altitude, please.
15:45:35~39	ATCt	Japan air ninerzero seven, maintain flight level three five zero until further advised.
15:45:40~44	JAL907	Japan air niner zero seven flight level three five •• three five zero.
15:46:38~40	ATCt	Japan air niner zero seven, climb and maintain flight level three niner zero.
15:46:41~45	JAL907	Japan air niner zero seven, climb and maintain flight level three nine zero.

15:47:02 ~ 15:56:28, All transcription recorded.

15:47: 02	ATCt	American one five seven, descend and maintain flight level three five zero, due to traffic.
15:47: 14	JAL952	Tokyo, Japanair nine five two, request direct VENUS.
15:47: 18	ATCt	Japanair niner five two, stand byyourrequest.
15:47: 56	ATCt	Americanone five seven, Tokyo control.
15:48: 08	ATCt	Japanair nine five two, contact Narita approach, one two five decimal eight,request againplease.
15:48: 12	JAL952	Roger.
15:48:14~17	JAL958	Tokyo control, Japan air nine five eight, flight level three seven zero.
15:48:18~20	ATCt	Japan air niner fiveeight, Tokyo control, roger.
15:48:21	JAS296	Tokyo control, Airsystem two niner six, flight level two three zero.
15:48: 26	ATCt	Airsystem two niner six, Tokyo control, roger.
15:48: 37	AAL157	Good afternoon, Tokyo, American one five seven, flight level three nine zero.
15:48:44	ATCt	American one five seven, Tokyo control, descend and maintain flightlevel three five zero, due to traffic.
15:48:49	AAL157	Descend to flight level three five zero, due to traffic, leaving flightlevel three nine zero, American one five seven.
15:48:56	ACcT	Allnippon six five eight, resume normal speed, contact Tokyo approach oneoneninerdecimalone.
15:49:00	ANA658	Allnippon six five eight, normal speed, one one nine decimal one, good day.
15:49:03	ACcT	Goodday.
15:49:10	ACcT	Airsystem three one two, contact Tokyo approach oneoneniner decimal one.
15:49:14	JAS312	Oneonenine one, Airsystem three one two, goodday.
15:49:19	ACcT	Goodday.
15:49:33	ACcT	Allnippon five six five,contactTokyo control one three three decimal five.
15:49:38	ANA565	One three three decimal five, Allnippon five six five.
15:49:42	JAS346	Tokyo control, Airsystem three four six, now reaching flight level two five zero, request further low.
15:49:47	ACcT	Airsystem three four six ••• stand by.

15:49:51	JAS346	Roger,request twoonezero,stand by.
15:50:08	ACCt	Airsystem two niner six, confirm, requestinglower altitude ?
15:50:14	JAS296	Airsystem two nine six, negative.
15:50:17	ACCt	Airsystem two niner six, roger.
15:50:19	JAS552	Tokyo control, Airsystem five five two, leaving twoonezero.
15:50:25	ACCt	Airsystem five five two, roger.
15:50:38	ACCt	Airsystem three four six, descend and maintain flight level two one zero.
15:50:42	JAS346	Airsystem three four six, leaving two five zero for twoonezero, thank you.
15:50:52	ACCt	Airsystem one seven four, descend and maintain flight levelone six zero, crossSpens at flightlevel one sixzero.
15:50:58	JAS174	Airsystem one seven four, descend cross Spens one six zero.
15:51:08	ACCt	Airsystem three four six, say speed.
15:51:12	JAS346	Airsystem three four six, indicate three one zero knots.
15:51:15	ACCt	Airsystem three four six, roger, maintain present speed or greater for spacing.
15:51:19	JAS346	Airsystem three four six, maintain present speed or greater.
15:51:23	ACCt	Airsystem two niner six, maintain speed two eight zero knots or less for spacing.
15:51:29	JAS296	Airsystem two nine six, maintain twoeight zero or less.
15:51:51	ACCt	Airsystem five five two, contact Tokyo approach, one one niner decimal one.
15:51:54	JAS552	Airsystem five five two, Tokyo approach one one nine one.
15:52:28	JAS206	Tokyo control, Airsystem two zero six, two five zero.
15:52:34	ACCt	Airsystem two zero six, Tokyo control, roger.
15:53:02	VVJT036	Tokyo, Navyjuliet tango zero three six.
15:53:09	ACCt	Navy juliet ••• , Navyjuliet tango zero three six, ••• go ahead.
15:53:15	VVJT036	Er justwonder, confirm er routing after Oshima.
15:53:18	ACCt	Navy juliet tango zero three six, after Oshima proceed direct to ••• Yankee Uniform thendirect.
15:53:24	VVJT036	Roger,after Oshima, Yankee Uniform and direct,thank you.
15:53:52	SKY006	Tokyo control, Skymark zero zero six, maintain flight level three sevenzero.
15:53:56	ACCt	Skymark zero zero six, Tokyo control, roger.

When Aircraft A and B approached.

15:54:22~25	ATCt	Hem.Japan air niner zero seven,corre ••• Disregard.
15:54:27~32	ATCt	Japan air niner zero seven, descend and maintain flight level three five zero, begin descentduetotraffic.
15:54:33~38	JAL907	Japan air niner zero seven, descend and maintain flight level three five zero, ••• traffic insight. climb •••climb •••climb. (54:35~38, RA sound inback ground)
15:54:38~41	ATCt	Anair niner fiveeight, fly heading one three zero for spacing.
15:54:49~52	ATCt	Japan air niner five eight, fly heading one t••one four zero for spacing.
15:54:55~57	ATCs	Japan air niner five seven,begin descent.
15:55:02~05	ATCs	Japan air niner zero seven, climb and maintain flight level three niner zero.
15:55:21~27	JAL958	Tokyo control, we have er RA er actuated now descending and erclimbingagain.
15:55:29~30	ATCs	Japan air niner zero •• eight, roger.
15:55:32~35	JAL907	Japan air niner zero seven, clear of traffic.
15:55:36~37	ATCs	Niner zero seven, roger.
15:55:47~48	?	" •••• "
15:55:58 ~56:17	JAL958	Er Tokyo control, Japan air nine five eight, we have a ••• er now er climbing to flight level three seven zero and we have RA, descend RA at three seven zero and we observe er Boeing seven four seven reaching from our left side and there also descend away er climb to flight level three seven zero, now leaving three five five.
15:56:17~19	ATCs	Japan air niner zero eight, roger.
15:56:21~24	ATCs	Japan air niner zero seven, now climb and maintain flight level three niner zero.
15:56:25~28	JAL907	Japan air niner zero seven, climb and maintain flight level three nine zero.

Hereafter, Only the communication recorded thatisrelated to Aircraft A and B

15:56:56~58	JAL958	Tokyo control, Japan air nine fiveeight, requestdescent.
15:57:01~05	ATCs	Japan air niner five eight, descend and maintain flight level two three, ercorrection,two five zero.
15:57:06~09	JAL958	Japan air nine five eight, er descend and maintain two five zero.

15:59:15~17	JAL907	Tokyo control, Japan air nine zero seven.
15:59:18~21	ATC	Japan air niner zero seven, Tokyo control, roger••go ahead.
15:59:22~40	JAL907	Er••• Japan air nine zero seven,日本語で申し上げます。先ほど焼津市近辺において、えー、当社DC-10とのニアリ•••ニアミスいたしました。大変危険な状態でした。高度差ひゃ、にひゃくフィート有ったか無かったかぐらいです。えー、以上を報告します。 (I say in Japanese. A while ago JAL907 experienced nearly, er••• a near-miss with a Japan Air Line's DC-10 over Yaizu-city. It was a very dangerous situation. I'm not sure whether we had one hundred, two hundred feet of vertical separation or not. This concludes my report.)
15:59:41~43	ATC	Japan air niner zero seven, roger. 了解いたしました。(Roger)
16:02:06~10	ATC	Japan air niner zero seven, contact Tokyo control one three three decimal five.
16:02:11~14	JAL907	Er, contact Tokyo control one three three decimal five, Japan air niner zero seven.

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Attachment 2 The progress of accident occurrence (details)

Note: Time omits 15o'clock and continue for several seconds phenomenon is enteringstarttime.

Remainder entering the remainder time until mostclosestoproximity.

Trainee means Air TrafficController trainee. And Supervisor means Air Traffic Controllerwatch supervisor.

With " " uttered communication.Furthermore, the exceptionisentering and is omittingthecallsignof oneself and partner, whenifisnecessary.

Time Remainder	TOKYO ACC	Aircraft A	Aircraft B	Reference information
	Trainee was OJT at Kanto South C sector radar position at 1440. SuperVisor instructed and supervised Trainee at 1515.	1536, Took off at Tokyo Int. Airport for NAHA. Cockpit: Left seat: Captain Right seat: Pilottrainee Left observer seat: Co-pilot Right observer seat: Pilottrainee		
41'16"13'55"	TraineeAcknowledged	Reported to Tokyo ACC that leaving 11,000ftforFL390.		
42'12"12'59"	Trainee "Aircraft A, fly heading 240 for vector to Yaizu."			
42'17"12'54"		"Heading 240."		
44'33"10'38"	Trainee "Aircraft A, proceed direct Yaizu."			
44'37"10'34"		"Direct Yaizu."		

Time	Remainder	TOKYO ACC	Aircraft A	Aircraft B	Reference information
45'25"	09'46"	Trainee "Aircraft A, maintain flight level three five zero until further advised."	"Comfirm altitude, please."		At this time AAL157 (Aircraft C) was flying foward Wakayama pref. from Izu Ooshima Island vicinity at FL390.
45'31"	09'40"				
45'35"	09'36"	Trainee "Aircraft A, maintain flight level three five zero until further advised."			
45'40"	09'31"				
46'38"	08'33"	Trainee "Aircraft A, climb and maintain flightlevel 390."			
46'41"	08'30"		"Flightlevel35 •• 350."		
			(ClimbingFL216)		
46'41"	08'30"		"Climbandmaintain flight level 390."		
46'51"	08'20"	At the Radar display of Kanto South C sector, [HND] was displayed in the datablock of Aircraft B.	-----	-----	The adjacent sector of Kanto South C, carried out the operation for the radar hand off of Aircraft B.
47'02"	08'09"	Trainee To instruct Aircraft C to descend to FL350, because there was other aircraft, buttherewas no answer from Aircraft C.			
47'14"	07'57"	-----	-----	-----	JAL952 (Aircraft D) requested Tokyo ACC to go direct VENUS new Tokyo Int. A/P vicinity.
47'18"	07'53"	Trainee "Aircraft D, stand by yourrequest."			
47'47"	07'24"	Kanto South C sector initiate the computer operation to recive control transfer of Aircraft B.			
47'56"	07'15"	Trainee To call Aircraft C, there was noanswer.			

Time Remainder	TOKYO ACC	Aircraft A	Aircraft B	Reference information
48'08" 07'03"	Trainee To make contact with New Tokto Int. A/P terminal control to Aircraft D.			Aircraft D was consent of the instruction.
48'12" 06'59"	-----	-----	-----	
48'14" 06'57"	-----	-----	"Flight level 350." (Position was West of Aircraft A.)	
48'18" 06'53"	Trainee "Aircraft B, roger." Trainee Communicated with other airplanes in succession.		Cockpit: Right seat: Captain Left seat: Copilot who is under upgrade to captain training Flight Engineer	"FL 390" was reported from Aircraft C to Kanto South C sector.
48'22" 06'49"	Air traffic Controller of Kanto South B sector who was communicating with Aircraft C, to instruct frequency change to Kanto South C sector to Aircraft C			
48'37" 06'34"	.	-----	-----	
48'44" 06'27"	Trainee "Aircraft C, descend and maintain flight level 350, due to traffic.			"Descend to FL350, due to traffic, leaving FL390." was reported from Aircraft C.
48'49" 06'22"	-----	-----	-----	

Time Remainder	TOKYO ACC	Aircraft A	Aircraft B	Reference information
53'50"01'21"	The trainee's control situation between 1543:00 -- 1552:00 He controledmaximum 14 aircrafts. The total transmission was 37 times. (Conrtol instructions 18 times.) Communication blank in 15 seconds3times. The trainee's control situation between 1552:00 -- 1554:22. 4 timestransmission to 3 aircraft. (Control instruction 1 time.) At this time, trainee recieved comments from supervisor on the ATC works performed until then.	Around 15:52, Aircraft A was seeing Aircraft B under VMC condition.		
54'15"00'56"	[CNF] was displayed on the radar screen. That moment, as for FL of Aircraft A is 367, and Aircraft B is 370.	Until then, Aircraft A climbing on heading 270° began to make left turn, and continued climbing with maintaining about 25° roll angle. The symbol of Aircraft B was displayed on the TCAS information indicator this time, Aircraft B during a cruise at same altitude, the arrow which show a climbing or descending was not displayed.	Around 15:54, Aircraft B was seeing Aircraft A. The symbol of Aircraft A was displayed on the TCAS information indicator and the upward arrow that shows AircraftAisclimbing.	

Time Remainder	TOKYO ACC	Aircraft A	Aircraft B	Reference information
54'18"00'53" 54'19"00'52"	FL of Aircraft A was displayed with 369.	<u>TA was issued on the TCAS indicator.</u> (Continued climbing left turn around FL369.)	<u>TA was issued on the TCAS indicator.</u> (Cruise at FL370, heading 095, south west of Aircraft A.)	
54'22"00'49" 54'26"00'45"00'42"	Trainee "Hem. Aircraft A, corre ... Disregard. -----	-----	Auto throttle → off (It didn't determine when became off during 26 to 29 sec.)	
54'27"00'44"	Trainee "Aircraft A, descend and maintain flight level 350, begin descent due to traffic." Tokyo ACC mistook the flight number of Aircraft B for that of Aircraft A, and issued an instruction to Aircraft A to avoid traffic.			
54'29"00'42" 54'32"00'39" 54'33"00'38"	FL of Aircraft A was displayed with 370. FL of Aircraft B was displayed with 370.	Autopilot → off Fuel flow, began to decrease. At 54'33" "Descend and maintain flight level three five zero, ... traffic insight." (This answer continued until 54'38")		
54'34"00'37"		Pitch angle, began to decrease.	<u>RA was issued on the TCAS indicator.</u> (Advised -1500ft/min descend.)	

Time Remainder	TOKYO ACC	Aircraft A	Aircraft B	Reference information
54'35"00'36"	Following instructions were carried out immediately after Aircraft A's answer completion.	<u>RA was issued on the TCAS indicator.</u> (Advised 1500 ft/min climb.) Voice of "CLIMBCLIMBCLIMB" (While turning, climbing around FL371 by inertia.) Although the decreasing pitch angle, that was increased a moment, after that continued decrease.	(Cruise at FL370, heading 095)	Voice of "CLIMB" was recorded for a period of about 3 seconds into the transmission from the Aircraft A that has begun from 54:33 of ATC transcription.
54'35"~ 38" 00'36"~ 33"				
54'37"00'34"				
54'38"00'33"	Trainee "An air (B), fly heading 130 for spacing. FL of Aircraft A was displayed with 372.	Auto throttle → off	No answer.	There was no answer from Aircraft B. ↓ *Part of the head of flight No. is difficult to catch. *Correspondence of RA, and instructions to the correspondence. *The warning sound of auto pilot at that time. For these reasons, the possibility that the ATC of calling Aircraft B was not recognized.
54'39"00'32"		Fuel flow went up temporarily, continued decrease after that.	Auto pilot → off	
54'40"00'31"		While continuing left turn, reaching the peak (FL372), after that, altitude began to decrease.		
54'43"00'28"	FL of Aircraft B was displayed with 370.		Altitude began to descend.	
54'46"00'25"		Roll angle exceeds the left of 30 degree temporarily, then shallow. It has already started rollout and heading began to face in the direction of 207 degree gradually.	The upward arrow that was showing climb to the side of the symbol of Aircraft A on the TCAS display, faded out.	
54'48"00'23"	FL of Aircraft A was displayed with 371.			

Time Remainder	TOKYO ACC	Aircraft A	Aircraft B	Reference information
54'49"00'22"	Trainee "Aircraft B, fly heading one t••140 for spacing.		Increase RA was issued on the TCAS indicator. (Advised -2500ft/min descend.)	No answer from Aircraft B ↓
54'51"00'20"		(Descending FL370)	The symbol of downward arrow that shows Aircraft A is descending was displayed on the TCAS information indicator	The possibility that ATC calling Aircraft B was not recognized by speed brake operation, vibration, and correspondence of Increase RA and instruction of this correspondence.
54'52"00'19"		(Descending FL369)	(Descending FL369)	
54'53"00'18"	FL of Aircraft B was displayed with 369.	(Descending FL369)	(Descending FL369)	
54'54"00'17"		(Descending FL368)	(Descending FL368)	
		The symbol of downward arrow that shows Aircraft B is descending was displayed on the TCAS information indicator		
54'55"00'16"	Supervisor "Japan air 957, begin descent."	(Descending FL368)	(Descending FL368)	There was not JAL957.
54'56"00'15"		(Descending FL367)	(Descending FL367)	
54'57"00'14"		(Descending FL366)	(Descending FL366)	
54'58"00'13"	FL of Aircraft A was displayed with 367.	(Descending FL366)	(Descending FL366)	Both aircraft descending almost the same altitude with a similar descending rate.
54'59"00'12"		(Descending FL366)	(Descending FL366)	
55'00"00'11"		(Descending FL365)	(Descending FL365)	
55'01"00'10"		(Descending FL365)	(Descending FL365)	
55'02"00'09"	Supervisor "Aircraft A, climb and maintain flight level 350."	No answer.		
55'03"00'08"	FL of Aircraft B was displayed with 366.	(Descending FL365)	(Descending FL364)	Aircraft B was flying lower altitude than
		(Descending FL364)	(Descending FL363)	

Time Remainder	TOKYO ACC	Aircraft A	Aircraft B	Reference information
55'04"00'07" 55'05"00'06"		(Descending FL363) (Descending FL363) The pitch angle of descending began to become bigger.	Signal from Aircraft A came not to receive it in TCAS. (Descending FL363) (Descending FL362) Angle of control column changed on the nose up side from nose downside.	Aircraft A during half of this period.
55'06"00'05"		Increase RA was issued on the TCAS indicator. (Advised 2500 ft/min climb.) CAS began to increase from this time, CAS 284 kt and was stabilizing during deacend. (Descending FL362)	(Descending FL361)	
55'07"00'04"		(Vertical acceleration: -0.55 G) The pitch angle became -10.8 maximum degrees on the side of nose reduction during this descending. Here after the pitch angle gradually nose up. (Descending FL362)	(Descending FL360)	
55'08"00'03"	FL of Aircraft A was displayed with 362.	Fuel flow had fallen to idle value. Becoming rapid descending, the descending rate was limit value 8,192 ft/min of DFDR. (Vertical acceleration: +1.33 G) (Descending FL360)	(Descending FL359) From to pull up the nose, the descend rate became low.	
55'09"00'02"			Symbol of Aircraft A faded away on the TCAS information indicator.	Because it continuously signal from Aircraft A was not able to receive in TCAS of Aircraft B, becoming a truck drop and faded away.

Time Remainder	TOKYO ACC	Aircraft A	Aircraft B	Reference information
55'10"00'01"		(Descending FL358)	(Descending FL358) Symbol of Aircraft A was redisplayed.	After that, it was received and was displayed.
55'11"00'00"		(Descending FL357) Closest proximity with Aircraft B. (Descending FL355)	(Descending FL358) Closest proximity with Aircraft A. (Descending FL357)	Aircraft A passed the lower part of Aircraft B.
55'12"	FL of Aircraft B was displayed with 359.	(Descending FL354)	(Descending FL357)	
55'13"		CAS reached maximum 299 kts during this descending. Fuel flow was around idle value, the pitch angle was returned to -5.5 degree. (Descending FL353)		
55'15"		RA became TA and became CLR CFT (clear conflict)	(Descending FL356)	
55'17"		(Vertical acceleration: +1.59 G)		
55'18"		Pitch angle began to become the value of positive. (Descending FL343)		
55'20"		(Maintain FL343)		
55'21"		Began to climb.	"We have er RA er actuated now descending and er climbing again." (Although there was no call sign in this report, analysis showed that it was from Aircraft B.)	

Time Remainder	TOKYO ACC	Aircraft A	Aircraft B	Reference information
55'29"	Supervisor "Japan air 90•• 8, roger.	-----	Although it descended to FL353, it bagantoclimbat55'26"	There was no JAL908
55'32"		"Clear of traffic. "		
55'36"	Supervisor "Aircraft A, roger."			
later		Autopilot } Autothrottle } Re engage	Auto pilot } Auto throttle } Re engage	
		Reported to Tokyo ACC that they met near mid-air collision with DC-10 type of aircraft. Because, there were wounded persons, demanding turn back to Tokyo International A/P, and was approved. At 16:44, Land at Tokyo International Airport.	At 16:32, Land at New Tokyo International Airport.	

Related documents to TCAS operation 1 (AIC)

006/01

航空機衝突防止装置(ACAS II)の運用について

平成11年1月28日0000JSTから、ACAS IIの運用が以下のとおり実施される。

なお、本AICの発行と同時に、平成13年1月6日付AIC Nr002/01を取り消す。変更部分は矢印により表示される。

1. ACAS II 運用の実施

東京FIR又は那覇FIR内を飛行する全てのACAS II 装備機のパイロットは、可能な限り本AICに基づき必要な措置を講じなければならない。

2. ACAS II の装備要件

ACAS II は、国際民間航空条約第10付属書第IV部の規定に適合するものであること。

3. パイロットの要件

ACAS II の運用を実施するパイロットは、ACAS II 訓練を終了していること。

4. パイロットがとるべき措置

(1) パイロットは、以下の手順に従うこと。

- a. パイロットは、トラフィックアドバイザリー（以下、「TA」という。）により自機の回避操作を行ってはならない。なお、接近する航空機の目視確認に努めるとともに、管制機関から交通情報の提供がない場合は、当該管制機関に対し確認することが望ましい。
- b. パイロットがレゾリューションアドバイザリー（以下「RA」という。）により回避操作を実施する場合には、衝突のおそれのある航空機の目視確認に努めるとともに自機が変更しようとする方向の外部監視も行うこと。
- c. RAにより高度を変更する場合、その変更は必要最小限にとどめること。
- d. RAによりパイロットが管制指示高度を逸脱し、その後衝突の危険が回避された場合には、直ちに所定の管制指示高度に復帰すること。また無線電話により管制機関へ可及的速やかにその旨の報告をすること。なお、管制機関への連絡に当たっては、以下の用語例に従うこと。

006/01

Operation of the Airborne Collision Avoidance System(ACAS II)

WEF 1500UTC 27 JAN 1999, ACAS II will be operated as follows.

This AIC supersedes AIC Nr002/01 dated 6 JAN 2001.

A change is indicated by arrow.

1. Operational use of ACAS II

Pilots shall observe this AIC as possible when they execute operational use of ACAS II in Tokyo FIR or Naha FIR.

2. Requirements for ACAS II equipments

ACAS II equipments shall comply with the requirements as defined by Annex 10, Volume IV to the Convention on International Civil Aviation.

3. Requirements of pilots

Pilots shall not execute operational use of ACAS II unless the training for it has been completed.

4. Procedures to be followed by pilots

(1) Pilots shall comply with the following procedures:

- a. Pilots shall not manoeuvre their aircrafts in response to a Traffic Advisory(TA) only. However, pilots shall search for the approaching traffic, and also it will be preferable to make confirmation to the ATC if you don't have ATC traffic information.
- b. In the event of a Resolution Advisory(RA) to alter the flight path, the search for the conflicting traffic shall include a visual scan of the airspace into which own ACAS aircraft might manoeuvre.
- c. The alteration of the flight path shall be limited to the minimum extent necessary to comply with the RA.
- d. Pilots who deviate from an ATC clearance in response to an RA shall promptly return to the terms of the previous ATC instruction or clearance when the conflict is resolved and they shall notify the appropriate ATC unit by the use of the following phraseologies as soon as possible on the radio frequency.

状 況(Circumstances)	用語例(Phraseologies)
ACAS RAに従って高度変更を行った場合 after modifying vertical speed to comply with an ACAS RA	TCAS CLIMB(or DESCENT)
ACAS RAに応答後「Clear of Conflict」となったとき after ACAS "Clear of conflict" is annunciated	RETURNING TO(assigned clearance)
ACAS RAに応答後、RAが消失したとき after the response to an ACAS RA is completed	TCAS CLIMB(or DESCENT), RETURNING TO(assigned clearance)
ACAS RAに応答後、現行の管制承認に復帰したとき after returning to clearance after responding to an ACAS RA	TCAS CLIMB(or DESCENT), COMPLETED(assigned clearance) RESUMED
ACAS RAに従うため、管制承認／指示に従えないとき when unable comply with a clearance because of an ACAS RA	UNABLE TO COMPLY, TCAS RA

(注) 管制用語として使用する場合のみ“ACAS”に替え“TCAS”を使用する。

NOTICE: “TCAS” should be used as ATC phraseology instead of “ACAS”.

- (2) パイロットは、RA発生毎に原則として別添の様式の報告書(RAレポート)を作成し提出すること。
- 本運用における個々のデータは航空交通の安全の向上に役立てるために用いられ、秘密は厳守される。
 - RAレポートは、異常接近報告書とは別個に提出されるべきものである。

- (2) Pilots shall file RA reports using the attached form or equivalent on each occurrence of an RA.
- Individual data will be used only for advance of air traffic safety and will be treated as confidential.
 - RA reports will be used independently of “Near Collision Reports” of which procedures remain unchanged.

5. 運航者がとるべき措置

- 運航者は、詳細な操作手順を運航規程に規定すること。
- 運航者は、パイロットから提出されたRAレポートを速やかに下記の住所あてに送付すること。
なお、ACAS IIのソフトウェアバージョン名が既知である場合には、RAレポートにそのバージョン名を加えて記述すること。

5. Aircraft operators involvement

- Operators shall stipulate detailed ACAS II operational procedures in each Airline Operations Manual.
- Operators shall collect all RA reports referred in 4.(2)above and dispatch them as soon as possible to the following address.
If the version of ACAS II software is known, it shall be added to RA reports.

〒100-8918
東京都千代田区霞が関2-1-3
国土交通省航空局 管制保安部 管制課
TEL 03(5253)8749
FAX 03(5253)1663

Air Traffic Control Division, Air Traffic Services Dept.
Civil Aviation Bureau, Ministry of Land, Infrastructure and Transport
2-1-3 Kasumigaseki, Chiyoda-ku Tokyo, Japan 100-8918
TEL (+81)3-5253-8749
FAX (+81)3-5253-1663

6. パイロットの責任

RAにより管制指示高度から逸脱を行う場合、パイロットは航空法第96条第1項の違反には問われない。

6. Pilot responsibility

When RA is initiated and pilot deviates from ATC clearance, the pilot is not considered to be violating against the Civil Aeronautics Law, article 96-1.

7. 管制官の責任

航空機がRAにより管制指示高度から逸脱している間、管制官は当該機と回避操作により影響を受ける他の航空機との間における管制間隔の設定について責任を有しない。
管制官の管制間隔設定の責任は、次の場合に再び生ずる。

- 航空機が回避を終了し、指示高度に復帰したとき。
- 航空機から回避を終了した旨の通報があり、当該機と他の航空機との間に管制間隔が設定されていることが管制官に確認されたとき。

7. Controller's responsibility during an RA

Once an aircraft departs from an assigned ATC clearance in compliance with an RA, a controller ceases to be responsible for providing ATC separation between that aircraft and other aircraft affected by the direct consequence of that RA manoeuvre. Controller's responsibility for providing separation for all affected aircrafts resumes when either;

- the aircraft returns to the assigned clearance, or
- the pilot reports a controller ATC that RA manoeuvre is completed and the controller confirms that separation is established.

Attachment 4 Related documents to TCAS operation 2 (PANS-OPS)

There is the following description in Volume I, Part VIII, Chapter 3 "OPERATION OF ACAS EQUIPMENT" of PANS-OPS (The Procedures for Air Navigation Services - Aircraft Operations) of ICAO.

3.1 GENERAL

3.1.1 The information provided by airborne collision avoidance system (ACAS) is intended to assist pilots in the safe operation of aircraft.

3.1.2 Nothing in the procedures specified in 3.2 hereunder shall prevent pilots-in-command from exercising their best judgement and full authority in the choice of the best course of action to resolve a traffic conflict.

3.2 USE OF ACAS INDICATIONS

ACAS indications are intended to assist the pilots in the active search for, and visual acquisition of, the conflicting traffic, and the avoidance of potential collisions. The indications generated by ACAS shall be used by pilots in conformity with the following safety considerations:

- a) pilots shall not manoeuvre their aircraft in response to traffic advisories only;

Note 1.— Traffic advisories are intended to assist in visual acquisition of conflicting traffic and to alert the pilot to the possibility of a resolution advisory.

Note 2.— The above restrictions in the use of traffic advisories is due to the limited bearing accuracy and to the difficulty in interpreting altitude rate from displayed traffic information.

- b) in the event of a resolution advisory to alter the flight path, the search for the conflicting traffic shall include a visual scan of the airspace into which own ACAS aircraft might manoeuvre;
- c) the alteration of the flight path shall be limited to the minimum extent necessary to comply with the resolution advisories;
- d) pilots who deviate from an air traffic control instruction or clearance in response to a resolution advisory shall promptly return to the terms of that instruction or clearance when the conflict is resolved and shall notify the appropriate ATC unit as soon as practicable, of the deviation, including its direction and when the deviation has ended.

Note.— The phraseology to be used for the notification of manoeuvres in response to a resolution advisory is contained in the PANS-ATM (Doc 4444), Chapter 12.

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Attachment 5

Related documents to TCAS operation 3 (PANS-RAC)

Note: PANS-RAC is revised as PANS-ATM from November, 2001.

- (1) There is the following entry about the relation between TCAS and air traffic control, in PANS-RAC part II that is the 2nd International Civil Aviation Treaty and also the 11th attachment supplement volume.

(An extract)

19.1 The procedures to be applied for the provision of air traffic services to aircraft equipped with ACAS shall be identical to those applicable to non-ACAS equipped aircraft. In particular, the prevention of collisions, the establishment of appropriate separation and the information which might be provided in relation to conflicting traffic and to possible avoiding action shall conform with the normal ATS procedures and shall exclude consideration of aircraft capabilities dependent on ACAS equipment.

19.2 When a pilot reports a manoeuvre induced by an ACAS resolution advisory, the controller shall not attempt to modify the aircraft flight path until the pilot reports returning to the terms of the current air traffic control instruction or clearance but shall provide traffic information as appropriate.

Note 1.— The ACAS capability of an aircraft will not normally be known to air traffic controllers.

Note 2.— Operating procedures for use of ACAS are contained in PANS-OPS(Doc 8168), Volume I, Part VIII, Chapter 3.

Note 3.— The phraseology to be used by controllers and pilots is contained in Part X, 3.1.2.

(2) Phraseologies that prescribed to ICAO PANS-RAC part X Phraseologies 3.1.2 is as follows.

<i>Circumstances</i>	<i>Phraseologies</i>
...after modifying vertical speed to comply with an ACAS resolution advisory (Pilot and controller interchange)	*TCAS CLIMB(or DESCENT) ; (<i>acknowledgement</i>);
...after ACAS "Clear of Conflict" is annunciated (Pilot and controller interchange)	*RETURNING TO (<i>assigned clearance</i>); (<i>acknowledgement</i>) (or <i>alternative instructions</i>) ;
...after the response to an ACAS resolution advisory is completed (Pilot and controller interchange)	*TCAS CLIMB (or DESCENT), RETURNING TO (<i>assigned clearance</i>) ; (<i>acknowledgement</i>) (or <i>alternative instructions</i>) ;
...after returning to clearance after responding to an ACAS resolution advisory (Pilot and controller interchange)	*TCAS CLIMB(or DESCENT), COMPLETED (<i>assigned clearance</i>) RESUMED; (<i>acknowledgement</i>) (or <i>alternative instructions</i>) ;
...when unable to comply with a clearance because of an ACAS resolution advisory (Pilot and controller interchange)	*UNABLE TO COMPLY, TCAS RESOLUTION ADVISORY ; (<i>acknowledgement</i>) .
	*Denotes pilot transmission.

Attachment 6

Proposals at an interim report on this accident

On June 22, 2001, Aircraft and Railway Accident Investigation Commission (ARAIC) submitted an interim report on this accident to Minister for Land, Infrastructure and Transport, and in addition made the following proposals

Ms. Chikage Oogi
Minister for Land, Infrastructure and Transport

Junzo Sato, Chairman
Aircraft and Railway Accidents Investigation
Commission

Proposals on the accident related to Boeing 747-400D (JA8904) belong to Japan Airlines (Propose No.14)

The above accident, which occurred over the sea off Suruga bay in the vicinity of 18 km south-south west of Yaizu city, Shizuoka prefecture, was the result of near mid-air collision with another aircraft. ARAIC has been carrying out many-sided investigations of all conceivably relevant factual information involving air traffic control, aircraft operation and operational condition of TCAS since this accident occurred, and has been assiduously analyzing these.

At present, because ARAIC is in the process of investigation, it is vital that the relationships between individual pieces of factual information and probable causes is left to the future careful investigation and that prediction of such is rejected, but the flight history, etc. presumed at present are as follows:

JA8904 was instructed to descend by air traffic control while climbing in accordance with an earlier ATC instruction. The aircraft's TCAS instructed it to climb just after that the descent to comply with the above ATC instruction was initiated.

After that, JA8904 continued to descend in accordance with the ATC instruction, contrary to the TCAS instruction.

Meanwhile, JA8904 was approaching closely to another aircraft, which descended in accordance with an instruction from its own TCAS.

Because JA8904 continued to descend while the other aircraft also was also descending, both aircraft were descending at the same altitude and approached each other closely.

Afterward, just before the path of the aircraft crossed, JA8904 descend rapidly and other aircraft nosed up.

During the above situation, there was a point when communications between an air traffic facility and the aircraft were not executed certainly; for example JA8904 did not respond to an instruction from air traffic control which requested it to change flight course, etc.

In consideration of the above matters, although the investigation of this accident is not completed, ARAIC makes following the proposals in accordance with the Establishment Laws of Aircraft and Railway Accidents Investigation Commission Article 22 as matters which should be studied and be carried out by the related authorities, to prevent the same type of accident in future:

(Communication)

In the case that urgent concentration on a specified matter is required under conditions of stress, as is the case where the possibility of a near mid-air collision is predicted, study communication methods and what communication measures should be, in order that the communication between an air traffic control and aircraft are executed rapidly and certainly

(Education and training)

Based on the study of the above paragraph 1, study about what the education and training should be to improve the cooperation between an air traffic control facilities and aircraft, and take the necessary measures.

(The investigation of actual conditions)

Investigate actual conditions of responses to TCAS resolution advisories during cruise. Person engage in ATC jobs, aircraft operation and design, and research of TCAS shall analyze the above conditions and, if necessary, study measures for improvement.