
In-Flight Engine Separation, Japan Airlines, Inc., Flight 46E, Boeing 747-121, N473EV, Anchorage, Alaska, March 31, 1993

Micro-summary: This Boeing 747-121 lost an engine on takeoff.

Event Date: 1993-03-31 at 1234 AST

Investigative Body: National Transportation Safety Board (NTSB), USA

Investigative Body's Web Site: <http://www.nts.gov/>

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NATIONAL TRANSPORTATION SAFETY BOARD

WASHINGTON, D.C. 20594

AIRCRAFT ACCIDENT REPORT

IN-FLIGHT ENGINE SEPARATION
JAPAN AIRLINES, INC., FLIGHT 46E
BOEING 747-121, N473EV
ANCHORAGE, ALASKA
MARCH 31, 1993



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**Adopted: October 13, 1993
Notation 6081A**

Abstract: This report explains the in-flight separation of the No. 2 engine and engine pylon from a B-747-121 airplane shortly after its takeoff from Anchorage International Airport, Anchorage, Alaska, on March 31, 1993. The safety issues discussed in the report focused on the inspection of B-747 engine pylons, meteorological hazards to aircraft, the lateral load-carrying capability of engine pylon structures, and aircraft departure routes at Anchorage International Airport during turbulent weather conditions. Safety recommendations concerning these issues were addressed to the Federal Aviation Administration and the National Weather Service.

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EXECUTIVE SUMMARY

On March 31, 1993, the No. 2 engine and engine pylon separated from Japan Airlines, Inc. flight 46E, a Boeing 747-121, that had been wet-leased from Evergreen International Airlines, Inc., shortly after departure from Anchorage International Airport, Anchorage, Alaska. The accident occurred about 1234 Alaska standard time. The flight was a scheduled cargo flight from Anchorage to Chicago-O'Hare International Airport, Chicago, Illinois. On board the airplane were the flightcrew, consisting of the captain, the first officer, and the second officer, and two nonrevenue company employees. The airplane was substantially damaged during the separation of the engine. No one on board the airplane or on the ground was injured.

Flight 46E departed Anchorage about 1224 local time. The flight release/weather package provided to the pilots by Evergreen operations contained a forecast for severe turbulence and indicated that severe turbulence was reported by other large airplanes. As flight 46E taxied onto the runway to await its takeoff clearance, the local controller informed the flightcrew that the pilot of another Evergreen B-747 reported severe turbulence at 2,500 feet while climbing out from runway 6R.

After takeoff, at an altitude of about 2,000 feet, the airplane experienced an uncommanded left bank of approximately 50 degrees. While the desired air speed was 183 knots, the air speed fluctuated about 75 knots from a high of 245 knots to a low of 170 knots. Shortly thereafter, the flightcrew reported a "huge" yaw, the No. 2 throttle slammed to its aft stop, the No. 2 reverser indication showed thrust reverser deployment, and the No. 2 engine electrical bus failed. Several witnesses on the ground reported that the airplane experienced several severe pitch and roll oscillations before the engine separated.

Shortly after the engine separated from the airplane, the flightcrew declared an emergency, and the captain initiated a large radius turn to the left to return and land on runway 6R. The No. 1 engine was maintained at emergency/maximum power. While on the downwind portion of the landing pattern, bank angles momentarily exceeded 40 degrees, alternating with wings level. About 1245, flight 46E advised the tower that they were on the runway.

The National Transportation Safety Board determines that the probable cause of this accident was the lateral separation of the No. 2 engine pylon due to an encounter with severe or possibly extreme turbulence that resulted in dynamic multi-axis lateral loadings that exceeded the ultimate lateral load-carrying capability of the pylon, which was already reduced by the presence of the fatigue crack near the forward end of the pylon's forward firewall web.

As a result of its investigation of this accident, the National Transportation Safety Board made seven recommendations to the Federal Aviation Administration, including the inspection of B-747 engine pylons, the potential meteorological hazards to aircraft, an increase in the lateral load capability of engine pylon structures, and the modification of the aircraft departure routes at Anchorage International Airport during periods of moderate or severe turbulence. The Safety Board recommended that the National Weather Service use the WSR-88D Doppler weather radar system at Anchorage, Alaska, to document mountain-generated wind fields in the Anchorage area and to develop detailed low altitude turbulence forecasts. Additionally, the Safety Board reiterated to the Federal Aviation Administration Safety Recommendation A-92-58, which urged the development of a meteorological aircraft hazard program to include other airports in or near mountainous terrain.

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1. FACTUAL INFORMATION

1.1 History of the Flight

On March 31, 1993, about 1234 Alaska standard time, the No. 2 engine and engine pylon separated from a Japan Airlines, Inc. (JAL) Boeing 747-121, flight 46E, shortly after departure from Anchorage International Airport (ANC), Anchorage, Alaska. The flight was a scheduled cargo flight from ANC to Chicago-O'Hare International Airport (ORD), Chicago, Illinois, operating under the provisions of Title 14 Code of Federal Regulations (CFR) Part 121, Supplemental. The airplane had been wet-leased from Evergreen International Airlines, Inc. (Evergreen). Under the terms of the wet-lease, Evergreen provided the airplane, fuel, and flightcrew, and performed the maintenance on the airplane. The flight was to be operated in accordance with an instrument flight rules (IFR) flight plan, as required by Evergreen's procedures. On board the airplane were the flightcrew, consisting of the captain, the first officer, and the second officer, and two nonrevenue company employees. The airplane was substantially damaged during the separation of the engine. No one on board the airplane or on the ground was injured.

Flight 46E departed Narita, Japan (NRT), on a scheduled flight to ORD with an en route stop at ANC to refuel and change flightcrews. The airplane arrived at ANC at 1005 on March 31, 1993. Flight 46E's scheduled departure time to ORD was 1125. The flight release/weather package was provided to the pilots

by Evergreen operations and contained SIGMET¹ India 1, which was valid until 1115. SIGMET India 1 provided a forecast for severe turbulence and indicated that severe turbulence was reported by aircraft below 12,000 feet within 60 nautical miles either side of a line from 80 west of Kodiak, Alaska, to Big Lake, Alaska.

As the aircraft taxied out of the ramp area about 1125, the No. 2 engine start valve "open" light illuminated. In response to this indication, the flight engineer shut down the No. 2 engine as a precautionary measure. The airplane returned to the ramp to have the discrepancy inspected by maintenance personnel. Evergreen mechanics replaced the start valve; however, the light remained illuminated. The mechanics determined that the indicator system was at fault and, in accordance with Evergreen's Federal Aviation Administration (FAA)-approved Minimum Equipment List (MEL), the discrepancy was recorded, and the repair was deferred to a later time.

While the start valve was being replaced, SIGMET India 3 was broadcast on the ground control frequency. SIGMET India 3 provided a forecast of moderate frequent severe turbulence from the surface to 12,000 feet and moderate frequent severe mountain wave turbulence from 12,000 feet through 39,000 feet for an area whose northern boundary was 36 miles south of Anchorage.

At 1221, flight 46E requested and received taxi clearance from the ANC ground controller. During the taxi to runway 6R, the ground controller alerted the flightcrew that Automatic Terminal Information Service (ATIS) Lima was current. The crew acknowledged the transmission. Information Lima, prepared at 1156, provided an estimated ceiling of 8,000 feet overcast; visibility 60 miles; temperature 49° F; dew point 21° F; wind 090° at 7 knots; altimeter setting 29.60 inches of Hg, and indicated that SIGMET India 3 was current. The flightcrew stated that, before the takeoff, they had received both Information Lima and SIGMET India 3.

As flight 46E taxied onto the runway to await its takeoff clearance, the local controller informed the flightcrew that, "Pilot reports severe turbulence leaving 2,500 (feet) climbing on the KNIK² off runway 6R by company (JAL/Evergreen

¹A Significant Meteorological Information (SIGMET) is a weather advisory about weather significant to the safety of all aircraft. SIGMET advisories cover severe and extreme turbulence, severe icing, volcanic ash, and widespread dust storms and sandstorms that reduce visibility to less than 3 miles.

²KNIK, a standard instrument departure route used after takeoff from runway 6R at ANC.

flight 42E) B-747." The flight engineer briefed the nonrevenue passengers concerning this reported turbulence.

The flightcrew of another Evergreen B-747, JAL flight 42E, later told investigators that as their airplane climbed through 2,000 feet they encountered several areas of severe turbulence and air speed fluctuations between 30 and 40 knots. The airplane's rate of climb decreased to between 100 and 200 feet per minute (fpm) at 3,000 feet. At 4,500 feet, the crew encountered what they termed as an "area of sink" where the airplane had a descent rate of about 1,000 fpm, despite their application of maximum climb power. The flightcrew reported four instances of momentary stall warnings that ceased before maximum power could be applied. After exiting the "area of sink," the flight experienced turbulence at a moderate level until reaching about 8,500 feet.

According to its flight plan, flight 46E was to depart ANC via the KNIK FOUR standard instrument departure (SID).³ The KNIK FOUR SID for runway 6R was as follows: "All aircraft climb as rapidly as practical through 3,000 feet. Fly runway heading until leaving 2,000 feet, or the ANC 11 DME/BGQ R-145 whichever occurs first, turn left heading 330 degrees...."

Flight 46E departed ANC about 1230. The captain was the flying pilot. The aircraft's maximum takeoff weight was 740,000 pounds, and the computed actual takeoff weight was 733,778 pounds. This weight necessitated the use of runway 6R and maximum engine thrust.

Air traffic control communications with the flight were switched to departure frequency about 1232. The first officer made the initial contact and told departure control that they were climbing out of 1,000 feet for flight level (FL) 200. Departure control issued the following pilot report, "expect severe turbulence 2,500 (reported by) heavy (Boeing) 747, smooths (sic) to moderate, continuous moderate 3,000 to 10,000." The flightcrew reported that the airplane began to encounter moderate "bumps" at 1,500 feet. The flightcrew later described the turbulence as "large wave action...with large vorticity."

About 2,000 feet, the flightcrew initiated a left 20° bank turn to a heading of 330°, as directed by the SID. While in the turn, they stated that the

³A standard instrument departure is a published IFR air traffic control procedure that provides pilots with a transition climb course from the runway environment to the en route segment of their flight.

airplane experienced an uncommanded left bank further increasing the bank angle to approximately 50°. At the same time, while the air speed was 183 knots indicated air speed (KIAS), the airspeed fluctuated about 75 knots, from a high of 245 KIAS to a low of 170 KIAS. Concurrent with these two events, the flightcrew reported a "huge" yaw, at which time the No. 2 throttle slammed to its aft stop, the No. 2 reverser indicator showed thrust reverser deployment, and the No. 2 engine electrical bus failed. Several witnesses on the ground reported that the airplane experienced several severe pitch and roll oscillations before the engine separated.

A flight of two U. S. Air Force F-15 airplanes was operating in the area, the pilots of which noticed something large fall from the B-747 as it departed ANC. The radios in the F-15s did not have the proper frequencies to communicate directly with either flight 46E or ANC tower; therefore, the pilots reported the event to the controllers at the Elmendorf Air Force Base (AFB) tower. Elmendorf AFB tower controllers telephoned the ANC tower controllers at 1234 and advised them that something had fallen off a B-747 that had just departed ANC.

Shortly after the engine separated from the airplane, the flightcrew performed the emergency checklist memory items for an engine failure. The first officer contacted ANC tower and declared an emergency. Responding to the captain's instructions, the second officer locked the leading edge devices (LEDs) down using the manual extension method and, shortly thereafter, began dumping fuel. The captain was initially unable to maintain altitude, and the airplane descended at 200 fpm to 300 fpm. The captain stated that he used emergency/maximum power on the No. 1 engine, full rudder authority, and almost full right aileron to maintain control. The flightcrew reported that the stickshaker and bank angle warnings activated intermittently throughout the remainder of the flight.

The two F-15 pilots flew close to the B-747 and inspected the damage. The pilots of the F-15s informed the Elmendorf tower that the B-747 had lost the No. 2 engine, all of the leading edge devices between the No. 1 and No. 2 engines and that the trailing edge flaps were damaged. This information was provided to ANC tower, which, in turn, notified the crew of flight 46E. The first officer acknowledged the transmission; however, when they were interviewed, the flightcrew did not remember being told of the lost engine and damage.

The captain initiated a large radius turn to the left to return and land on runway 6R. The No. 1 engine was maintained at emergency/maximum power.

While on the downwind portion of the landing pattern, bank angles momentarily exceeded 40° alternating with wings level. Manual steering was used, and the captain reported that occasionally, full right rudder application was necessary to maintain control.

The captain ordered the second officer to stop dumping fuel as the airplane turned on final approach in the vicinity of Fire Island. The landing gear was extended while the airplane was on short final. The airplane intercepted the glideslope between 500 feet and 600 feet. At 300 feet, the flaps were lowered to 25°. About 1245, flight 46E advised the tower that they were on the runway.

It is estimated that the airplane weighed about 685,000 pounds when it landed. The normal maximum certificated landing weight is 585,000 pounds. The captain taxied the airplane to the ramp area and informed the ground personnel that the brakes on the left side of the airplane were very hot. Precautions were taken to protect ground personnel from the potential danger of an explosion of the wheels and brakes due to the hot brakes.

The accident occurred during the hours of daylight, at 61°10' north latitude and 149°56' west longitude.

1.2 Injuries to Persons

<u>Injuries</u>	<u>Crew</u>	<u>Passengers</u>	<u>Others</u>	<u>Total</u>
Fatal	0	0	0	0
Serious	0	0	0	0
Minor	0	0	0	0
None	<u>3</u>	<u>2</u>	<u>=</u>	<u>5</u>
Total	3	2	0	5

1.3 Damage to Aircraft

The airplane was substantially damaged during the separation of the No. 2 engine. It is estimated that the repairs to the airplane would cost about \$12 million.

1.4 Other Damage

Several private dwellings, automobiles, and landscaping were damaged by the impact of the No. 2 engine and various parts of the engine pylon and wing LEDs. Figure 1 is a diagram of the airplane's flightpath and the wreckage location.

1.5 Personnel Information

The flightcrew was properly trained and qualified for the flight, in accordance with applicable Federal Aviation Regulations (FARs). None of the crewmembers' FAA records contained any history of accidents, incidents, or violations. The investigation revealed that the flightcrew was in general good health.

The captain, age 42, was hired by Evergreen on August 3, 1987. He holds an Airline Transport Pilot (ATP) certificate (No. 470589106), airplane multiengine land with type ratings in the Lear Jet, DC-8, and B-747. He holds commercial privileges for airplane single-engine land, rotorcraft-helicopter, and instrument helicopter.

His most recent first class medical certificate was issued on October 27, 1992, with the limitation, "Must wear corrective lenses for near and distant vision." His flight records showed that he had logged in excess of 10,000 hours of flight time, of which more than 8,000 hours were as pilot-in-command (PIC). The captain had accumulated about 750 hours in the B-747, and had flown about 138 hours in the capacity of captain of an Evergreen B-747 in the 90 days before the accident. His last simulator proficiency check was conducted on February 5, 1993, and his most recent line check was on July 31, 1992.

The first officer, age 47, was hired by Evergreen on February 2, 1991. He holds an ATP certificate (No. 1833274), airplane multiengine land with the type ratings in the B-737 and B-727. He holds commercial privileges for airplane single-engine land.

His most recent first class medical certificate was issued on August 3, 1992, with the limitation, "Holder shall wear correcting lenses for distant vision while exercising the privileges of this airman's certificate." His logbooks show that he had accumulated about 10,500 hours of flight time, more than 4,100 hours of

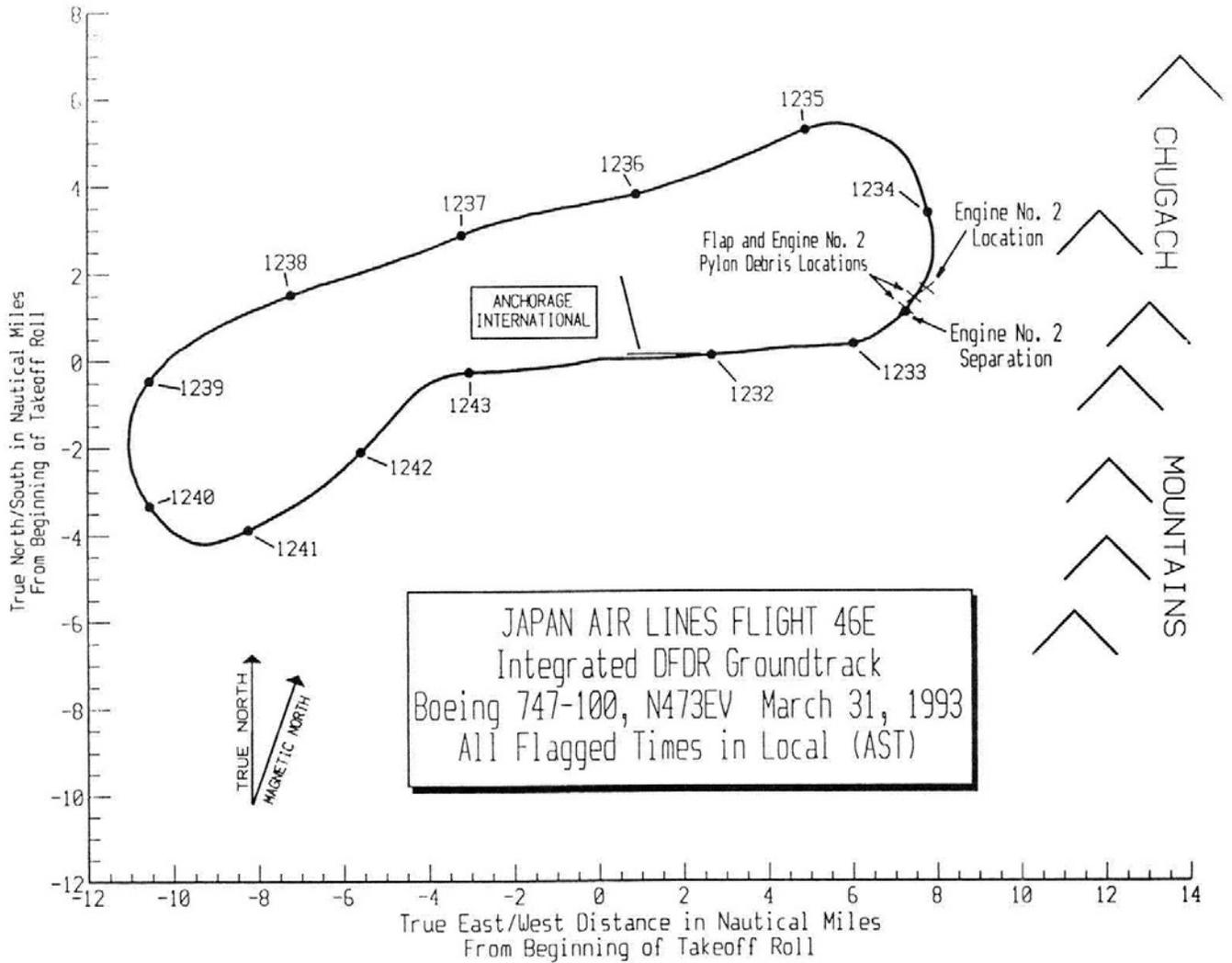


Figure 1.--Flightpath and wreckage location.

which were as PIC. At the time of the accident, he had accumulated about 600 hours in the B-747, with about 137 hours in the 90 days before the accident. His last simulator proficiency check was dated July 13, 1992, and a line check was accomplished on March 21, 1992.

The second officer, age 33, was hired by Evergreen on November 27, 1989, and holds a Flight Engineer certificate (No. 261452481) with the rating turbojet powered. Additionally, she holds a mechanic certificate with ratings for airframe and powerplant. She is not a licensed pilot.

Her most recent second class medical certificate was dated September 11, 1992, with the limitation, "Holder shall wear correcting lenses for distant vision while exercising the privileges of this airman's certificate." She has logged in excess of 2,600 hours of flight time, with 1,201 hours in the B-747. In the 90 days before the accident, she logged 115 hours in the B-747. Her last simulator proficiency check was dated September 19, 1992.

Company training records showed that the flightcrew had satisfactorily completed training in windshear recovery techniques.

1.6 Aircraft Information

The airplane, registration N473EV, was a Boeing model 747-121, serial number 19657. The airplane was manufactured in June 1970, and was originally configured to carry passengers. The airplane was acquired by Evergreen International Airlines in December 1988, and was subsequently reconfigured to carry cargo. The airplane had seating for the three flightcrew members and two observers/passengers. The airplane was equipped with four Pratt & Whitney JT9D-7 engines and appropriate equipment for IFR operations. At the time of the accident, the airplane had accumulated 83,906 flight hours and 18,387 cycles. Boeing reported that the forecasted economic design life for the B-747 is 20,000 flights, 60,000 hours and 20 years. The No. 2 engine, serial number 662812, had accumulated a total of 56,709.8 hours and 10,923 cycles since new. The engine had accumulated 5,752.5 hours and 1,200 cycles since being overhauled on March 11, 1991.

The maintenance records contained no deferred repair items regarding the No. 2. engine pylon structure. The airplane was maintained under an FAA-approved continuous airworthiness maintenance program. The last major inspection

was a "C/D" check performed on April 3 to September 4, 1992; a "B" check was completed on September 9, 1992; and an "A" check was completed on March 3, 1993. The maintenance logs had no reports of severe engine vibration on the No. 2 engine. Sections of the engine pylons were inspected during these various checks.

The airplane was equipped with a Sunstrand Data Control Mark VI-J4 ground proximity warning system (GPWS). In addition to providing GPWS alerts, this system provides windshear caution, windshear warning, and bank angle warning. The system derives its information from the MK VII Warning Computer, No. 1 Radio Altimeter, No. 1 Air Data Computer, the navigational radios selected for the captain's instruments, the stall warning system, the No. 1 inertial navigation system (INS), and the landing gear and flap indication systems. The system provides windshear warning and cautions between 5 feet and 1,500 feet during the initial takeoff and between 1,500 feet and 30 feet during the final approach phases of flight.

The bank angle advisory indicates a roll attitude that is excessive for the flight condition. The advisory consists of the aural message "BANK ANGLE - BANK ANGLE." Generally, above 1,500 feet, the callout occurs at 40° of bank. The callout occurs again if roll attitude increases by 20 percent. When roll attitude increases to 40 percent above the initial callout angle, the callout repeats continuously. Below 1,500 feet, the callout angle is reduced progressively.

The windshear caution or windshear warning did not activate because the turbulence encounter occurred above 1,500 feet, which is outside the warning envelope of the system. The system did provide bank angle warnings during the turbulence encounter.

1.7 Meteorological Information

1.7.1 General

At 1255, the reported surface weather observation taken at ANC was as follows:

Clouds--Estimated ceiling 8,000 feet broken, 20,000 feet overcast;
Visibility--60 miles; Temperature 49° F; Dew point 20° F; Wind--
100° at 13 knots; Altimeter setting--29.59; Remarks--showers to the
southeast and southwest.

The 1254 surface weather observation at Merrill Field, which is about 5 nautical miles (nmi) northeast of ANC, was:

Clouds--6,000 feet scattered, 8,000 feet scattered; estimated ceiling 18,000 feet broken; Visibility--50 miles; Temperature 51° F; Dew point--18° F; Wind--060° at 9 knots; Altimeter setting--29.58.

The 1255 reported surface weather at Elmendorf AFB, which is about 8 nmi northeast of ANC, was:

Clouds--5,000 feet scattered, 8,000 feet scattered, estimated ceiling 18,000 feet broken; Visibility--50 miles; Temperature--50° F; Dew point 21° F; Wind--030° at 17 knots, gusting 22 knots; Altimeter setting 29.57; Remarks--wind direction 180° variable 040°; peak wind estimated 350° at 32 knots.

The 1255 recorded surface weather observation at Fort Richardson, which is about 12 nmi northeast of ANC, was:

Clouds--5,000 feet scattered, 8,000 feet scattered, estimated ceiling 18,000 feet broken; Visibility--15 miles; Temperature--47°F; Dew point 21° F; Wind--110° at 23 knots, gusting 36 knots; Altimeter setting 29.57. At 1308, Fort Richardson reported the wind to be from 110° at 23 knots gusting to 45 knots.

A wind warning for the Turnagain Arm and the Anchorage Hillside was issued at 1000 by the National Weather Service (NWS) forecast office at ANC. The warning called for gusty easterly winds to 60 miles per hour (mph) along the upper Hillside and near Turnagain Arm.

The Area Forecast (FA) issued by the NWS at 1145 and valid until 2400 was as follows:

Cook Inlet and Susitna Valley--Scattered ceilings below 1,000 feet and visibility below 3 miles, light rain, light snow, fog southern entrance and along west side southern inlet. Otherwise 3,500-5,000 feet broken west side sloping 7,000 feet scattered-broken with scattered layers above along east side. Wind east

northeast 45 knots local strong gusts southern inlet and from passes and channels along east side.

The turbulence alert, SIGMET India 3, was issued at 1145 and was valid until 1545. This SIGMET provided that moderate and frequent severe turbulence could be encountered from the surface to 12,000 feet and that moderate and frequent severe mountain wave turbulence could be encountered from 12,000 feet to 39,000 feet within an area bounded by Bethel, Johnstone Point, Sitkinak Island, and Dillingham, Alaska.

The area encompassed by this advisory did not include ANC. The northern extent of the area was about 36 nmi south of ANC. A correction to SIGMET India 3 was made at 1342 adding McGrath (MCG) to the list of locations describing the advisory area. The resulting advisory area included ANC. According to an individual of the NWS forecast office at ANC, the delay in issuing the correction (about 2 hours) was due to the workload. The delay caused the omission of MCG from the SIGMET location points to go unnoticed.

In-flight weather advisory (AIRMET) Tango was issued by the NWS forecast office in Anchorage at 1145 and was valid until 1800. AIRMET Tango indicated that moderate turbulence below 12,000 feet, with scattered severe turbulence within 3,000 feet above ground level, could be encountered. The AIRMET also provided that there was a low level windshear potential associated with the strong low level winds.

The aviation forecaster on duty at the NWS forecast office at ANC at the time of the accident stated that turbulence east of the airport was not an infrequent event in the presence of a strong easterly flow near mountain top level. He believed that in addition to the strong easterly flow, the turbulence was increased by an upper level trough moving through the area, which, coupled with heating, made the atmosphere unstable. He stated that he did not remember previously seeing as many severe turbulence pilot reports as he saw that afternoon. He had been a forecaster at ANC for 18 months.

The deputy meteorologist-in-charge (DMIC) of the NWS forecast office at ANC stated that the turbulence generated by an easterly flow over the Chugach Mountains occurred fairly frequently--about 15 times per year. He stated that the events occur most often in the fall through the spring but that they can occur anytime. He believed that the large-scale weather features that generate the

turbulence are well forecasted by numerical models. He further stated that these events can last from 6 to 10 hours to several days. He stated that the most turbulent volume of air is close to the mountains east of the airport. The DMIC characterized the event of March 31 as "garden variety." He stated that an event in December 1992 produced 110 plus knots of wind on the ground near the mountains.

The DMIC stated that there are two physical mechanisms for turbulence near the airport: mechanical turbulence, which results from the disruption of air as it moves over a rough surface; and mountain wave turbulence, which results from energy being transported away from the Earth's surface in the form of a wave and released some distance above or downstream from the point of energy input. The DMIC had been at the forecast office since 1978.

In October 1993, a WSR-88D radar system was installed at ANC, as part of the next generation weather radar (NEXRAD) program. The WSR-88D system is an advanced doppler weather radar system that will allow winds and turbulence in the atmosphere to be measured. This system can be used to forecast and detect turbulence and to increase the understanding of mountain flows. The NEXRAD program is a joint agency program involving the Departments of Defense, Commerce, and Transportation to develop, procure, and deploy an advanced weather surveillance radar. A network of WSR-88 systems will be deployed throughout the United States and selected overseas sites.

Several private individuals measured strong winds at the surface during the afternoon in the area east of ANC. Measured wind speeds varied from about 34 knots to a peak gust of 62 knots. The 62-knot gust was measured about 10.5 miles southeast of ANC. One individual estimated gusts of 75 to 80 mph at his home, about 7 miles north-northeast of ANC, just prior to seeing the accident aircraft. Another individual, also located about 7 miles north-northeast of ANC, reported a funnel of rotating debris, consisting of garbage cans and paper building supplies that rose to a height of at least 500 feet to 1,000 feet in the air between about 1215 and 1230.

NWS data indicates that strong windstorms are not a rare occurrence for east Anchorage and the foothills of the Chugach Mountains. Typically, the destructive winds are confined to eastern Anchorage in the foothills of the mountains. Ten to fifteen times a year winds reach 40 mph. About three to five times a year wind speeds exceed 70 mph. Most windstorms result from gap winds produced by strong pressure gradients across the Chugach Mountains. Some of the

strongest winds near the mountains are induced by standing mountain waves. Synoptic situations conducive to strong southeast winds in Anchorage are well documented in station studies. The pattern consists of high pressure over the eastern Gulf of Alaska combined with a strong low pressure and occluded front west of Anchorage, near Bristol Bay. The preferred track of low pressure areas associated with strong windstorms is from south of Kodiak Island toward the southwest Alaskan mainland. A review of the 0900, 1200, and 1500 NWS surface analyses showed that these conditions existed.

Upper air data from Anchorage for 1500 showed a strong easterly flow from the surface up through 6,000 feet. The maximum windspeeds reached 55 knots.

1.7.2 Pilot Reports

Several other pilots reported severe turbulence encounters about the time of the accident. At 1210, a pilot of a B-747 reported severe turbulence at 2,500 feet and moderate turbulence between 3,000 feet and 10,000 feet during the climbout to the north. At 1311, the pilot of a DC-8 reported severe turbulence during a climbout to the north at 2,000 feet over ANC. He reported that the airplane experienced severe low level wind shear with air speed fluctuations of +/- 35 knots.

The pilot of a U.S. Marshall Service Cessna 310 reported that he took off from runway 15 at Merrill Field on a maintenance flight about 1200. About 300 feet above the ground, the airplane encountered a downdraft and the airplane's air speed went from 120 knots to 90 knots, and the airplane lost about 200 feet of altitude. After the airplane exited the downdraft, the pilot stated that he turned the airplane to a heading of 120° and climbed to 900 feet. Shortly thereafter, the airplane encountered an updraft. The pilot reported that the airplane's vertical velocity indicator pegged the needle at 4,000 fpm upward and that despite reducing the throttles to idle, he could not keep the air speed below 160 knots. The pilot stated that as he maneuvered the airplane back to the airport for landing, the airplane encountered severe turbulence with 50-knot variations in air speed. The pilot concluded his written report with, "in 20 years of flying up here, this was the worst turbulence I have encountered, and it was the first time I have ever wondered if I would make it back because, at times, I was not really flying this aircraft."

1.8 Aids to Navigation

There were no reported difficulties with the navigation aids at the time of the accident.

1.9 Communications

There were no reported or known air-to-ground communications difficulties. However, as previously stated, the pilots of the F-15 airplanes who saw the engine fall from the B-747 and later accomplished an in-flight inspection were unable to communicate directly with the flightcrew of the B-747. This communication problem arose because the F-15's UHF radios could not be used to communicate with the VHF-equipped civilian airplanes. The F-15 pilots were able to relay information to the crew of the B-747 via the local controllers at the Elmendorf AFB tower, who telephoned the ANC tower.

1.10 Aerodrome Information

ANC is 4 miles southwest of Anchorage, Alaska, at an elevation of 144 feet. The airport is certified under 14 CFR Part 139. The airport has three runways: 14/32, which is 10,496 feet long; 6L/24R, which is 10,300 feet long; and 6R/24L, which is 10,897 feet long. All runways are 150 feet wide. Noise abatement procedures were in effect for areas to the south and east at the time of the accident.

1.11 Flight Recorders

The airplane was equipped with a digital flight data recorder (FDR) and a cockpit voice recorder (CVR). The FDR was a Lockheed Aircraft Service Company model 209, serial number 378. The CVR was a Fairchild model A-100, serial number 1766. Both recorders were returned to the Safety Board's laboratory and were found to have operated during the event. The FDR recorded 32 parameters. See appendix B for a transcript of the CVR. Additionally, the FDR from flight 42E was returned to the Safety Board's laboratory and was found to have operated throughout the takeoff from ANC.

1.12 Wreckage and Impact Information

Damage to the airplane consisted of the loss of the No. 2 engine and its pylon and the loss of most of the left wing LEDs between engines Nos. 1 and 2. During the investigation, the fuse pins holding the engine pylons to the wings were removed from the airplane. The two midspar fuse pins for the No. 2 engine were found to be deformed. The aft diagonal brace fuse pin was fractured. The inboard midspar fuse pin for the No. 1 engine was found to be substantially deformed. None of the other fuse pins on the airplane had any indications of damage or deformation. Relatively small areas of impact damage were also noted on the wings and trailing edge flaps. The No. 2 engine, all portions of the No. 2 engine pylon, and most of the leading edge structure between the No. 1 and No. 2 engines were recovered.

1.12.1 Pylon Structure

The B-747 engine pylon is essentially two closed-cell box beams with reinforcements at appropriate intervals. The pylons are held to the wing by the upper link (at the forward top of the pylon), by the diagonal brace (at the aft end of the pylon), and by the midspar fuse pins. There is also a side brace between the midspar fuse pins from the wing diagonally to the pylon. The engines are held to the pylon at the front mount bulkhead, at the rear mount bulkhead, and through the thrust link near the aft end of the engine. The thrust link connects to the pylon aft lower spar. The pylon midspar progresses forward and slightly downward from the midspar fuse pin fittings, then continues horizontally as the forward firewall to the forward engine mount. The primary components of the midspar are the inboard midspar chord, the outboard midspar chord, and the web between the chords. Figure 2 depicts the pylon structure.

1.12.2 Damage to No. 2 Engine Pylon

The No. 2 engine pylon was separated into four pieces as a result of three principal fracture areas. These fractures were located just aft of the forward engine mount bulkhead, along a jagged vertical plane aft of the rear engine mount bulkhead, and around the inboard midspar fuse pin fitting. The two forward pieces of the pylon remained attached to the engine through the forward and rear engine mounts. Examination of the fractures around the perimeter of the break aft of the forward engine mount bulkhead revealed features typical of overstress separations, with the exception of a small, flat fracture region in the firewall web.

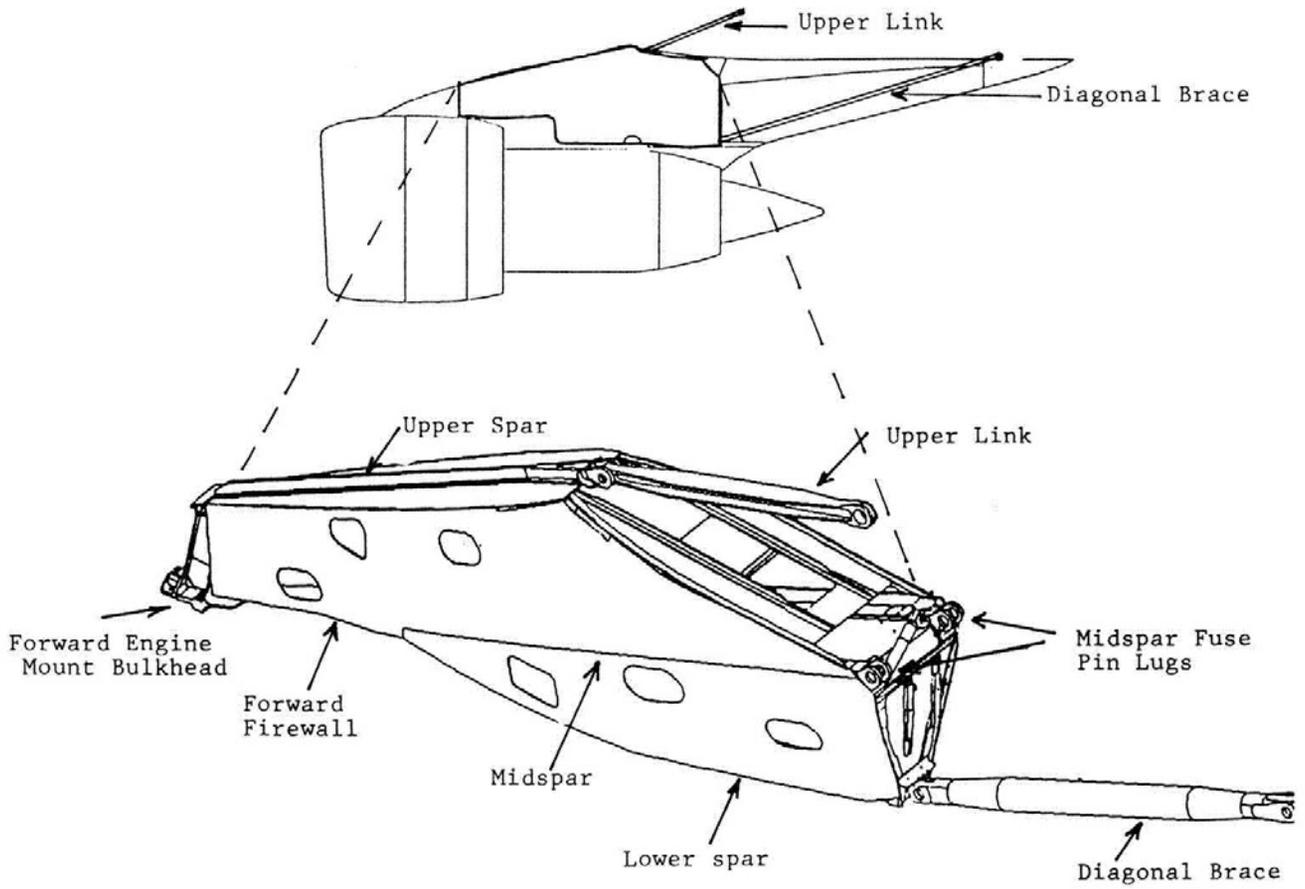


Figure 2.--Pylon structure.

The flat fracture area was approximately in the middle of the web, on the outboard side of the web centerline. The fracture was a lateral fracture about 2 inches long through the thickness of the web and was aft of the third transverse stiffener behind the forward engine mount bulkhead. The location of this fracture area is indicated in figure 3. Investigators cut the flat fracture area from the remainder of the firewall and examined it in detail with a bench binocular microscope and a scanning electron microscope. The mating fracture faces had been heavily rubbed. Despite the rubbing, isolated areas of fatigue striations, indicative of through-the-thickness propagation, were noted. Compression buckling of the firewall web extended from the fatigue crack area forward to the outboard side of the pylon at the second transverse stiffener. Inspection of the other three pylons on the airplane found no similar cracks.

The pylon piece that remained with the portion of the pylon that was attached to the wing had a 3-inch-long fatigue crack in the midspar web. The fatigue crack area was not on the fracture surface that separated the web into two pieces, but was on a crack that extended into the web where it was held between the jaws of the inboard midspar fitting. Nearly all of this fatigue crack was on a portion of the web that was sandwiched between other structure. The plane of cracking in the fatigue area was oriented 45° to the fore-and-aft direction, consistent with propagation under shear loading of the web.

The inboard midspar fuse pin was removed and was found slightly deformed from excessive contact with the wing fitting. The crescent shaped deformation was on the forward side of the inboard shear plane, extending about one quarter of the circumference of the pins and centered between the 8:00 and 9:00 positions, looking inboard. The location of the deformation on this pin is consistent with movement of the forward end of the pylon in the outboard direction, coupled with the pylon structure exerting a load in the forward direction on the pin.

The outboard midspar fuse pin was also removed and was excessively deformed from heavy contact with the wing fitting. The deformation was on the aft side of the outboard shear plane, centered around the 2:00 position looking inboard. The location of this crescent shaped deformation was consistent with movement of the pylon to the outboard direction, coupled with the pylon structure exerting a load in the aft direction on the pin.

The fuse pin from the underwing fitting for the diagonal brace was the only one that was found broken. This pin was sheared at the inboard shear

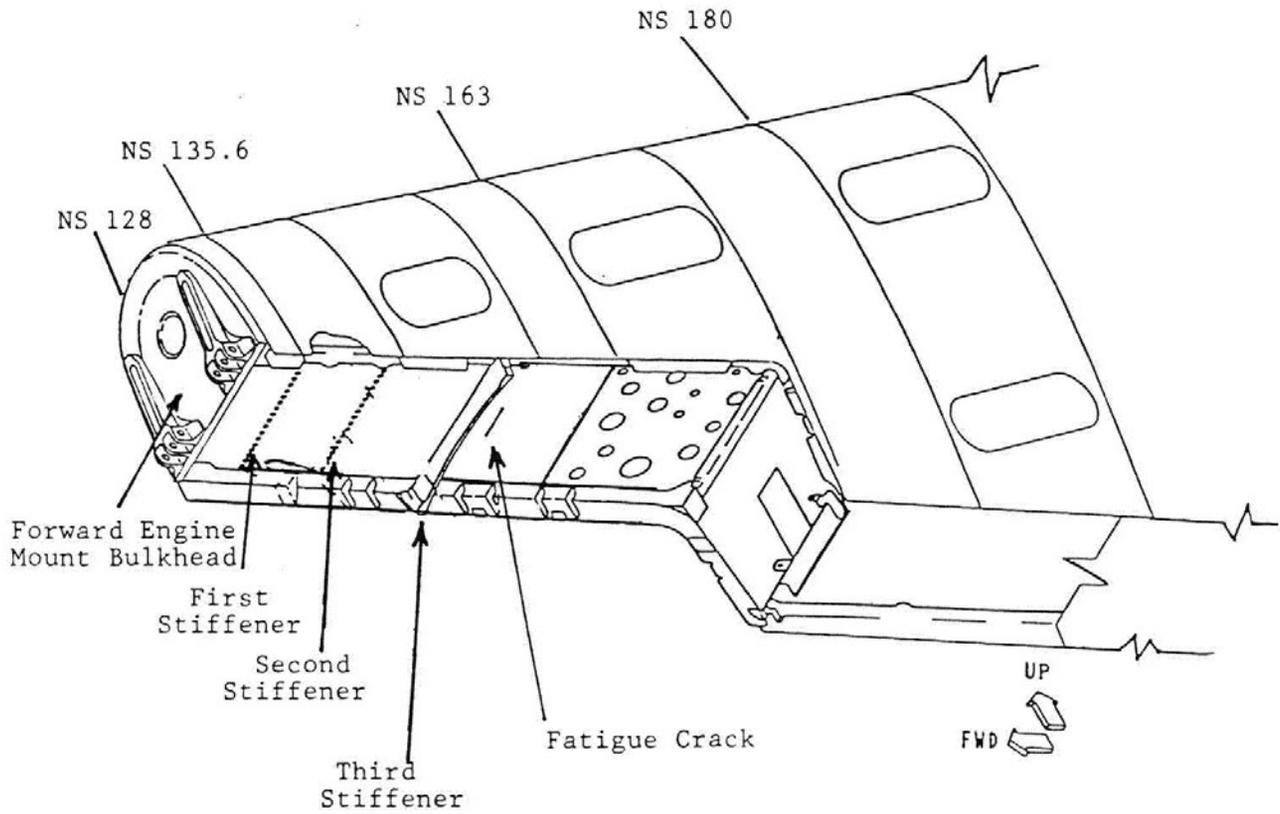


Figure 3.--Flat fracture area.

plane. The outboard (longer) portion of the pin was cocked within the underwing fitting. The inboard piece of this fuse pin was recovered on the ground near the aft portion of the pylon. The fuse pin retainer bolt was fractured; both pieces of this bolt were found within the fairing below the underwing fitting. The fractures on the fuse pin and retainer bolt appeared typical of overstress separations.

The investigation found that all of the remaining fractures and buckling of the structure were consistent with deformation of the pylon structure in an outboard and upward direction. Examination of the other fracture surfaces disclosed no evidence of preaccident damage or cracking. All separations, except where previously noted, appeared typical of overstress separations.

Selected sections from the primary structures of the pylon were returned to the Safety Board's materials laboratory for examination. The material from the sections was found to be within applicable manufacturer's specification requirements for composition, conductivity, and hardness.

1.12.3 Left Wing Structure

All of the entire upper surface fixed leading edge panels from approximately inboard leading edge station (ILES) 695 to ILES 930 on the left wing were missing (see figure 4). The wing leading edge "D" beam and thermal anti-ice duct from ILES 695 to ILES 930 on the left wing were missing. The leading edge variable camber (VC) flaps Nos. 7, 8, 9, and 10, including their drive motors, torque tubes, and 50 percent of all the linkage had been torn from the wing. Additionally, all of the leading edge flap support ribs were either missing or partially missing in this area.

The pneumatic duct was pushed against the wing front spar and was crushed and separated in three places. The lower fixed leading edge panels were intact; however, their forward edges were bent upward over most of the span between the No. 1 and No. 2 engines.

One VC flap was recovered nearly intact; however, its preaccident position could not be determined. Portions of one or more VC flaps were found, including segments of the VC flap folding nose. All the VC flap drive motors, most of the leading edge VC flap support ribs, and portions of the D beam and thermal anti-ice duct were found. However, only small portions of the fixed leading edge



Figure 4.--Left wing damage.

upper panels were found and the outboard power drive unit was still attached to the airplane. The inboard power drive unit was missing.

The D beam and thermal anti-ice duct portions, as well as many of the VC flap folding nose sections, were crushed and appear to have been struck by a large, heavy object. The recovered VC flap portions were split in the spanwise direction. The leading edge flap support ribs were broken near the front spar's upper chord attachment and the rib post lug tension tube attachment. The appearance of these fractures and the position of the rib portions that were still attached to the front spar were consistent with an upward and outboard motion of the object that impacted the structure. The VC flap linkage parts that were recovered exhibited compression and torsion damage that was also consistent with this motion. Some parts of the wing's upper surface fixed leading edge honeycomb panels smelled of fuel. A puncture in the No. 4 spoiler was consistent with an object that entered on the upper surface and exited on the lower surface, when the spoiler was deployed. The remaining punctures, gouges, and dents were typical of impact with small objects.

Other damage was found on the wing's trailing edge outboard fore, mid, and aft flaps, inboard aft flap outboard corner, spoiler No. 4, the lower fixed trailing edge panel aft of the "sailboat" fairing, and the left side of the lower rudder. This damage consisted of punctures and tears. Dents, scrapes, and scratches were found on the left wing upper and lower skin panels as well as on the left stabilizer leading edge. Figure 4 shows the damage to the leading edge of the wing.

1.12.4 No. 2 Engine

The No. 2 engine came to rest with its horizontal axis parallel to the ground on its 7:30 to 8:00 positions (aft looking forward). The inlet duct, one of two fan cowls, both fan reverser sleeves, the tail pipe and exhaust plug remained with the engine. The section of pylon forward of the rear engine mount remained with the engine. All four reverser ballscrew actuators remained attached to the engine and were in the fully stowed position.

The engine sustained external radial impact damage from its 6:00 to 9:00 arc throughout its length. All fan exit case struts were fractured, which separated the fan case from the core engine. Several engine case flanges were fractured, which exposed some of the internal components of the engine.

Additionally, the low pressure turbine (LPT) case was cracked circumferentially through approximately 180° of arc at the 4th stage.

There was no evidence of blade or disk separations prior to the accident. There was no evidence of fire on the engine outer cases or nacelle components. All engine components except the starter air valve were found either attached to the engine or at the impact site. The starter showed no evidence of overspeed or failure. There were no metal particles in the main oil filter element.

A section of nose stringer folding fairing support from the left wing leading edge flap was found embedded in the turbine exhaust sleeve at the 4:00 to 4:30 position. The section of stringer penetrated the tail pipe at an oblique angle radially inward and forward toward the centerline of the engine. The piece of stringer was about 23 inches long by 4.5 inches wide.

The engine thrust frame was intact and remained attached to all of its attachment brackets. The mounting brackets between the thrust frame and intermediate case had pulled free, deforming and fracturing the bolts, bolt holes, and the flange. The forward engine mount was intact and remained attached to the fan exit case. The rear engine mount was also intact.

A new fan blade rubstrip had been installed when the engine was overhauled in March 1991. The on-scene inspection of the fan rubstrip disclosed evidence of both new and old fan tip rubs. The heaviest rub removed enough material to reach the bottom of the axial skewed grooves but did not penetrate to the metal case. As examined, the fan case was ovalized with the long axis passing through the 5:00 to 11:00 positions, aft looking forward. Fresh fan tip rub marks ran through 240° of arc, around the top of the fan case beginning at 8:00 and ending at approximately 4:00. Additional damage to the rubstrip material included gouging, chipping, and cracking.

The low pressure compressor (LPC) blades had no rotational damage or any leading or trailing edge damage. The LPC 2nd stator rubber rubstrip did not reveal any rub. The blades were visible at 5:00 and 10:00, and the rubstrip was visible at 6:00 behind the fan. The 3rd and 4th stage blades and vanes, which were visible through a split in the intermediate case at 5:30, had no rotational damage or leading or trailing edge damage.

Some of the high pressure compressor (HPC) blades and stators could be viewed through the 10th stage bleed ports. The trailing edges of the 12th stage HPC blades were not damaged. However, the airfoils that were visible were bent tangentially, just above the blade platform, opposite the direction of rotation. Examination of the 15th stage HPC stator at the 4:00 and 9:00 positions revealed no damage or metal spatter. However, there was a cut circumferentially around the center of the outer air seal honeycomb consistent with rubbing of the blade tip knife edge.

The high pressure turbine 1st stage vanes showed no evidence of excessive temperature, metal spatter, or gas path distress. The 4th, 5th, and 6th LPT stage vanes and blades exhibited no leading edge or trailing edge damage or metal spatter. The 6th and 5th stage LPT outer air seals were not damaged.

1.12.5 Damage to Flight 42E

A severe turbulence inspection of flight 42E, the Evergreen sister ship that departed about 5 minutes prior to flight 46E, was accomplished after it landed at John F. Kennedy International Airport. The inspection indicated that the midspar fuse pins for the No. 2 engine were slightly deformed. No other damage was found during the inspection. Subsequent inspection of the forward firewall webs found no evidence of cracks.

1.13 Medical and Pathological Information

The flightcrew and the mechanics who had worked on the airplane before the flight volunteered to be tested for the presence of alcohol and licit and illicit drugs. All of the test results were negative.

1.14 Fire

There was no evidence of an in-flight fire prior to the separation of the No. 2 engine. Several witnesses on the ground reported seeing a flash or ball of fire as the engine separated from the airplane. There were no reported fires on the ground as a result of falling debris. Persons who first saw the engine after it struck the ground reported steam rising from the engine. Firemen from the Anchorage Fire Department sprayed water on the engine to prevent a possible fire.

1.15 Survival Aspects

Not applicable.

1.16 Tests and Research

1.16.1 Metallurgical Examination

The two fatigue cracks that were found in the No. 2 engine pylon structure were subjected to metallurgical examinations. One of the fatigue cracks was a lateral fracture about 2 inches long and was in the web of the pylon forward firewall, just aft of the third transverse stiffener behind the forward engine mount bulkhead. This fatigue crack was lateral to the web. Although most of the features of this crack had been obliterated by rubbing, a few isolated areas of fatigue striations were found. The orientation of the striations indicated that the cracking propagated through the thickness of the web. The web material (nickel alloy) and construction appeared to comply with specification requirements. There was no evidence of damage or defects that may have contributed to initiation of the fatigue cracking.

The pieces of the midspar web from near the aft end of the web (the area adjacent to the midspar fittings) had been deformed into a wave shape, consistent with compression buckling. A fatigue crack was found in this portion of the web, on the only piece of the pylon structure that remained attached to the wing. Almost the entire length of this crack was sandwiched between portions of the inboard midspar fitting and other pieces of structure at the aft end of the midspar. The plane of cracking was oriented 45 degrees to the fore-and-aft direction, consistent with propagation under tensile stresses from shear loading of the web. The cracking initiated from both sides of a fastener hole. Additional disassembly of the inboard midspar fitting and complete removal of the web piece showed extensions of the fatigue cracking. The overall length of the fatigue cracking area, including the extensions, was about 3.0 inches. The web material (aluminum alloy) and construction (three layers) appeared to comply with specification requirements. There was no evidence of any damage or defects that may have contributed to initiation of the fatigue cracking.

An X-ray energy dispersive spectroscopy (EDS) examination was accomplished on the thick, dark deposit on the center web sheet on each side of the fastener hole. That examination generated spectra consistent with the spectra

generated from sealant (BMS 5-95) found nearby. During the examination of the crack, sealant was removed from the portion of the fatigue crack on the forward-inboard side of the fastener hole.

Metallurgical examination of the fracture in the fuse pin from the aft end of the diagonal brace revealed features typical of a direct shear overstress separation. The retention bolt for this pin was fractured as a result of excessive bending and/or shear loads.

The inboard midspar fuse pin from the No. 1 engine of the accident airplane had a crescent shaped circumferential distortion on one of the shear planes.⁴ The maximum amount of this displacement from one side of the damage area to the other was 0.0664 inch. No evidence of cracking was found on the pin.

The inboard and outboard midspar fuse pins from the No. 2 engine of JAL flight 42E, N481EV, were also examined in the laboratory. The inboard and outboard ends of the pins and their vertical alignment had not been requested before the pins were removed, and this information was therefore not available. Examination of the fuse pins revealed that one of the shear planes on each pin contained a slight deformation. Although the deformation was not discernible when the pins were viewed with the unaided eye, the deformation could be noticed by tactile examination along the shank of the cleaned pin. Using an optical comparator, it was estimated that the maximum offset in the surface of the pin from one side of the deformation to the other was between 0.002 inch and 0.003 inch on both pins.

Hardness measurements were conducted on a section cut from the fractured fuse pin from the accident airplane and on sections cut from the two fuse pins from N481EV. The average of the hardness measurements taken in the laboratory was within the manufacturer's specifications.

1.17 Additional Information

1.17.1 Maintenance Records

The maintenance records for N473EV were examined at Evergreen's corporate headquarters in McMinnville, Oregon. This examination included a

⁴Because the orientation of the pin was not documented when it was removed, it was not determined which was the inboard end of the pin or how the pin may have been aligned in the fitting.

review of flight log entries, nonroutine work order cards, work order cards generated by all levels of routine checks and inspections, engineering orders, engineering changes and repair authorizations, mechanical reliability report files, airworthiness directive (AD) tracking sheets, major alteration record lists, engine logs, engine status reports, and engine trend monitoring sheets.

The maintenance records indicate that N473EV was modified to carry cargo in 1989. The cargo handling system installation included modification to the floor structure and to the fuselage structure around the cargo door area, but did not alter any wing or pylon structure. The aircraft was maintained under contract by Pan Am until July 23, 1990. Following termination of the contract, Evergreen assumed full maintenance responsibility for the airplane.

Pan Am's last major Service Option Check/Inspection of N473EV (equivalent to Evergreen's "D" check) was completed in 1986. Evergreen performed a C/D check from April 3 to September 4, 1992, completed a "B" check on September 9, 1992, and an "A" check on March 3, 1993. There were no deferred maintenance items regarding the No. 2 engine pylon structure, and no recent maintenance had been accomplished on the structure. Inspection of the engine maintenance logs found no reports of severe engine vibration on the No. 2 engine, and there were no reported surges of the No. 2 engine since its last overhaul in March 1991.

The records did not reveal any previous encounters with severe turbulence. The three major alterations/repairs involving the wing were either far outboard of the strut wing station, or were performed on the right wing. Two overweight landings had been recorded since the aircraft was put into service with Evergreen. In both cases, an inspection of the airplane was accomplished in accordance with the Boeing Maintenance Manual.

The midspar fuse pins were replaced on January 14, 1993, as part of compliance with AD 93-01-05. At that time, the aircraft had accumulated 83,262.8 hours and 18,280 cycles.

A "D" check was started in April 1992 and completed in September 1992. During the check, a structural inspection was performed on the No. 2 engine pylon. The inspection procedures called for the notation of any structural irregularities, corrosion, loose or missing fasteners, cracks, bulges, deformities, and delaminations. This check specifically called for "...inspection of

the torque bulkhead, particularly in the area of the midspar fittings and diagonal brace fittings."

During the "D" check, two cracks were found in the skin on the bottom of No. 2 pylon, just aft of the aft engine mount thrust link. The cracks were stop-drilled, and two doublers were fabricated and installed. A third crack was found on the diagonal brace upper end outboard clevis lug bushing. The diagonal brace and lug were subsequently replaced. A fourth crack was found 6 inches from the aft end of the outboard bottom edge of the No. 2 pylon internal lower angle. A new internal lower angle was fabricated and installed. Additionally, numerous loose and missing rivets were discovered on the No. 2 engine pylon to bottom wing leading edge.

During a "B" check performed in November 1990, the entire No. 2 engine pylon was removed from the wing. During the time in which the pylon was removed, extensive inspection and repair work was accomplished on the pylon and its fittings. These maintenance actions included the inspection and rework, as necessary, of the upper link forward lug, the diagonal brace lug, and the midspar attach fitting horizontal clevis; replacement of the upper link fuse pins; inspection of the forward engine mount bulkhead structure; replacement of the forward support fitting bolts; rework of the rear engine mount bulkhead fitting; and rework of the midspar outboard attach fitting and the inboard pylon attach fitting. The forward engine mount bulkhead had been modified in accordance with AD 82-22-02 in order to prevent cracking in the firewall web near the bulkhead.

Examination of the maintenance records indicated that all ADs applicable to the engine pylon had been accomplished. No "open" maintenance writeups, or writeups closed without documented action, were discovered during the records review.

An Evergreen maintenance records representative stated that the pylon forward web area would be inspected during a "D" check. The review of the accident airplane's maintenance work cards revealed that the last heavy inspection was accomplished during the "D" check. Inspection of the No. 2 engine pylon occurred between April 7, and 24, 1992. The maintenance work cards revealed no specific instructions to inspect the fourth bay of the forward midspar web between nacelle station (NS) 151 and 163. (The forward midspar web extends from NS 128 to 180.) In addition, the work cards did not contain instructions to inspect the forward midspar web between NS 128 and 151. The work cards did recommend a visual inspection of the web directly aft of the fourth bay between NS 163 and 180.

The work cards also recommended a thorough visual inspection of the adjacent pylon external skin near the forward firewall between NS 128 and 180.

At the time of the accident, the B-747 Maintenance Manual did not address inspection of the pylon forward firewall web where the fatigue crack was found on the accident airplane. Boeing had previously issued a service bulletin (SB) on February 14, 1986, for operators to inspect for fatigue cracking of an adjacent lower spar web, located aft of NS 163, at NS 216. The SB reported an operator experiencing "two cracks on one airplane approximately 6 inches long in the aft lower spar web of pylon No. 1, after 8,500 flight-hours."

Following the accident, on September 9, 1993, Boeing issued SB 747-54-2160, which called for a detailed visual inspection of the horizontal firewall from NS 135.6 through NS 163 of the inboard engine pylons on B-747 airplanes powered by JT9D-3A or -7 series engines. The SB provides that airplanes with over 15,001 flight cycles should be inspected within 6 months of the release of the service bulletin. Airplanes with between 6,001 and 15,000 flight cycles should be inspected within 12 months, and airplanes with less than 6,000 flight cycles should be inspected at 6,000 flight cycles or within 12 months, whichever is later. There have been no operator reports of finding cracks in the forward web as a result of the inspections from this service bulletin. Additionally, following the accident Boeing requested selected operators of high time B-747s to inspect their airplanes for cracks in the forward web. Boeing reports that the operators found no evidence of cracking.

1.17.2 Evergreen Turbulence Encounter Procedures

The Operating Procedures section of the FAA-approved Evergreen General Operations Manual provides flightcrew procedures in the event of an encounter with turbulence. The section contains a statement that instructs pilots to make reasonable efforts to "avoid flight areas of excessive turbulence" for passenger comfort and possible structural damage. The remainder of the section contains classifications of turbulence, followed by "general rules that apply to flying in turbulent areas." The Operational Control section of the manual gives the PIC the authority to delay, divert, or discontinue a flight for safety considerations.

After this accident, the Operating Procedures section was supplemented by a Flight Crew Letter. This letter contains a Turbulence Reporting Criteria Table, a request for Pilot Reports (PIREPs), and a definition of microburst,

and it directs pilots to the turbulence information in the operations manual. Both the operations manual and the Flight Crew Letter are oriented towards avoiding in-flight turbulence, flying through turbulence, and the reporting of turbulence. Neither the operating manual nor the letter discuss the suspension of operation for windshear or reported turbulence.

1.17.3 Acceleration Data

The flight recorder data from JAL/Evergreen flights 46E and 42E indicated that both airplanes encountered moderate to severe turbulence shortly after they departed ANC. Flight 42E encountered increased levels of turbulence between 2,000 feet and 9,000 feet. In addition to the continuing turbulence, the airplane encountered even greater levels of turbulence at four separate times. The increased turbulence occurred while the airplane was between 3,500 feet and 4,500 feet. Increased activity was noted in roll, heading, pitch, and the accelerometer (vertical, longitudinal, and lateral) data.

The acceleration data recovered from the FDR show that the dynamic loads at the center of gravity (CG) were vertical 0.5 G to 1.8 G;⁵ lateral +/- 0.25 G; and longitudinal 0.1 G to 0.3 G. It is possible that acceleration loads were greater than indicated by the recorded data. The acceleration data is sampled at four times a second, allowing sufficient time intervals for greater accelerations to occur without being sampled.

Flight 46E encountered increased levels of turbulence above 2,000 feet. At about 2,800 feet, the airplane experienced a 50-knot loss of airspeed, a negative 0.5 vertical G, and a 300 feet to 400 feet net loss of altitude. The airplane twice encountered even greater levels of turbulence. The first time was about 10 seconds before the engine/pylon separation, and the second was when the engine and pylon separated. The recorded data indicated that the No. 2 engine and pylon separated about 3,400 feet and the airplane initially descended to about 1,500 feet for the return to ANC.

The FDR data from both airplanes were not significantly different, and all parameters appeared to be within the normal range for safe operation. The climb rates were similar, and the air speed of flight 42E was 10 knots to 20 knots less than

⁵A G is a unit of acceleration equal to the acceleration of the Earth's gravity, used to measure the force on a body undergoing acceleration, and expressed as a multiple of the Earth's acceleration.

flight 46E at the times of encounter with the greater levels of turbulence. Typical air speed changes were about 20 knots for flight 42E and about 30 knots for flight 46E. About 40 seconds prior to the engine separation, flight 46E encountered the previously mentioned 50-knot decrease in air speed, and the other recorded parameters did not show significant deviations. The magnitudes of vertical accelerations and rates of change of acceleration were slightly greater on the accident airplane as were the magnitudes of lateral acceleration and rates of change of acceleration. In addition, the rudder was more active on the accident airplane, moving left and right to the limits of the yaw damper command more often and more rapidly than that which occurred on flight 42E. When the engine separated, roll excursions and control wheel deflections were greater for the accident airplane than for flight 42E. Pitch and heading excursions were about the same for both airplanes.

Aileron command data showed that after engine separation, the combination of engine/pylon separation, weight shift, and damage to the airfoil surfaces and flight controls required the crew to command wheel deflections in the range of 60° to maintain a steady state lateral control. Although the graphs show aileron commands greater than 20°, the ailerons are limited to 20° deflection.

The aileron command data come from a linear variable differential transformer (LVDT) at or near the control wheel mixer. The data do not come directly from the aileron position. Therefore, wheel deflections from about 50° to 80° would generate aileron commands greater than 20° although the aileron could only move to 20°.

The following table relates the intensity of turbulence to the change in vertical G:

Moderate Turbulence...	Change in Vertical G of .5 to 1.0...
Severe Turbulence...	Change in Vertical G greater than 1.0 to 2.0...
Extreme Turbulence...	Change in Vertical G greater than 2.0...

On flight 46E, the maximum vertical G change prior to the separation was about 1.2 or severe turbulence.

Previous large commercial airplane encounters with severe turbulence provided the following information on recorded vertical accelerations, "G":⁶

⁶"Flight-Data Analysis and Operating Problems," R.C. Wingrove, NASA/Ames.

<u>Date</u>	<u>Aircraft Type</u>	<u>Location</u>	<u>Altitude</u>	<u>G Load</u>
11/03/75	DC-10	Calgary, Canada	33,000	+1.6-0.2
04/04/81	DC-10	Hannibal, MO	37,000	+1.7-1.0
07/16/82	DC-10	Morton, WY	39,000	+1.6-0.6
10/12/83	DC-10	Near Bermuda	37,000	+1.6-0.6
11/25/83	L-1011	Offshore SC	37,000	+2.1-1.0
01/22/85	B-747	Over Greenland	33,000	+2.7-0.0
04/07/86	DC-10	Jamestown, NY	40,000	+1.8-0.4
09/27/87	L-1011	Near Bermuda	31,000	+2.2-0.5
11/12/87	A-310	Near Bermuda	33,000	+2.0-0.6
01/20/88	B-767	Chicago, IL	25,000	+1.4-0.2
03/24/88	B-767	Cimarron, NM	33,000	+1.7-0.2
06/06/89	DC-10	Garden City, KS	37,000	+1.9-0.9
06/16/89	L-1011	Jacks creek, TN	24,000	+2.2-1.0

Additionally, on December 9, 1992, the No. 1 engine separated from a DC-8 aircraft near Denver, Colorado, during an encounter with severe turbulence. Unfortunately, the FDR did not function properly and the G data was not recorded.

1.17.4 Engine Pylon Design and Stresses

The pylon is designed to carry the thrust and torque loads of the engine as well as lateral, longitudinal, and vertical loads from maneuvers and gusts. Lateral loads are ultimately absorbed by the midspar fuse pins and side brace. According to Boeing, the fuse pins can withstand an ultimate lateral load of more than 2.8 G on the engine.⁷ Additionally, Boeing reported that the portion of the structure of the pylon that is critical under lateral loads is the firewall just aft of the forward engine mount. The Boeing calculations indicated that this firewall will fracture at a lateral load of between 2.35 G and 2.88 G when it contains a fatigue crack of the size found in this structure. Boeing reported that all structural strength calculations are based on unidirectional loading and that calculations for structural response to bi-directional loads are not required by Federal Aviation Regulations (FARs).

The B-747 airplane and its pylon structure were designed in the mid-1960's using the computer capabilities and analytical skills of the time. Boeing's

⁷14 CFR Sections 25.301 and 25.303 provide that the limit loads on a structure are the maximum loads to be expected in service, and ultimate loads are the limit loads multiplied by a factor of safety of 1.5.

current computer modeling of the pylon structure and the loads applied to it is considerably more complicated and provides greater resolution of the data than would have been possible with the techniques employed when the airplane was designed. The use of modern computer structural design programs allowed considerable modeling of the pylon's response to various load inputs with various structural failures.

Boeing's structural engineers reported that the change in fuse pin loads due to the observed fatigue crack in the aft portion of the midspar web would be negligible. Boeing performed a finite element modeling of the pylon structure with the cracked midspar web in this area completely removed. This analysis showed that for the same lateral loads on the engine, the fuse pin stresses increased only by about 8.7 percent. Boeing reported that the aft portion of the midspar is loaded primarily by torsion (e.g. engine seizure) and is not critical for lateral loads.

Boeing's review of the G loads recorded by the FDR indicated that the equivalent loads (aerodynamic plus inertia) at the center of gravity of the No. 2 engine nacelle could have been as high as -2.5 G vertical, 2.1 G to 3.0 G outboard lateral, and 0.1 G to 0.3 G longitudinal. These loads may or may not have been acting on the pylon at the same time. Additionally, the calculated G loads do not necessarily represent the peak or maximum loads experienced by the pylon due to the sampling rate of the recorded G data. The Boeing calculations found that the loads in individual directions experienced by the accident airplane were not substantially different from the loads experienced by flight 42E.

The Boeing engineers stated that the gyroscopic loads of the engine on the pylon are relatively minor and that the structure is designed to withstand the gyroscopic loads that are induced during maneuvering. However, once the engine started to depart the wing, the gyroscopic loads would progressively increase as the engine changed its plane of rotation.

Boeing's calculations indicated that the repairs made to the pylon structure over its life would not have decreased its load-carrying capability, nor would they have had any effect on the distribution of loads between the major load paths. However, the manufacturer's calculations indicated that the repairs would cause the overall stiffness to increase slightly but that the increased stiffness would not result in any significant change in the response to dynamic loads with intact or partially failed strut structural components.

1.17.5 Service Damage to Pylon Structure

Boeing's records indicated six cases in which deformed midspar pins were discovered during a scheduled inspection. In all of the cases, there were no reports of hard landings, engine surges, or encounters with severe turbulence. Two cases involved deformed midspar pins at the No. 2 engine position, two were at the No. 3 engine position, and there was one report each for the No. 1 and No. 4 engine positions. There were nine cases in which pilots or mechanics reported that visual examination indicated that the strut was drooping. Upon inspection it was disclosed that structural failures had occurred within the pylon. In an additional 11 cases, during a maintenance inspection, midspar lugs were found cracked. There were no reports that any of these airplanes had experienced hard landings, severe turbulence, or engine surges prior to the time that the droop was detected.

Boeing's records indicated three reported instances of cracks found in the pylon webs on the inboard engine locations and 11 instances of cracking reported in the pylon webs of outboard engine locations.

Boeing has recently proposed to the FAA several structural modifications to the B-747 pylon to increase its load-carrying capability. The proposed modifications are being reviewed by the FAA and will significantly strengthen the engine pylons in the area of the midspar fuse pins. Boeing engineers report that the modifications will increase the pylon's vertical and longitudinal strength. However, the modification will provide a slight, if any, increase in the structure's lateral load-carrying strength. Additionally, it was provided by Boeing engineers that the greatest lateral loads on the pylons normally occur during taxiing.

2. ANALYSIS

2.1 General

The investigation found that the flightcrew was properly certificated and qualified in accordance with applicable FARs and company requirements. The pilots were in good general health and had proper FAA medical certificates at the time of the accident. There was no evidence of adverse medical conditions that affected the flightcrew, and they were not under the influence of, or impaired by, drugs or alcohol.

The airplane had been maintained in accordance with applicable FARs and company operations specifications and maintenance procedures. Examination of the airplane's fuselage and wing structure, flight control systems, and powerplants disclosed no evidence of a malfunction that would have caused or contributed to the accident. Two fatigue cracks were found in the No. 2 engine pylon web that will be discussed later in the report.

The circumstances of this accident indicated that the No. 2 engine and pylon departed the airplane during an encounter with severe and possibly extreme turbulence. The Safety Board's investigation examined the possible conditions that could have contributed to this event.

The Safety Board has been monitoring two ongoing foreign investigations involving the in-flight separation of an engine pylon from B-747 airplanes.⁸ The preliminary data indicate that a failure of a midspar fuse pin or pylon midspar fitting might have been a factor in the accidents. The investigation of the accident involving flight 46E found neither the pylon midspar fuse pins nor the pylon midspar fittings contributed to the accident. Since the events that resulted in the accident involving flight 46E were unrelated to the previous two accidents, the Safety Board will not address the previous two pylon separations in this report.

2.2 Weather

The investigation determined that moderate to severe turbulence had been forecast for the Anchorage area by the NWS. Additionally, there were several

⁸El Al Airlines flight 1862, Amsterdam, The Netherlands, Boeing 747-200F, October 5, 1992; China Airlines flight CI-358, Taipei, Taiwan, Boeing 747-200F, December 29, 1991.

reports of severe turbulence encounters by pilots of other large airplanes, including another Evergreen B-747, JAL flight 42E, that departed about 5 minutes prior to the accident flight. The investigation determined that the crew of flight 46E was aware of these reports before takeoff.

The interaction of strong easterly winds with the mountains east of Anchorage was responsible for the production of moderate to severe mountain wave and mechanical turbulence. This turbulence, which occurred during the morning and afternoon on the day of the accident, was more intense a few thousand feet above the surface. It was found that winds from the east flow across and around the mountains, as well as through valleys in the mountains before reaching Anchorage. The interaction of the wind with the mountain valleys results in the acceleration of the wind speed due to the channeling effect of the valleys. The combination of these effects produces a complicated wind flow pattern and turbulence to the east of the airport in the lower layers of the atmosphere.

The Safety Board's investigation was unable to develop an accurate description of the wind field that affected the airplane. Horizontal and vertical gusts, as well as horizontal and vertical vortices, would most likely have existed. Several individuals reported strong winds at the surface during the afternoon east of the airport, with a maximum gust of 62 knots reported about 10 miles southeast of the airport at an elevation of 2,500 feet to 3,000 feet. In addition, an individual located about 7 miles north-northeast of the airport reported seeing a funnel of rotating debris that rose to a height of between 500 feet and 1,000 feet. The crew of flight 42E reported that about 10 nmi from the airport, the aircraft began an uncommanded left turn that required full right aileron to counter. While climbing through 2,000 feet, they encountered severe turbulence and air speed fluctuations of +/- 30 to 40 knots. Their rate of climb decreased from 200 fpm to 100 fpm at 3,000 feet. At 4,500 feet an "area of sink" was encountered with a descent rate of 1,000 fpm, even though maximum climb power was applied. The crew of flight 46E reported air speed excursions greater than 50 knots. They also described the turbulence as "large wave action...a large vorticity (vortex)." These reports indicate a complex wind flow that most likely generated random intensities of turbulence.

The Safety Board has previously investigated the possible effects of severe mountain-induced winds and turbulence on an airplane. Most recently, as a

result of its investigation of an accident involving a B-737 on March 3, 1991,⁹ the Safety Board recommended that the FAA:

A-92-57

Develop and implement a meteorological program to observe, document, and analyze potential meteorological aircraft hazards in the area of Colorado Springs, Colorado, with a focus on the approach departure paths of the Colorado Municipal Airport. This program should be made operational by the winter of 1992.

A-92-58

Develop a broader meteorological aircraft hazard program to include other airports in or near mountainous terrain, based on the results obtained in the Colorado Springs, Colorado, area.

In its letter of March 26, 1993, the FAA stated that it agreed with the intent of these two recommendations and was planning to study the applicability of airborne sensors to detect clear air turbulence and mountain wave phenomena in fiscal year 1994. Additionally, the FAA's Aviation Weather Services Improvements Program was currently studying a number of wind phenomena. However, the FAA's letter stated that due to budget constraints and program priorities, the specific work on these recommendations could be delayed until fiscal year 1995. In its letter dated June 10, 1993, the Safety Board classified Safety Recommendations A-92-57 and -58 as "Open--Acceptable Response," pending further information about the FAA's plans to write a meteorological program plan to study mountain-induced wind phenomena.

On September 13, 1993, the FAA responded again to these Safety Recommendations stating:

The FAA has tasked the National Oceanic and Atmospheric Administration's Forecast Systems Laboratory to: (1) organize a planning group to formulate a program plan to provide a definitive study of mountain-induced wind phenomena and their effect on

⁹Aircraft Accident Report--"United Airlines Flight 585, Boeing 737-291, N999UA, 4 Miles South of Colorado Springs Municipal Airport, Colorado Springs, Colorado, March 3, 1991" (NTSB-AAR-92/06)

aircraft in flight; and (2) develop initiatives to define and implement an awareness program to alert pilots to this potential hazard.

The first task will result in a detailed plan focusing on methodology, scientific analysis, and an assessment of the effect of mountain-induced wind phenomena on aircraft in flight. The second task will result in the first phase of a long-term pilot awareness initiative. This pilot awareness initiative will include educational material for industry and general aviation users and preliminary scientific definition of the phenomena to be used by aircraft manufacturers and commercial airlines in training programs, particularly those that use simulators.

The FAA stated that it would keep the Safety Board aware of its progress on these actions. However, the FAA did not provide a time table as to when the plan would be completed or a forecast as to when the implementation of a system to observe, document, and analyze potential meteorological aircraft hazards would begin.

The Safety Board finds that the accident involving flight 46E further amplifies the need for a better understanding of mountain-induced meteorological phenomena and their effects on aircraft. Therefore, the Safety Board reiterates Safety Recommendation A-92-58, which addresses that need. Additionally, the Safety Board believes that the FAA should develop and implement a meteorological program to observe, document, and analyze potential meteorological aircraft hazards in the area of Anchorage, Alaska, with a focus on the approach and departure paths of the Anchorage International Airport. Further, the Safety Board believes that the NWS should use the WSR-88D system at ANC to document mountain-generated wind fields in the Anchorage area. The WSR-88D system should also be used by the NWS to develop in greater detail low altitude turbulence forecasts.

2.3 Pylon Separation Sequence

The investigation found that there were multiple separations in the No. 2 engine pylon that allowed the engine to separate from the wing. There was evidence that the direction of separation was outboard (to the left) and up. This evidence included the lack of damage on the inboard side of the pylon, the fractures and deformation in the major structural members of the pylon, and a piece of the wing leading edge structure that was embedded in the rear of the engine.

The examination and analysis of the pylon structure also yielded sufficient clues to determine the sequence of pylon fractures that culminated in the loss of the engine. The rear engine mount fitting in the pylon was intact and, when recovered, a major piece of the pylon was still attached to the engine. However, the fitting was cracked and heavily distorted in relation to the pylon structure around it. This cracking and distortion were consistent with motion of the forward end of the engine in the outboard and up directions. The fact that the fitting was damaged in this manner indicates that the pylon structure was intact when the damage occurred. If the pylon had been separated at any location aft of the rear mount fitting, the fitting would not have been distorted as it was because the pylon structure would have moved with the fitting as engine motion attempted to generate the cracking and distortion.

The condition of the rear engine mount fitting indicates that the forward end of the engine separated from the main portion of the pylon and moved in the outboard direction while the remainder of the pylon was intact and attached to the wing. The examination of the front end of the pylon revealed that the pylon structure was fractured just aft of the forward engine mount bulkhead, and that a small piece of the forward portion of the pylon was attached to the engine at the forward engine mount position. The fracture area on this small piece of the pylon contained features typical of overstress separations with the exception of the 2-inch-long fatigue crack in the forward firewall.¹⁰ The firewall contained compression buckling (from shear loading) that extended to the fatigue area. This buckling was probably the first additional damage created by the lateral engine loads at the time of the engine separation. Overstress separations from shear loading were found on both sides of the fatigue area. These overstress separation areas probably occurred immediately after the compression buckling and were the start of the complete fracture of the pylon aft of the forward engine mount bulkhead.

After the pylon separated aft of the forward engine mount bulkhead, the front end of the engine was free to swing to the left under the same lateral loads that produced the initial separation of the pylon. All other fractures and damage to the pylon were secondary to the fracture at the front end of the pylon. The movement of the front of the engine to the left created the heavy distortion and cracking in the rear mount fitting. As the front end of the engine swung to the left, the pylon structure would have been bent in the outboard direction. At the same

¹⁰The firewall in this location is the web of the forward extension of the pylon midspar. The firewall is composed of 0.025-inch-thick Inconel material.

time, the engine would have been producing thrust at an unusual angle. The combination of the bending of the pylon and the unusual thrust angle would account for the damage found on the midspar fuse pins, the large vertical fracture in the middle of the pylon, the shear buckling of the midspar web, and the direction of fracture of the major structural members of the pylon.

2.4 Engine Pylon Structural Loads

The investigation determined that the acceleration data recovered from the FDRs of both Evergreen airplanes, flights 46E and 42E, were not significantly different. Of concern was the fact that the No. 2 engine and pylon separated from flight 46E while flight 42E sustained only very minor damage. Additionally, several other airplanes operating in the area at the time of the accident were not damaged. Therefore, the Safety Board's investigation examined whether the turbulence that was present at the time of the accident was sufficient to induce separation of the engine and pylon.

The Safety Board notes that examination of the airplanes found substantial deformation on a midspar fuse pin on the No. 1 engine pylon of flight 46E and very minor deformation on the midspar fuse pins on the No. 2 engine pylon of flight 42E. Service experience has shown that deformed fuse pins are relatively rare occurrences. It is possible that the midspar fuse pins on flight 46E were deformed prior to the day of the accident. However, there were no pilot reports or maintenance writeups of encounters with severe turbulence, hard landing reports or any reports of other damage to the pylon since the fuse pins were replaced about 3 months prior to the accident. Therefore, the severe deformation to the fuse pin on the No. 1 engine pylon from the accident airplane was most likely created at the time of the accident, and is a sign that the turbulence encountered by the accident airplane was very severe. The minor damage to the fuse pins on flight 42E may not have been detected during routine maintenance and could have been created on the day of the accident or at any time prior. Once again, there were no reports of any events that might have deformed the pins prior to the day of the accident. Therefore, physical evidence indicates that the turbulence encountered by flight 42E induced pylon stresses that were lower than those experienced by the accident airplane. Although the FDR data indicates similar G loadings for the two airplanes, the sampling rate of the recorders may not have recorded the peak loads or time phasing of the loads experienced by flight 46E. Therefore, it is possible that flight 46E experienced G loadings that were considerably greater than the loads imposed on flight 42E.

Acceleration loading at the center of gravity (CG) of the airplane will produce dynamic and harmonic motion at other positions on the airplane, resulting in higher acceleration loading at those positions. During certification of the B-747, Boeing developed a finite element computer model that would calculate the acceleration loading throughout the airplane. The model found that lateral loading at the CG may induce lateral and vertical loads at the engine/pylon. In addition, vertical loading at the CG may produce vertical and lateral loading at the engine/pylon, primarily as a result of wing bending. In addition, engine weight, thrust, and aerodynamic loads produce loads at the engine/pylon.

Loading of the engine pylon structure is a result of the combination of the static, thrust, aerodynamic, and acceleration (dynamic) loading of the engine. The static, thrust and aerodynamic loads are relatively well understood and more easily calculated. However, information on the acceleration loading of the engine can only be derived from the recorded values for the acceleration at the approximate CG of the airplane, as recorded on the FDR at a sample rate of once every 4 seconds.

The recorded acceleration data for the airplane shows moderate to severe turbulence, but no values that appear to exceed the design allowances for the airplane. Nevertheless, it is possible that the static loads combined with the time phasing of the gusts could result in increased loads to the engine and pylon. Unfortunately, the sampling rate of the FDR prevented determining if the time phasing of the measured acceleration loads on the airplane would actually result in the maximum combined loads at the engine/pylon. Additionally, as previously mentioned, the actual acceleration loads on the airplane may have been considerably greater than the recorded acceleration loads. Therefore, it is possible that the airplane occasionally experienced periods of extreme turbulence. Based on the FDR data, the maximum, combined loads, assuming maximum time phasing, are about 2.1 G to 3.0 G, which is close to or above the ultimate load (2.8 G) for the pylon in the lateral direction. The severe damage to the midspar fuse pin of the No. 1 engine pylon of the airplane indicates that the loads were sufficient to deform the pin and, therefore, were near the ultimate design load. Therefore, it is possible that the severe and possibly extreme turbulence, alone, was sufficient to cause the separation of the engine. However, the operating history of the B-747 fleet indicates that such an event is unlikely.

Boeing performed a finite element analysis of the forward portion of the pylon structure. This analysis showed that the presence of the fatigue crack in

the firewall (at the point of the initiation of the pylon fracture) would reduce the stress capacity of the pylon by about 10 percent. The model predicted that in the presence of the cracked web, the No. 2 engine pylon would fail at a lateral load of between 2.35 G and 2.88 G, acting outboard. Because this fatigue crack in the firewall web aft of the forward engine mount reduced the pylon's lateral load-carrying ability, the Safety Board concludes that the separation of the No. 2 engine pylon was due to an encounter with severe or possibly extreme turbulence that resulted in dynamic multi-axis lateral loadings that exceeded the ultimate lateral-load carrying capability of the pylon which was already reduced by the presence of the fatigue crack near the forward end of the pylon's forward firewall web.

The Safety Board notes that the design requirements specified in 14 CFR Part 25 allow manufacturer's to analyze each axis of G loading independently when determining how strong a structure should be to withstand ultimate load. Manufacturers are not required to design the structure to withstand ultimate loads from multiple directions at the same time. During the investigation, it was found that Boeing's engineers believed that maximum lateral load on the pylon would be encountered during taxiing. Additionally, it was noted that Boeing's structural modification plan for the B-747 pylons would not significantly increase the lateral load-carrying ability of the structure.

The computer analysis found that encounters with reported severe turbulence can produce sufficient lateral loads to separate the pylon from the wing even without the presence of any cracks in the pylon web. The Safety Board believes that the wind fields and conditions that create severe turbulence are very complex and that areas or periods of extreme turbulence can be present at any time. Additionally, encounters with moderate and severe turbulence are considered relatively normal events by pilots and controllers, and operations are not curtailed by the forecast or pilot reports of severe turbulence. Therefore, it would appear that there is a safety-of-flight concern regarding the lateral design loads for engine pylons during severe turbulent conditions. However, moderating this concern is the fact that B-747 airplanes, as well as many other makes and models of airplanes, have been operating successfully for many years without engines or pylons separating from the wings solely because of turbulence. In general, it would appear that airline operating procedures and pilots actions have been effective in avoiding operations into extreme or very severe turbulence that could damage their airplanes. In view of the operating history of air carrier airplanes with few reported cases of structural damage to engine pylons due to turbulence, the Safety Board believes that

a requirement for structural modifications of all pylon structures is not warranted at this time. However, the Safety Board believes that, based upon the accident involving flight 46E, the FAA should modify the design load requirements of 14 CFR Part 25 to consider multiple axis loading and to more adequately consider the magnitude of the loads that can be experienced in turbulence conditions. The Safety Board also believes that if the FAA approves the Boeing-proposed B-747 engine pylon structural modifications, the modification should include increasing the lateral load capability of the structure. Additionally, the Safety Board believes that any future structural modifications of existing engine pylons should consider multiple axis loading and the feasibility of increasing the lateral strength of the pylon structure.

2.5 Engine Pylon Inspections

The forward firewall extends from nacelle station (NS) 128.0 to NS 180.0. Airworthiness Directive (AD) 82-22-02 requires a visual inspection of the very forward portion of this firewall (NS 128 to NS 135, adjacent to the front engine mount bulkhead) because of cracks that have been found in this area. In addition, at the time of the accident, there were Boeing-recommended inspections of the firewall web from NS 163 to NS 180. However, the fatigue crack that was found in the firewall of the No. 2 engine pylon of the accident airplane was not within these inspection areas. There were no required or recommended inspections of this area at the time of the accident. Recently, Boeing issued SB 747-54-2160, which addresses inspecting the firewall web from NS 135.6 to NS 163, which would cover the area where the fatigue crack was found.

The fatigue cracking found on flight 46E's No. 2 engine pylon midspar web probably resulted from sheet bending due to flexing or vibration of the web material. The Safety Board believes that the crack probably would have been detected if there had been a requirement to inspect this area. Therefore, to reduce the likelihood of similar failures of the B-747 pylon, the Safety Board believes that the FAA should require all operators to inspect the entire pylon forward firewall web at specific flight hour intervals.

Following the accident involving flight 46E, the sister ship that had also experienced the severe turbulence encounter, flight 42E, received a thorough structural inspection. During the inspection, it was found that two No. 2 engine midspar fuse pins were deformed. The Safety Board is concerned that if the engine pylon had not separated from flight 46E, the midspar fuse pins on flight 42E would

not have been removed and inspected. Therefore, the airplane could have continued in service with deformed fuse pins. Although the pins were not severely deformed, the deformation may have resulted in a stress raiser that could have increased the pin's susceptibility to fatigue, thereby reducing their service lives. Additionally, it was noted that a midspar fuse pin from the No. 1 engine position on flight 46E was severely deformed. It was found that in both these cases external examination of the pylon did not reveal any problem. Only when the pins were removed were the deformations found.

2.6 Operations

A review of data on large vertical G load changes encountered by airliners showed that the accident involving flight 46E ranked lowest among the events noted. The maximum vertical mean G value change of the 14 events was 2.35, with a standard deviation of 0.56. The maximum change in vertical G value recorded during the accident involving flight 46E, which was not necessarily the maximum G load experienced by the airplane, was almost two standard deviations less than the mean. From this, it would appear that the intensity of turbulence encountered by flight 46E was significantly less than the intensity of turbulence noted in the other events, many of which resulted in no damage to the airplane. Examination of the maximum accelerations in the recorded data indicates that the turbulence encountered by flight 46E would not have been expected to result in airplane structural damage. However, the other turbulence encounters occurred at higher altitudes where the wind pattern may not be as complex as at lower levels. Additionally, the data are only for vertical G and do not indicate lateral G loads, which were the primary load direction that initiated the pylon separation from flight 46E.

According to the NWS at ANC, the strong wind events that produce significant turbulence occur about 15 times a year. Interviews with meteorologists and pilots in the Anchorage area indicated that the weather and turbulence on the day of the accident were fairly typical and that airplane operations are routinely carried out on similar days. Because the captain of flight 46E had operated B-747 airplanes out of Anchorage during similar turbulent conditions and because other airplanes were operating in the area at the time of the accident without difficulty, the Safety Board finds that there was no reason for the captain to have suspected that flight 46E would be damaged during the climbout.

The investigation of this accident found that it is possible for a B-747 to be substantially damaged by the level of turbulence that was present on the day of the accident. The Safety Board does not believe that it would be reasonable to suspend operations at the airport during similar turbulence because, historically, aircraft have been able to operate safely at the airport during such conditions. However, according to the NWS at ANC, the most intense turbulence occurs near the mountains at low altitude. Therefore, by staying away from the mountains on departure, aircraft may lessen the chance of encountering severe turbulence. The Safety Board believes that the FAA should consider modifying the departure routes of aircraft at ANC during periods of moderate or severe turbulence in order to minimize an aircraft's encounter with mountain-induced low level turbulence.

3. CONCLUSIONS

3.1 Findings

1. The airplane was certificated, equipped, and maintained in accordance with Federal Aviation Regulations and approved procedures.
2. The flightcrew was properly certificated and qualified for their duties according to company procedures and Federal Aviation Regulations.
3. The weather was essentially the same as forecast by the National Weather Service.
4. Flight 46E took off toward the mountains and encountered severe and possibly extreme mountain wave and mechanical turbulence on departing Anchorage. The crew was aware of the approximate location and intensity of the turbulence prior to departing.
5. The meteorological factors that produced the turbulence occur frequently in the Anchorage area. However, the production of significant turbulence and accompanying vortices due to the interaction of wind with mountains is common in all mountainous areas.
6. Based upon the records of prior severe turbulence encounters, flight 46E's encounter with turbulence on March 31, 1993, would not have been expected to result in structural damage to the airplane. However, the inherent limitations of flight data recorders precludes drawing a firm conclusion.
7. The flightcrew's actions were not a factor in the accident.
8. The turbulence encounter induced high lateral loads in the No. 2 engine pylon structure.

9. The turbulence-induced G-loads recorded on the recorders of flights 46E and 42E can be combined and time-phased such as to cause the ultimate lateral strength of the Boeing 747 engine pylon structure to be exceeded.
10. Current design and certification procedures do not require consideration of multi-axis loading of engine pylons.
11. The engine separated from the airplane as a result of the structural breakup of the No. 2 engine pylon. The breakup began at a 2-inch-long fatigue crack in the forward firewall web, near the front engine mount bulkhead.
12. The fatigue crack in the forward firewall web reduced the ultimate lateral load carrying capability of the pylon structure by about 10 percent.
13. There was no specific requirement to perform inspections in the area of the forward firewall web of the pylon where the crack was found, however, to date, inspections of other Boeing 747s have found no additional evidence of cracking in this area.
14. Boeing's proposed structural modification program for the B-747 engine pylons did not include considerations for increasing the lateral load-carrying capability of the pylon.

3.2 Probable Cause

The National Transportation Safety Board determines that the probable cause of this accident was the lateral separation of the No. 2 engine pylon due to an encounter with severe or possibly extreme turbulence that resulted in dynamic multi-axis lateral loadings that exceeded the ultimate lateral load-carrying capability of the pylon, which was already reduced by the presence of the fatigue crack near the forward end of the pylon's forward firewall web.

4. RECOMMENDATIONS

As a result of its investigation of this accident, the National Transportation Safety Board makes the following recommendations:

--to the Federal Aviation Administration:

Develop and implement a meteorological program to observe, document, and analyze potential meteorological aircraft hazards in the area of Anchorage International Airport, Anchorage, Alaska, with an emphasis on the approach and departure paths of the airport. (Class II, Priority Action) (A-93-136)

Amend the design load requirements of 14 CFR Part 25 to consider multiple axis loads encountered during severe turbulence. (Class III, Longer Term Action) (A-93-137)

Require the Boeing-proposed B-747 engine pylon structural modification program to include increasing the lateral-load capability of the pylon structure. (Class II, Priority Action) (A-93-138)

Require any future structural modifications of existing engine pylons to consider multiple axis loading. (Class II, Priority Action) (A-93-139)

Issue an Airworthiness Directive to require compliance with Boeing Service Bulletin 747-54-2160. (Class II, Priority Action) (A-93-140)

Consider the necessity and feasibility of requiring the modification of the aircraft departure routes at Anchorage International Airport during periods of moderate or severe turbulence to minimize the potential of aircraft encountering mountain-induced low level turbulence. (Class II, Priority Action) (A-93-141)

--to the National Weather Service:

Use the WSR-88D doppler weather radar system at Anchorage, Alaska, to document mountain-generated wind fields in the Anchorage area and to develop in greater detail low altitude turbulence forecasts. (Class II, Priority Action) (A-93-142)

A-92-58: Additionally, the Safety Board reiterates Safety Recommendation

Develop a broader meteorological aircraft hazard program to include other airports in or near mountainous terrain, based on the results obtained in the Colorado Springs, Colorado, area.

BY THE NATIONAL TRANSPORTATION SAFETY BOARD

Carl W. Vogt
Chairman

Susan Coughlin
Vice Chairman

John K. Lauber
Member

Christopher A. Hart
Member

John Hammerschmidt
Member

October 13, 1993

5. APPENDIXES

APPENDIX A

INVESTIGATION AND HEARING

1. Investigation

The Safety Board's northwest field office in Anchorage, Alaska, was notified of an event involving JAL flight 46E shortly after it departed from Anchorage International Airport. The field office was subsequently informed that one engine had separated from the airplane and that the airplane had landed safely back at the airport. An investigator from the office arrived at the scene shortly after the airplane landed. The investigator-in-charge of the accident and a partial investigative team were dispatched from the Safety Board's Washington, D.C., Headquarters. The investigative team was composed of the following groups: operations, structures, powerplants, metallurgy, and meteorology. In addition, specialist reports were prepared to summarize findings relevant to the CVR, FDR, and aircraft performance.

Parties to the field investigation were the FAA, Boeing Commercial Airplane Group, Evergreen International Airways, Japan Airlines, and Pratt & Whitney.

The Aircraft Accident Investigation Commission of Japan was notified of the accident and was granted investigative status in this investigation in accordance with Annex 13 to the Convention on International Civil Aviation.

2. Public Hearing

A public hearing was not held regarding the accident involving JAL flight 46E.

APPENDIX B

COCKPIT VOICE RECORDER TRANSCRIPT

Transcript of a Fairchild A-100 cockpit voice recorder (CVR), s/n 1766, installed on a Boeing B-747-121F, N743EV, which was involved in a turbulence accident near Anchorage International Airport, Alaska, on March 31, 1993.

LEGEND	
RDO	Radio transmission from accident aircraft
CAM	Cockpit area microphone voice or sound source
INT	Transmissions over accident aircraft's interphone system
- 1	Voice identified as Captain
- 2	Voice identified as First Officer
- 3	Voice identified as Flight Engineer
- 4	Voice identified as additional crew member #1 (ACM)
- 5	Voice identified as additional crew member #2 (ACM)
- 6	Voice identified as accident aircraft's "electronic voice"
- 7	Voice identified as ground crewman
- ?	Voice unidentified
EVV - 1	Radio transmission from Evergreen Anchorage operations
GND - 1	Radio transmission from Anchorage ground control
TWR - 1	Radio transmission from Anchorage control tower
DEP - 1	Radio transmission from Anchorage departure control
PNS -	Radio transmission from Peninsula flight 4205
JA 42 -	Radio transmission from Japan Air (Evergreen) flight 42 Echo heavy
K 084 -	Radio transmission from Korean Airlines flight 084
835 -	Radio transmission from aircraft 835
*	Unintelligible word
@	Non pertinent word
#	Expletive
%	Break in continuity
()	Questionable insertion
(())	Editorial insertion
- - -	Pause

Note: Times are expressed in Alaska standard time (AST).
Times shown in brackets { } are computer reference times.

INTRA-COCKPIT COMMUNICATION

AIR-GROUND COMMUNICATION

TIME & SOURCE	CONTENT	TIME & SOURCE	CONTENT
START OF RECORDING			
START OF TRANSCRIPT			
		1221:18 GND-1	{00:02} forty six Echo heavy, taxi runway six right via Mike Romeo Kilo, hold short of runway three two. contact tower holding short.
		1221:28 RDO-2	{00:12} Mike Romeo Kilo holding short three two, contact, tower when we are holding short, short of three two.
1221:32 CAM-3	{00:16} thank you.		
		1221:36 GND-1	{00:20} four six Echo, Lima is current, altimeter is two nine six zero.
1221:38 CAM-1	{00:22} good job.		
1221:38 CAM-3	{00:22} • good job.		
1221:39 CAM-1	{00:23} is that all?		
1221:40 CAM-3	{00:24} as far as I know, yea. --- *****		
1221:42 CAM-1	{00:26} sure do.		

INTRA-COCKPIT COMMUNICATION

AIR-GROUND COMMUNICATION

TIME & SOURCE	CONTENT	TIME & SOURCE	CONTENT
1221:44 CAM-?	{00:28} (several unintelligible comments by several cockpit occupants)		
1222:21 CAM-3	{01:05} ya, well today I'm sorry you're gonna miss your flight out of Chicago.		
1222:26 CAM-1	{01:10} *** knew about that.		
1222:27 CAM-3	{01:11} ya, well now it's, affirmative.		
1222:30 CAM-1	{01:14} roger, time to go home?		
1222:32 CAM-3	{01:16} yea, I got a eight fifteen out of Chicago. -- mighta' made it had we nota' been late to begin with, an then, you know it's *** gettin' the airplane late and, and the maintenance problem.		
1222:53 CAM-1	{01:37} **** to be worried about ****		
		1223:01 K084	{01:45} Korean zero eight four, we got about a ten knot shear at uh, about fifteen hundred feet.
		1223:03 RDO-3	{01:47} Evergreen ops, ah, forty six Echo.
		1223:06 GND-1	{01:50} ten knot shear at fifteen hundred feet, was it?

INTRA-COCKPIT COMMUNICATION

AIR-GROUND COMMUNICATION

TIME & SOURCE	CONTENT	TIME & SOURCE	CONTENT
		1223:07 K084	{01:51} yea, fifteen hundred, just about ten knots.
		1223:08 GND-1	{01:52} OK, thank you very much.
		1223:09 EVV-1	{01:53} four six echo, Evergreen ops, go ahead.
		1223:10 RDO-3	{01:54} yea roger, ah, we're back out again, and I'll give you a time in a little bit ah, just wanted you to know our fuel on board for the first segment, was ah, two two nine decimal four with an uplift of two six two four nine. and I'll call everything else on the ah, new one will be the same cargo weight and all that. I'll call on the departure.
		1223:35 EVV-1	{02:19} OK, thank you.
1223:43 CAM-3	{02:27} we're back out as planned here.		
1223:45 CAM-1	{02:29} OK.		
1223:47 CAM-3	{02:31} I don't know what time it was, I'll have to figure out ***.		
1223:51 CAM-1	{02:35} ***		
1223:52 CAM-3	{02:36} three minutes, four minutes to get around the corner?		
1223:54 CAM-1	{02:38} ya. --- flaps ten, taxi check.		

INTRA-COCKPIT COMMUNICATION

AIR-GROUND COMMUNICATION

TIME & SOURCE	CONTENT	TIME & SOURCE	CONTENT
1224:02 CAM-	{02:46} ((sound of two clicks))		
1224:03 CAM-3	{02:47} taxi.		
1224:05 CAM-	{02:49} ((ratcheting sound similar to stabilizer trim wheel))		
1224:17 CAM-1	{03:01} the stab is what?		
1224:19 CAM-3	{03:03} six point two.		
1224:23 CAM-2	{03:07} **** --- checking the controls right. --- left --- forward --- aft.		
1224:47 CAM-3	{03:31} flaps?		
1224:50 CAM-1	{03:34} ten degrees, handles, gauges, lights checked.		
1224:52 CAM-2	{03:36} ten degrees, handles, gauges, light check.		
1224:54 CAM-3	{03:38} flight controls?		
1224:55 CAM-1	{03:39} check.		
1224:56 CAM-2	{03:40} check.		

INTRA-COCKPIT COMMUNICATION

AIR-GROUND COMMUNICATION

TIME & SOURCE	CONTENT	TIME & SOURCE	CONTENT
1224:57 CAM-3	{03:41} yaw damper.		
1224:58 CAM-1	{03:42} check.		
1224:59 CAM-3	{03:43} stab trim.		
1225:00 CAM-1	{03:44} six point two units checked.		
1225:02 CAM-2	{03:46} six point two **, checked.		
1225:03 CAM-3	{03:47} INS?		
1225:04 CAM-1	{03:48} checked ((concurrent with next transmission))		
		1225:10 RDO-2	{03:54} and good morning again ah, Japan Air forty six Echo heavy is with you.
1225:11 CAM-2	{03:55} checked. ((concurrent with next transmission))		
		1225:12 TWR-1	{03:56} forty six Echo heavy Anchorage tower, cross runway three two, taxi to runway six right.
		1225:13 RDO-2	{03:57} OK, cross three two for six right Japan Air thirty -- forty six Echo heavy.

INTRA-COCKPIT COMMUNICATION

AIR-GROUND COMMUNICATION

TIME & SOURCE	CONTENT	TIME & SOURCE	CONTENT
1225:15 CAM-3	{03:59} forty two, that's going to be a nice picture.		
1225:18 CAM-	{04:02} ((sound similar to electric seat noise))		
1225:20 CAM-3	{04:04} photo opportunity.		
1225:24 CAM-?	{04:08} clear. --- *****		
		1225:27 TWR-1	{04:11} Japan Air forty two Echo heavy, cleared for takeoff.
		1225:30 JA 42	{04:14} cleared for takeoff, Japan Air forty two Echo heavy.
1225:32 CAM-3	{04:16} ***** ((simultaneous with previous transmission)) after you get passed the red line. OK? --- you gotta' get your priorities right.		
1225:40 CAM-1	{04:24} ya, right.1		
225:42 CAM-3	{04:26} OK, you want **** for me?		
1225:44 CAM-1	{04:28} ya. --- what'd you come up here for?		
1225:50 CAM-?	{04:34} ****		
1225:53 CAM-3	{04:37} ***** this is (best) one right here that I can see.		

INTRA-COCKPIT COMMUNICATION

AIR-GROUND COMMUNICATION

TIME & SOURCE	CONTENT	TIME & SOURCE	CONTENT
1225:55 CAM-?	{04:39} ****		
1225:57 CAM-3	{04:41} there ya go. --- ****		
1226:01 CAM-1	{04:45} we are.		
1226:19 CAM-2	{05:03} get both of them in the same picture.		
1226:21 CAM-3	{05:05} I am.		
1226:21 CAM-?	{05:05} ****		
1226:24 CAM-	{05:08} ((sound of laughter))		
1226:24 CAM-1	{05:08} do it.		
1226:25 CAM-3	{05:09} oh ya I got it, actually.		
1226:26 CAM-	{05:10} ((sound of laughter))		
1226:29 CAM-3	{05:13} oh, I got it twice. that's cool. I didn't even see what you're talking about. I won't get the rotate but those are good pictures. actually I got more of the little guy than I had of our plane but it's kinda' of neat for comparison.		

INTRA-COCKPIT COMMUNICATION

AIR-GROUND COMMUNICATION

TIME & SOURCE	CONTENT	TIME & SOURCE	CONTENT
		1226:45 RDO-?	{05:29} fun stuff, huh?
1226:46 CAM-3	{05:30} (really)		
1226:48 CAM-?	{05:32} priorities.		
1226:49 CAM-3	{05:33} OK, uh, let's see where were we? we did uh, stab trim then we did INS. how 'bout pitot heat?		
1226:56 CAM-2	{05:40} on.		
		1226:57 TWR-1	{05:41} Japan Air forty two heavy, contact departure.
		1226:58 JA42	{05:42} forty two Echo, see ya.
1226:59 CAM-3	{05:43} fuel heat's checked and off, anti-ice?		
1227:00 CAM-2	{05:44} checked and off.		
1227:05 CAM-3	{05:49} shoulder harness?		
1227:05 CAM-1	{05:49} on.		
1227:06 CAM-2	{05:50} on.		

INTRA-COCKPIT COMMUNICATION

AIR-GROUND COMMUNICATION

TIME & SOURCE	CONTENT	TIME & SOURCE	CONTENT
1227:07 CAM-3	{05:51} comin' on. --- takeoff brief?		
1227:09 CAM-2	{05:53} understood.		
1227:12 CAM-1	{05:56} same brief as before, ah, the departure is still eleven miles, two thousand feet, three hundred and thirty degree heading, going two zero zero. OK?		
1227:21 CAM-3	{06:05} yep. understood.		
1227:23 CAM-2	{06:07} (roger) ((simultaneous with previous comment))		
1227:24 CAM-3	{06:08} flight instruments?		
1227:25 CAM-1	{06:09} checked.		
1227:25 CAM-2	{06:09} checked.		
1227:27 CAM-3	{06:11} taxi check complete.		
1227:37 CAM-1	{06:21} all the, brake temperatures should be right down cool now, right?		

INTRA-COCKPIT COMMUNICATION

AIR-GROUND COMMUNICATION

TIME & SOURCE	CONTENT	TIME & SOURCE	CONTENT
1227:58 CAM-3	{06:42} • --- ***. that was a cool picture though. I didn't even see the other guy comin' and I was just looking, 'cause all I saw was the little tube you know and uh, and what I saw my view finder. all of a sudden he came in there and ****. there's a one forty one piece of crap or a C-5, one of the two.		
1228:22 CAM-2	{07:06} are you still flying those?		
1228:25 CAM-3	{07:09} ya, I hate 'em.		
1228:26 CAM-1	{07:10} Skyliifter.		
1228:28 CAM-3	{07:12} it's gross. --- the whole air conditioning system stinks. get off the airplane you smell like a one forty one. ya, that's what it is.		
1228:39 CAM-?	{07:23} ** --- ****		
1228:44 CAM-?	{07:28} had a model of a one forty one in there and on the box it said sky lizard.		
1228:48 CAM-3	{07:32} did it really?		
1228:49 CAM-?	{07:33} ya.		
1228:50 CAM-3	{07:34} *** huh? ****		

INTRA-COCKPIT COMMUNICATION

AIR-GROUND COMMUNICATION

TIME & SOURCE	CONTENT	TIME & SOURCE	CONTENT
1229:01 CAM-1	{07:45} before takeoff to the line.		
1229:03 CAM-3	{07:47} OK. flaps, V speeds, trim?		
1229:06 CAM-1	{07:50} rechecked for six right.		
1229:07 CAM-2	{07:51} checked for six right.	1229:08 TWR-1	{07:52} Peninsula forty two zero five, gain of three zero knots reported on departure runway three two prior to rotation approximately mid field by heavy Boeing 747, pass behind the heavy C-5 crossing left to right Elmendorf final. caution wake turbulence. cleared for takeoff.
1229:11 CAM-3	{07:55} checked. (six right) six right anti-ice? off, INS? ((concurrent with previous transmission))		
1229:11 CAM-1	{07:55} checked. ((this statement and the two following intermixed with previous transmission))		
1229:15 CAM-2	{07:59} radio ((concurrent with next statement))		
		1229:27 CAM-3	{08:11} **
		1229:28 PNS	{08:12} Peninsula forty two oh five, roger. cleared for takeoff runway three two.

INTRA-COCKPIT COMMUNICATION

AIR-GROUND COMMUNICATION

TIME & SOURCE	CONTENT	TIME & SOURCE	CONTENT
1229:29 CAM-1	{08:13} radio three operating.		
1229:30 CAM-2	{08:14} radio three operating.		
1229:31 CAM-3	{08:15} radio three. altitude alert?		
1229:35 CAM-1	{08:19} two zero zero.		
1229:36 CAM-2	{08:20} two zero zero set.		
1229:37 CAM-3	{08:21} APU goin' off. fuel system set for takeoff.		
		1229:40 TWR-1	{08:24} eight thirty five Anchorage tower runway six left, cleared to land.
		1229:42 835	{08:26} cleared to land six left eight thirty five. 1229:44 {08:28}
CAM-3	forty two Echo said expect a rough ride. ((concurrent with previous transmission))		
1229:48 CAM-2	{08:32} Japan Air, forty six Echo heavy is ready.		
		1229:48 TWR-1	{08:32} Japan Air forty six Echo heavy Anchorage tower runway six right, taxi into position and hold. pilot reports severe turbulence leaving two thousand five hundred, climbing on the Knick off runway six by a company heavy Boeing 747.

INTRA-COCKPIT COMMUNICATION

AIR-GROUND COMMUNICATION

TIME & SOURCE	CONTENT	TIME & SOURCE	CONTENT
1230:02 CAM-1	{08:46} OK.		
		1230:06 RDO-2	{08:50} roger, understood, thank you.
1230:06 CAM-?	{08:50} batten down the hatches folks.		
1230:07 CAM-3	{08:51} we're expecting a rough ride. ((yelled in a loud voice))		
		1230:09 TWR-1	{08:53} Japan Air forty six Echo heavy, runway six right, cleared for takeoff.
1230:13 CAM-3	{08:57} (reports of) severe turbulence on climbout, I don't what else is out on that galley now, but we're getting ready to blast off so just keep an eye out.		
1230:19 CAM-?	{09:03} ** aw right.		
1230:20 CAM-1	{09:04} all the way on the check list.		
1230:21 CAM-3	{09:05} all the way.		
1230:22 CAM-1	{09:06} cleared to go.		
1230:24 CAM-3	{09:08} transponder?		

INTRA-COCKPIT COMMUNICATION

AIR-GROUND COMMUNICATION

TIME & SOURCE	CONTENT	TIME & SOURCE	CONTENT
1230:25 CAM-2	{09:09} on, fifteen sixty one.		
1230:27 CAM-3	{09:11} ignition is on, ** air conditioning set, body ****		
		1230:35 TWR-1	{09:19} Peninsula forty two zero five, contact departure.
		1230:38 PNS	{09:22} forty two oh five.
1230:53 CAM-	{09:37} ((sound of click))		
1230:54 CAM-1	{09:38} centered disarmed.		
1230:55 CAM-3	{09:39} anunciator panel checked. lights?		
1230:56 CAM-1	{09:40} on.		
1230:58 CAM-3	{09:42} before takeoff check complete.		
1230:59 CAM-	{09:43} ((sound of engine power increasing))		
1231:02 CAM-1	{09:46} max power.		
1231:02 CAM-3	{09:46} max power. --- max power is set, and you've got --- ninety three percent.		

INTRA-COCKPIT COMMUNICATION

AIR-GROUND COMMUNICATION

TIME & SOURCE	CONTENT	TIME & SOURCE	CONTENT
1231:23 CAM-1	{10:07} thanks.		
1231:24 CAM-2	{10:08} eighty knots.		
1231:25 CAM-1	{10:09} checked.		
1231:31 CAM-3	{10:15} **		
1231:45 CAM-2	{10:29} V 1.		
1231:46 CAM-1	{10:30} *		
1231:49 CAM-2	{10:33} rotate.		
1231:51 CAM-1	{10:35} *		
1231:52 CAM-2	{10:36} V 2.		
1231:58 CAM-	{10:42} ((sound of snap, then ratcheting sound similar to stabilizer trim))		
1232:00 CAM-2	{10:44} positive rate.		
1232:01 CAM-1	{10:45} gear up.		

INTRA-COCKPIT COMMUNICATION

AIR-GROUND COMMUNICATION

TIME &
SOURCE

CONTENT

TIME &
SOURCE

CONTENT

1232:17 {11:01}
CAM- ((ratcheting sound similar to stabilizer trim))

1232:02 {10:46}
TWR-1 ---- Twin Otter, midfield winds zero niner zero at one two runway one four, cleared for takeoff.

1232:18 {11:02}
TWR-1 Japan Air, forty six Echo heavy, contact departure.

1232:20 {11:04}
RDO-2 gooday.

1232:24 {11:08}
DEP-1 Japan Air forty two Echo heavy, turn right heading three five zero.

1232:31 {11:15}
JA42 right turn three five zero, forty two echo.

1232:34 {11:18}
RDO-2 good afternoon Japan Air forty six Echo out of one thousand for two zero zero.

1232:38 {11:22}
DEP-1 Japan Air forty six Echo heavy Anchorage departure, radar contact, expect severe turbulence two thousand five hundred, heavy 747, smooth to moderate, continuous moderate three thousand through one zero thousand.

1232:51 {11:35}
RDO-2 roger ***

1232:52 {11:36}
CAM-1 *** thirty knots.

INTRA-COCKPIT COMMUNICATION

AIR-GROUND COMMUNICATION

TIME & SOURCE	CONTENT	TIME & SOURCE	CONTENT
1232:53 CAM-3	{11:37} yea.		
1232:54 CAM-1	{11:38} max climb power.		
1232:55 CAM-3	{11:39} max climb. ---		
		1232:57 DEP-1	{11:41} Japan Air four two Echo heavy, contact Anchorage center, one three three point seven.
		1233:02 JA42	{11:46} center thirty three seven, bye bye.
1233:04 CAM-3	{11:48} ##, hang on guys.		
1233:06 CAM-2	{11:50} left three three zero.		
1233:09 CAM-1	{11:53} flaps five.		
1233:12 CAM-2	{11:56} flaps five.		
1233:12 CAM-1	{11:56} (flaps up)		
1233:13 CAM-3	{11:57} (flaps up) --- you mean one.		
1233:18 CAM-1	{12:02} forty knot loss.		

INTRA-COCKPIT COMMUNICATION

AIR-GROUND COMMUNICATION

TIME & SOURCE	CONTENT	TIME & SOURCE	CONTENT
1233:20 CAM-3	{12:04} OK.		
1233:25 CAM-1	{12:09} you didn't put 'em up further, did ya?		
1233:27 CAM-2	{12:11} no no.		
1233:28 CAM-1	{12:12} **		
1233:30 CAM-3	{12:14} ##. --- ## ((sound of laughter)) --- whoa, whoa, whoa.		
1233:50 CAM-	{12:34} ((sound of snap and sound of warning horn))		
1233:51 CAM-3	{12:35} whoa, whoa, thrust reverser. --- got auto fail. we lost something.		
1233:59 CAM-2	{12:43} lost number one and two.		
1234:00 CAM-3	{12:44} ** generator.		
1234:01 CAM-1	{12:45} number two's gone.		
1234:01 CAM-3	{12:45} number two engine shut, down. (whoa, whoa)		

INTRA-COCKPIT COMMUNICATION

AIR-GROUND COMMUNICATION

TIME & SOURCE	CONTENT	TIME & SOURCE	CONTENT
1234:06 CAM-6	{12:50} bank angle, bank angle.		
1234:08 CAM-1	{12:52} alright.		
1234:09 CAM-	{12:53} ((sound of continuous horn))		
1234:10 CAM-1	{12:54} action the emergency.		
1234:12 CAM-3	{12:56} OK, number one ** off.		
1234:15 CAM-2	{12:59} ****		

INTRA-COCKPIT COMMUNICATION

AIR-GROUND COMMUNICATION

TIME & SOURCE	CONTENT	TIME & SOURCE	CONTENT
1234:16 CAM-3	{13:00} two, number two start levers cutoff.	1234:17 DEP-1	{13:01} Japan Air four six Echo heavy ah, Elmendorf tower said that something large just fell off your airplane.
1234:21 CAM-?	{13:05} ***		
1234:21 CAM-	{13:05} ((horn sound stops))		
1234:22 CAM-1	{13:06} yea, we know it		
1234:23 CAM-3	{13:07} OK.	1234:23 RDO-2	{13:07} OK, we know that ah, we're ah, declaring an emergency.
1234:28 CAM-2	{13:12} we know that **** ---- flaps to one.		
1234:28 CAM-?	{13:12} concur.		
1234:30 CAM-1	{13:14} we are returning to ***	1234:29 DEP-1	{13:13} Japan Air four six Echo heavy, will you need to return to Anchorage?
		1234:32	{13:16}

INTRA-COCKPIT COMMUNICATION

AIR-GROUND COMMUNICATION

TIME & SOURCE	CONTENT	TIME & SOURCE	CONTENT
		RDO-2	standby returning and we are declaring an emergency.
		1234:34	{13:18}
		DEP-1	Japan Air three four six Echo heavy, turn left heading two four zero. maintain three thousand, vector ILS runway six right final approach course.
1234:38	{13:22}		
CAM-6	bank angle, bank angle. ((simultaneous with previous transmission))		
1234:40	{13:24}		
CAM-3	OK, hang on.		
1234:42	{13:26}		
CAM-1	sorry we're ****		
1234:44	{13:28}		
CAM-3	do you wanna dump fuel?		
		1234:46	{13:30}
		RDO-2	standby one, standby one, we've got an airplane comin' to us.
1234:47	{13:31}		
CAM-?	*** dump fuel.		
1234:48	{13:32}		
CAM-3	verify number two fire handle.		
		1234:49	{13:33}
		DEP-1	yes sir, there's traffic ten o'clock, two miles, three thousand eight hundred, climbing rapidly.
1234:50	{13:34}		
CAM-	((sound of warning horn))		

INTRA-COCKPIT COMMUNICATION

AIR-GROUND COMMUNICATION

TIME & SOURCE	CONTENT	TIME & SOURCE	CONTENT
1234:52 CAM-1	{13:36} we got traffic over ***		
1234:55 CAM-3	{13:39} number two, verify, fire handle.		
		1234:57 DEP-1	{13:41} Japan Air four six Echo heavy, that traffic's leaving five thousand five hundred.
1235:03 CAM-2	{13:47} number two set.		
		1235:04 RDO-2	{13:48} roger, we are, ah, we are
1235:04 CAM-3	{13:48} pulled. --- we're turning back Anchorage. --- we got two leading edge devices out on the left side.		
1235:10 CAM-1	{13:54} OK. --- give me manual down on the leading edge.		
		1235:14 DEP-1	{13:58} Japan Air four six Echo heavy, descend and maintain one thousand six hundred. can you use runway one four, it's closer?
1235:15 CAM-3	{13:59} OK, manual down leading edge.		
1235:19 CAM-1	{14:03} you dumping fuel?		
		1235:21 RDO-2	{14:05} roger, standby one please.

INTRA-COCKPIT COMMUNICATION

AIR-GROUND COMMUNICATION

TIME & SOURCE	CONTENT	TIME & SOURCE	CONTENT
1235:23 CAM-3	{14:07} not yet. --- need some help up here.		
1235:25 CAM-1	{14:09} OK, now OK, give me (your) flaps back.		
1235:28 CAM-2	{14:12} five, five?		
1235:30 CAM-1	{14:14} five.		
1235:31 CAM-2	{14:15} flaps coming five.		
1235:32 CAM-3	{14:16} OK, fuel's comin' off.		
1235:35 CAM-1	{14:19} it's secured ***		
1235:37 CAM-3	{14:21} OK flaps are comin' down. Number two engine's secured. fuel dumping is in progress. you wanna dump down to five eighty five, correct?		
1235:46 CAM-1	{14:30} we're gonna, well, I'm having a real hard, (you got) LEDs manual down?		
1235:50 CAM-3	{14:34} manual down, they're in progress.		
1235:51 CAM-1	{14:35} alright we're gettin'		

INTRA-COCKPIT COMMUNICATION

AIR-GROUND COMMUNICATION

TIME & SOURCE	CONTENT	TIME & SOURCE	CONTENT
1235:53 CAM-3	{14:37} you got all but two and three, down at this point. --- watch my fuel, give me five hundred eighty five landing weight. ** zero fuel **		
1236:01 CAM-?	{14:45} **.		
1236:02 CAM-2	{14:46} I think we lost the engine.		
1236:04 CAM-3	{14:48} ya, we lost number two engine.		
		1236:05 DEP-1	{14:49} Japan Air four six Echo heavy, say your intentions.
1236:10 CAM-3	{14:54} *** thirty minutes dump. ((concurrent with next transmission))		
		1236:10 RDO-2	{14:54} OK, we, we are ah, we are going to maintain this heading to ah, we are having problem with our flight controls, and also ah, speed, standby one.
1236:13 CAM-1	{14:57} everybody secured?		
1236:14 CAM-3	{14:58} *** (everybody's) secured.		
		1236:25 DEP-1	{15:09} roger, any runway, Japan Air four six Echo heavy, ah, any runway you need. ((concurrent with next statement))

INTRA-COCKPIT COMMUNICATION

AIR-GROUND COMMUNICATION

TIME & SOURCE	CONTENT	TIME & SOURCE	CONTENT
1236:27 CAM-3	{15:11} tell me what kinda' gross, what kinda' fuel weight that is, (I gotta') zero fuel (weight).		
1236:32 CAM-1	{15:16} are you dumping fuel?		
1236:33 CAM-3	{15:17} ** yes, we are. --- would you like the quick return?		
1236:38 CAM-1	{15:22} quick return to the line please.		
1236:39 CAM-3	{15:23} OK, quick return, to the line --- landing gear?		
1236:43 CAM-2	{15:27} off, uh,		
1236:46 CAM-1	{15:30} off.		
1236:46 CAM-2	{15:30} off.		
1236:47 CAM-3	{15:31} I need five eighty five **.		
1236:51 CAM-1	{15:35} did we loose ah, LEDs?		
1236:52 CAM-3	{15:36} you got all but number two, number three is down, it's in progress.		

INTRA-COCKPIT COMMUNICATION

AIR-GROUND COMMUNICATION

TIME & SOURCE	CONTENT	TIME & SOURCE	CONTENT
1236:55 CAM-1	{15:39} **		
1236:57 CAM-3	{15:41} OK, quick return. landing gear?		
1237:00 CAM-2	{15:44} ah up, ah (up).		
1237:04 CAM-3	{15:48} lights out. --- flaps?		
1237:06 CAM-2	{15:50} flaps are maintaining five degrees.		
1237:08 CAM-3	{15:52} five degrees and we're waiting on number three LED. speed brake handle?		
1237:12 CAM-2	{15:56} (forward)		
		1237:18 DEP-1	{16:02} Lion One, Anchorage approach.
1237:19 CAM-3	{16:03} that's complete to the line, OK, the emergency from the top.		
1237:22 CAM-1	{16:06} did you declare an emergency for us?		
		1237:24 DEP-1	{16:08} Japan Air four six Echo heavy, are you able to maintain terrain clearance.

INTRA-COCKPIT COMMUNICATION

AIR-GROUND COMMUNICATION

TIME & SOURCE	CONTENT	TIME & SOURCE	CONTENT
1237:25 CAM-?	{16:09} (OK)		
1237:27 CAM-3	{16:11} I need that data card. --- thank you.		
		1237:29 RDO-2	{16:13} affirmative at this time, and ah, we are maintaining ah, thirteen hundred.
		1237:36 DEP-1	{16:20} Japan Air four six Echo heavy, roger.
		1237:43 RDO-2	{16:27} four six echo, we are dumping fuel.
		1237:43 DEP-1	{16:27} Japan Air four six Echo heavy, roger.
1237:47 CAM-3	{16:31} OK.		
1237:48 CAM-1	{16:32} you did declare an emergency?		
		1237:49 DEP-1	{16:33} Lion zero one, ident. traffic two o'clock, one five miles southbound, three thousand eight hundred, descending to three thousand, Boeing seven two seven. verify three thousand three hundred.
1237:55 CAM-2	{16:39} yes, affirmative.		
1237:55 CAM-3	{16:39} OK, ah. --- ah roger. can you make a call to Evergreen ops and ah, check ***		

INTRA-COCKPIT COMMUNICATION

AIR-GROUND COMMUNICATION

TIME & SOURCE	CONTENT	TIME & SOURCE	CONTENT
1237:57 CAM-1	{16:41} **, we don't need this.		
1237:58 CAM-3	{16:42} I'll just get @ to do it. OK, quick return, the emergency for the engine shut -- failure. --- from the top.		
		1238:03 DEP-1	{16:47} Lion zero one, that traffic off the left is having control ah, difficulties. can you tell how much he's lost?
1238:15 CAM-1	{16:59} give me some speeds quickly.		
1238:16 CAM-3	{17:00} yes, we are. where the ## is my book? --- OK, speeds gonna be --- for five eighty five, I believe one forty five.		
1238:29 CAM-1	{17:13} alright. --- how's our weight doing @.		
1238:35 CAM-3	{17:19} we got it. *** one thirty nine, one (forty) six. -- I'll get it to you in a second. don't have time to do it perfect.		
1238:44 CAM-1	{17:28} give me ah, ILS on the ah, radios.		
1238:54 CAM-3	{17:38} OK, what was the fuel weight? that you came up with.		
1238:55 CAM-?	{17:39} (I don't have it)		
1238:56 CAM-3	{17:40} well we need it now.		

INTRA-COCKPIT COMMUNICATION

AIR-GROUND COMMUNICATION

TIME & SOURCE	CONTENT	TIME & SOURCE	CONTENT
		1238:58 DEP-1	{17:42} Lion one, roger.
1239:01 CAM-1	{17:45} we're gonna lose number, number one here for temperatures.		
1239:04 CAM-	{17:48} ((sound of warning horn))		
1239:08 CAM-3	{17:52} ** EGT, high EGT number one.		
1239:10 CAM-1	{17:54} I know it.		
		1239:12 DEP-1	{17:56} Japan Air four six heavy, I have two F-15s off your right wing three miles, they have you visually, and if you'd like any panel inspection they said they get in closer and ah, and look you over.
1239:23 CAM-1	{18:07} yea, go ahead.		
		1239:25 RDO-2	{18:09} OK, go ahead.
		1239:27 DEP-1	{18:11} Lion One, they said ah, you can proceed on in and take a look and see how much damage has been done.
1239:34 CAM-3	{18:18} OK.		
1239:40 CAM-2	{18:24} OK, which runway do you want?		

INTRA-COCKPIT COMMUNICATION

AIR-GROUND COMMUNICATION

TIME & SOURCE	CONTENT	TIME & SOURCE	CONTENT
1239:41 CAM-1	{18:25} (we're gonna) want six right.	1239:44 RDO-2	{18:28} OK, we'd like the runway six right, this is ah, Japan Air forty six Echo.
1239:45 CAM-3	{18:29} in-flight failure check, shutdown check is complete.		
1239:46 CAM-1	{18:30} why am I loosing air speed here?	1239:47 DEP-1	{18:31} Japan Air four six Echo heavy, understand turning inbound to runway six right.
1239:49 CAM-3	{18:33} what's the airspeed, oh we got # --- (simultaneous with previous transmission))	1239:52 DEP-1	{18:36} Lion, traffic is ah, turning inbound to runway six right now.
1239:58 CAM-6	{18:42} one thousand feet		
1240:02 CAM-2	{18:46} OK, you want ah, some ah, some, rudder trim? rudder trim?		
1240:08 CAM-1	{18:52} ** that's not gonna help.		
1240:10 CAM-3	{18:54} ** fuel **		

INTRA-COCKPIT COMMUNICATION

AIR-GROUND COMMUNICATION

TIME & SOURCE	CONTENT	TIME & SOURCE	CONTENT
1240:13 CAM-1	{18:57} let's try to get this thing turned around.		
1240:20 CAM-3	{19:04} these numbers are wrong. one forty five, one fifty one. -- I don't know, it's back here. *** piece of paper, @ had it. ** departure **		
1240:25 CAM-1	{19:09} ***		
1240:27 CAM-2	{19:11} ***		
1240:28 CAM-3	{19:12} ** no, (I mean on like departure), that fuel oil schedule.		
1240:33 CAM-2	{19:17} OK, number two is on VOR. number two needle, ah is on VOR and can **** VOR.		
1240:38 CAM-3	{19:22} *** cabin.		
1240:40 CAM-1	{19:24} I just want to stay out of the water here you guys.		
1240:42 CAM-2	{19:26} OK.		
1240:43 CAM-?	{19:27} ** nothing else.		
1240:44 CAM-1	{19:28} emergency power.		

INTRA-COCKPIT COMMUNICATION

AIR-GROUND COMMUNICATION

TIME & SOURCE	CONTENT	TIME & SOURCE	CONTENT
1240:45 CAM-?	{19:29} OK, I got it.		
1240:49 CAM-3	{19:33} ***** fuel oil slip.		
1240:50 CAM-1	{19:34} *** flaps. well no we can't.		
1240:51 CAM-?	{19:35} *** operations.		
1240:53 CAM-3	{19:37} don't worry about the call. I need this bad.		
1240:55 CAM-?	{19:39} ****		
1240:57 CAM-3	{19:41} — fell back on the ***		
1240:58 CAM-2	{19:42} you want flaps?		
1240:59 CAM-1	{19:43} no.		
1241:00 CAM-6	{19:44} too low, gear. ((voice similar to ground proximity warning))		
1241:07 CAM-3	{19:51} ** hundred feet. --- ***		
1241:09 CAM-2	{19:53} ***		

INTRA-COCKPIT COMMUNICATION

AIR-GROUND COMMUNICATION

TIME & SOURCE	CONTENT	TIME & SOURCE	CONTENT
1241:10 CAM-3	{19:54} *** fuel weight of seven hundred, right now.		
1241:14 CAM-1	{19:58} how much the airplane weigh?		
1241:15 CAM-3	{19:59} the airplane right now weighs seven hundred, your V speeds for flaps thirty -- ref speed is ----		
		1241:28 DEP-1	{20:12} Lion one, how much can you see and do you have VHF?
1241:32 CAM-?	{20:16} OK, ah,		
1241:33 CAM-3	{20:17} one sixty three --- V ref.		
1241:37 CAM-?	{20:21} right, *****		
1241:41 CAM-3	{20:25} ****		
1241:43 CAM-1	{20:27} how much does the airplane weigh, @?		
1241:46 CAM-3	{20:30} I'm showin' it weighs six eighty seven, right now. --- (there's) fuel dumping in progress.		
1241:52 CAM-1	{20:36} (we have) to land heavy.		

INTRA-COCKPIT COMMUNICATION

AIR-GROUND COMMUNICATION

TIME & SOURCE	CONTENT	TIME & SOURCE	CONTENT
1241:54 CAM-3	{20:38} OK, land heavy, heavy weight landing for ---		
		1241:57 DEP-1	{20:41} understand, ah, he's lost the ah, left (flap) on the left wing?
1242:01 CAM-?	{20:45} we got a fighter over out over here.		
1242:01 CAM-3	{20:45} six eighty five.		
1242:02 CAM-2	{20:46} no, he's looking at, he's looking at us, ya.		
1242:03 CAM-3	{20:47} six eighty five.		
1242:05 CAM-1	{20:49} alright we're going to get ** left flap, how much.		
1242:06 CAM-?	{20:50} rag.		
1242:07 CAM-3	{20:51} what? ---		
1242:11 CAM-3	{20:55} ** rag?		
1242:11 CAM-3	{20:55} no, don't worry about it, write, right over it, I don't care. *** that's cool.		
1242:13 CAM-1	{20:57} alright, quick return, below the line.		

INTRA-COCKPIT COMMUNICATION

AIR-GROUND COMMUNICATION

TIME & SOURCE	CONTENT	TIME & SOURCE	CONTENT
1242:15 CAM-3	{20:59} (below)		
		1242:17 DEP-1	{21:01} Japan Air four six Echo heavy, you've lost ah, approximately fifty percent of the leading edge slats on the left wing, and structural damage to the trailing edge flaps.
1242:19 CAM-3	{21:03} --- approach brief. --- approach brief's understood. --- ASI, EPR, bugs.		
1242:27 CAM-1	{21:11} alright.		
1242:28 CAM-2	{21:12} OK, set.		
1242:30 CAM-2	{21:14} you want to land (on this runway)?		
1242:32 CAM-1	{21:16} I want to land on that runway, right now.		
1242:33 CAM-3	{21:17} OK, *** speeds.		
1242:34 CAM-2	{21:18} you want flaps, more flaps?		
1242:37 CAM-3	{21:21} one sixty eight is your thirty ref speed.		
		1242:39 DEP-1	{21:23} Japan Air four six Echo heavy, runway six right, cleared to land.

INTRA-COCKPIT COMMUNICATION

AIR-GROUND COMMUNICATION

TIME & SOURCE	CONTENT	TIME & SOURCE	CONTENT
1242:40 CAM-1	{21:24} alright. alright. we're landing ****		
1242:42 CAM-2	{21:26} we're on six left.		
		1242:43 RDO-2	{21:27} cleared to land. ((simultaneous with next comment))
1242:44 CAM-1	{21:28} discontinue dump.		
		1242:47 DEP-1	{21:31} and ah, loss of two zero knots reported on final runway six right, one thousand two hundred feet, Japan Air four six Echo heavy.
1242:50 CAM-3	{21:34} alright, discontinuing dump, and you want gear down?		
1242:52 CAM-2	{21:36} OK, slow down, --- you can slow down now.		
1242:53 CAM-1	{21:37} gear down.		
1242:53 CAM-3	{21:37} LED number three never came out.		
1242:54 CAM-2	{21:38} (gear down?)		
1242:56 CAM-1	{21:40} ya, I know, it's gone.		
1243:00 CAM-6	{21:44} glide slope.		

INTRA-COCKPIT COMMUNICATION

AIR-GROUND COMMUNICATION

TIME & SOURCE	CONTENT	TIME & SOURCE	CONTENT
1243:01 CAM-?	{21:45} here's the card.		
1243:02 CAM-3	{21:46} OK, thanks.		
1243:02 CAM-1	{21:46} before landing @.		
1243:03 CAM-3	{21:47} before landing		
1243:04 DEP-1	{21:48} Japan Air four six Echo Heavy, did you copy the wind shear report sir?		
1243:05 CAM-3	{21:49} --- landing gear and tilt?		
		1243:06 RDO-2	{21:50} roger we copy, we are coming for runway six right.
1243:09 CAM-2	{21:53} OK, do you wan' more flap, or flap five is OK?		
1243:11 CAM-1	{21:55} we're gonna go **		
1243:12 CAM-3	{21:56} landing gear tilt, down and green.		
1243:14 CAM-2	{21:58} huh?		
1243:14 CAM-3	{21:58} tilt checked. no smoking sign on.		

INTRA-COCKPIT COMMUNICATION

AIR-GROUND COMMUNICATION

TIME & SOURCE	CONTENT	TIME & SOURCE	CONTENT
1243:19 CAM-6	{22:03} glide slope, glide slope.		
1243:21 CAM-3	{22:05} OK, quick return. ASI, EPR bugs, radio altimeters, altimeters set, nav radios, tuned and identified, CDIs, you guys are set, INS,		
		1243:31 DEP-1	{22:15} Japan Air forty six Echo heavy, all the gear appears to be good.
1243:35 CAM-3	{22:19} set, VOR ADF selectors?		
		1243:38 RDO-2	{22:22} thank you.
1243:40 CAM-3	{22:24} you got ADF on both, flight instruments, radio no flags, air condit ---.		
1243:41 CAM-?	{22:25} turn it down.		
1243:42 CAM-3	{22:26} no no no, hey, leave it alone, please. --- air conditioning pressurization set, auto brake landing switch, we got it set for medium --		
1243:51 CAM-2	{22:35} ****		
1243:51 CAM-3	{22:35} quick return check complete. before landing. landing gear and tilt, down and green, tilt checked, no smoking sign on		

INTRA-COCKPIT COMMUNICATION

AIR-GROUND COMMUNICATION

TIME & SOURCE	CONTENT	TIME & SOURCE	CONTENT
	—		
1243:54 CAM-6	{22:38} terrain --- terrain.		
1244:02 CAM-1	{22:46} zero trim.		
1244:03 CAM-2	{22:47} two hundred feet. zero the trim.		
1244:07 CAM-3	{22:51} speed brake handle.		
1244:08 CAM-1	{22:52} flaps twenty five.		
1244:09 CAM-2	{22:53} flaps are comin' twenty five. flaps is twenty five.		
1244:10 CAM-6	{22:54} one hundred. -- fifty. -- thirty.		
1244:13 CAM-3	{22:57} before landing checklist complete.		
1244:14 CAM-6	{22:58} twenty -- ten.		
1244:15 CAM-3	{22:59} hang on guys. -- spoilers extended, reverse available one two three, or one three four.		
1244:22 CAM-2	{23:06} **		

INTRA-COCKPIT COMMUNICATION

AIR-GROUND COMMUNICATION

TIME & SOURCE	CONTENT	TIME & SOURCE	CONTENT
1244:23 CAM-3	{23:07} got seventy percent, seventy five.		
		1244:25 DEP-1	{23:09} Lion One, advise when he's down. ----- Lion One, wilco and thank you for the assistance.
1244:32 CAM-2	{23:16} # me.		
1244:33 CAM-3	{23:17} no #.		
1244:34 CAM-1	{23:18} thank you.		
1244:36 CAM-3	{23:20} thank you. --- I can't see your speed so uh,		
1244:38 CAM-2	{23:22} ninety.		
1244:39 CAM-3	{23:23} eighty knots.		
1244:41 CAM-1	{23:25} tell that guy thanks for his help.		
1244:45 CAM-3	{23:29} that's cool.		
1244:48 CAM-3	{23:32} OK, we've got thrust reverser lights out.		
1244:51 CAM-1	{23:35} alright, secure ***.		

INTRA-COCKPIT COMMUNICATION

AIR-GROUND COMMUNICATION

TIME & SOURCE	CONTENT	TIME & SOURCE	CONTENT
1244:52 CAM-3	{23:36} check. sorry for *** stuff like that.		
1244:58 CAM-?	{23:42} no problem. no problem.		
1244:59 CAM-3	{23:43} there were just certain priorities we had.		
1245:03 CAM-?	{23:47} ya, I couldn't I couldn't find anything ***		
		1245:04 RDO-2	{23:48} ah, thank you very much tower, this is Evergreen ah, Japan Air forty six Echo, thanks the fighters for us.
1245:10 CAM-3	{23:54} ya, I don't know, they (just fell off) onto the left side, *** and all that. ##, a ground abort and an air abort. ---		
		1245:12 DEP-1	{23:56} Japan Air four six Echo heavy, and ah, they wish to say you did a good job an ah, thank you.
1245:17 CAM-3	{24:01} OK, would you ((laughter)) like, an after landing check? ---		
		1245:21 DEP-1	{24:05} Japan Air four six Echo heavy, contact Anchorage ground one two one point niner.
		1245:23 RDO-2	{24:07} thank you and roger good day.

INTRA-COCKPIT COMMUNICATION

AIR-GROUND COMMUNICATION

TIME & SOURCE	CONTENT	TIME & SOURCE	CONTENT
1245:24 CAM-3	{24:08} now that number three didn't come out, he lost all his instruments over there.		
1245:29 CAM-2	{24:13} oh, thank you very much.		
1245:30 CAM-3	{24:14} thanks @, buddy. --- I don't care how much, you, I, how many beers I owe you in the past. this one I'm going to pay off on. OK?		
		1245:39 RDO-2	{24:23} and ground, Japan Air forty six Echo heavy.
		1245:41 GND-1	{24:25} Japan Air four six Echo heavy, Anchorage ground.
1245:47 CAM-1	{24:31} OK. did we get **** we're not dumping fuel?		
1245:48 CAM-3	{24:32} *** no, it's secured.		
		1245:49 RDO-2	{24:33} OK, we just cleared the runway.
		1245:50 GND-1	{24:34} Japan Air four six Echo heavy, taxi to parking. say your gate number.
		1245:51 RDO-2	{24:35} roger, Romeo ten, and ah, it's very very extremely heavy turbulence, on ah, our takeoff on the left turn.
1245:53 CAM-3	{24:37} ****		

INTRA-COCKPIT COMMUNICATION

AIR-GROUND COMMUNICATION

TIME & SOURCE	CONTENT	TIME & SOURCE	CONTENT
		1246:01 GND-1	{24:45} roger, taxi to Romeo ten.
1246:04 CAM-1	{24:48} ***		
1246:05 CAM-3	{24:49} aye, aye Captain. --- flaps maybe??		
1246:08 CAM-1	{24:52} we ripped off some flaps and stuff.		
1246:12 CAM-2	{24:56} flaps and leading edge.		
1246:13 CAM-3	{24:57} we did some damage ****.		
1246:16 CAM-1	{25:00} lotsa parts missing out there.		
1246:18 CAM-3	{25:02} good job guys, both of ya.		
1246:22 CAM-1	{25:06} thank you for your help. sorry we got disorganized.		
1246:24 CAM-3	{25:08} OK, should we do some of the others, after landing? I'm gonna to turn the probe heat and all that kind of stuff off though.		
1246:31 CAM-1	{25:15} ya, go ahead I got the spoilers ***		

INTRA-COCKPIT COMMUNICATION

AIR-GROUND COMMUNICATION

TIME & SOURCE	CONTENT	TIME & SOURCE	CONTENT
1246:32 CAM-3	{25:16} that was cool, that fighter out there takin' our pictures.		
1246:36 CAM-1	{25:20} I think you'll, did we lose number two engine?		
1246:38 CAM-3	{25:22} yes we did.		
1246:41 CAM-2	{25:25} no -- huh? ya, wait a minute.		
1246:42 CAM-3	{25:26} we lost it. we lost number two engine.		
1246:43 CAM-2	{25:27} lost or ** --		
1246:45 CAM-3	{25:29} I don't know.		
1246:47 CAM-1	{25:31} #, I had a hard time gettin' this thing trimmed enough ***		
1246:48 CAM-3	{25:32} jeez, that bank angle and stuff, man, that was like crazy.		
1246:51 CAM-1	{25:35} I was goin' full full right rudder to get recover the bank.		
1246:54 CAM-3	{25:38} OK, I admit it now. I was scared.		
1246:57 CAM-1	{25:41} we were all scared ***.		

INTRA-COCKPIT COMMUNICATION

AIR-GROUND COMMUNICATION

TIME & SOURCE	CONTENT	TIME & SOURCE	CONTENT
1246:58 CAM-3	{25:42} OK. after the landing ***.		
1247:00 CAM-?	{25:44} it was a nice landing too you guys.		
1247:02 CAM-	{25:46} ((sound of laughter))		
1247:06 CAM-3	{25:50} it was very nice. --- after landing, body gear steering?		
1247:06 CAM-1	{25:50} never got turned on.		
1247:10 CAM-3	{25:54} that's OK. it did now. -- auto brake switch, is off, speed brake handle?		
1247:13 CAM-1	{25:57} forward detent.		
1247:14 CAM-3	{25:58} flaps we're leaving down, lights, set for taxi, radar standby all that crap. --- Anchorage has had a hell of a morning, the fire department, huh?		
1247:34 CAM-1	{26:18} ah, tell 'em that we did get severe turbulence at twenty five hundred feet (today).		
1247:35 CAM-3	{26:19} severe. enough to blow us into a forty five fifty degree bank angle.		

INTRA-COCKPIT COMMUNICATION

AIR-GROUND COMMUNICATION

TIME & SOURCE	CONTENT	TIME & SOURCE	CONTENT
1247:40 CAM-1	{26:24} ya. -- I'll, I'll talk to them. that's alright.		
1247:42 CAM-2	{26:26} OK.		
1247:43 CAM-3	{26:27} ignition is off, window heat off, pressurization checked --- forty five, pressurization checked, hydraulics and brakes.		
1247:54 CAM-1	{26:38} how are the brakes?		
1247:55 CAM-3	{26:39} um.		
1247:56 CAM-1	{26:40} they gotta be hot.		
1247:58 CAM-3	{26:42} I'm sure they must be. um, ya, they're hot. -- all your left sides are really hot.		
1248:05 CAM-?	{26:49} we don't have the number two engine.		
1248:06 CAM-3	{26:50} that's what I thought.		
1248:07 CAM-1	{26:51} alright, I want somebody to talk to ops.		
1248:08 CAM-3	{26:52} we lost the engine.		
1248:10 CAM-1	{26:54} just a minute.		

INTRA-COCKPIT COMMUNICATION

AIR-GROUND COMMUNICATION

TIME & SOURCE	CONTENT	TIME & SOURCE	CONTENT
1248:10 CAM-?	{26:54} it's gone.		
1248:11 CAM-1	{26:55} I want somebody to talk to ops.		
1248:12 CAM-3	{26:56} I got it.		
1248:14 CAM-1	{26:58} tell 'em that we got really hot brakes on the airplane.		
1248:16 CAM-3	{27:00} OK.		
1248:17 CAM-1	{27:01} so, ***		
1248:18 CAM-2	{27:02} ***		
		1248:18 RDO-3	{27:02} Evergreen ops, Japan Air four six Echo.
		1248:21 EVV-1	{27:05} four six Echo Evergreen ops, go ahead.
		1248:24 RDO-3	{27:08} we did indeed lose number two engine and we have very hot brakes on the left side of the aircraft. how copy?
1248:32 CAM-?	{27:16} yep, we sure as ## shucked number two engine, it's gone.		
		1248:34 EVV-1	{27:18} copy all. you on the blocks now?

INTRA-COCKPIT COMMUNICATION

AIR-GROUND COMMUNICATION

TIME & SOURCE	CONTENT	TIME & SOURCE	CONTENT
		1248:35 RDO-3	{27:19} ah negative, we're taxiing in I just wanted you to warn maintenance that the brakes on the left side are indeed very hot. *****.
		1248:45 EVV-1	{27:29} OK, copy all. thanks @.
1248:51 CAM-3	{27:35} OK, somebody can kiss me and tell me I'm still here ****		
1248:53 CAM-1	{27:37} I'll kiss you in a minute here @, **		
1248:55 CAM-3	{27:39} OK. you got it.		
1248:57 CAM-1	{27:41} saved my butt.		
1248:58 CAM-3	{27:42} OK, everybody did.		
1249:01 CAM-1	{27:45} ***** had this problem *** and it didn't get any better ** turbulence ****		
1249:05 CAM-3	{27:49} I want pictures. --- um, what were we doing? --- guess we can crank the APU.		
1249:18 CAM-1	{28:02} go ahead and get the APU running.		
1249:22 CAM-2	{28:06} I asked them to come closer.		

INTRA-COCKPIT COMMUNICATION

AIR-GROUND COMMUNICATION

TIME & SOURCE	CONTENT	TIME & SOURCE	CONTENT
1249:24 CAM-3	{28:08} number four's steady, number one hydraulics?		
1249:31 CAM-?	{28:15} the the gauge is just going in circles **		
1249:34 CAM-3	{28:18} OK. that was like, look at his gauges ***** I'm just gonna crank the APU and we'll see what happens. ----- it's out over the water at least hopefully. no actually, it's over Anchorage somewhere. we took off on six left and hit all that # ****		
1249:41 CAM-1	{28:25} OK, uh, everybody.		
1250:03 CAM-3	{28:47} yes.		
1250:05 CAM-1	{28:49} we need to gart start gettin' our story right so we can start detailing everything that happened.		
1250:08 CAM-3	{28:52} OK, let's, do you wanna get blocked in first, or, do you wanna do it now?		
1250:11 CAM-1	{28:55} *** just thinking about it, no we're gonna get blocked in, and everything secured so we won't catch the ## on fire from the brakes.		
1250:17 CAM-3	{29:01} it was eighteen hundred feet is where we first started catching the # is what I saw. APU is start, check. Now we got indications all over the place it's real weird #.		

INTRA-COCKPIT COMMUNICATION

AIR-GROUND COMMUNICATION

TIME & SOURCE	CONTENT	TIME & SOURCE	CONTENT
1250:30 CAM-1	{29:14} ya, well ****		
1250:32 CAM-3	{29:16} including a wing overheat on the left side. can we turn off the air?		
1250:37 CAM-1	{29:21} I don't, I don't know if the turbulence ripped that engine loose or ****		
1250:40 CAM-2	{29:24} it did. I think ****		
1250:43 CAM-1	{29:27} **** or if the engine blew and.		
1250:47 CAM-2	{29:31} they want the other one, the other one.1		
250:49 CAM-1	{29:33} turn off **** number one.		
1250:53 CAM-3	{29:37} number one, it's two ADPs are comin' off. we've got a wing overheat. I'm taking all the air off the left wing. OK?		
1250:59 CAM-1	{29:43} I'm sure we do. I'm sure we do. --- isolate the wing, please.		
1251:07 CAM-3	{29:51} ya, it's isolated and ah, I'm gonna wait on the APU and all that crap.		

INTRA-COCKPIT COMMUNICATION

AIR-GROUND COMMUNICATION

TIME & SOURCE	CONTENT	TIME & SOURCE	CONTENT
1251:08 CAM-2	{29:52} you're lucky that that one didn't take the number one out.		
1251:10 CAM-1	{29:54} yes, yes. we're real lucky. with all the parts that came off *****		
1251:16 CAM-3	{30:00} I think everybody here is going to get their medical ***** good thing no one drank last night, huh?		
1251:23 CAM-1	{30:07} that's right.		
1251:28 CAM-3	{30:12} OK, I don't know what you want *****		
1251:31 CAM-1	{30:15} tell me to turn left, #. *****		
		1251:34 RDO-3	{30:18} Evergreen ops, we're going to need a power unit out here. we got overheat on the left wing also and we don't want to crank the APU so bring us the ground power unit.
1251:39 CAM-1	{30:23} I can turn left all day. ((simultaneous with previous transmission)) down one and four.		
		1251:47 RDO-3	{30:31} OK, thanks.
1251:49 CAM-3	{30:33} um, I don't know, I don't have the APU cranked because of that wing leading edge overheat.		
1251:52	{30:36}		

INTRA-COCKPIT COMMUNICATION

AIR-GROUND COMMUNICATION

TIME & SOURCE	CONTENT	TIME & SOURCE	CONTENT
CAM-1	we gotta get these brakes off.		
1251:54	{30:38}		
CAM-3	OK. -- copy. -- number one and four comin' down. power's comin' off.		
1251:57	{30:41}		
INT-1	OK, you got the chocks in?		
1251:59	{30:43}		
INT-7	chocks are in.		
1252:02	{30:46}		
INT-1	OK, we don't have an APU, we're powerin' it down right now. ah, brakes are very very hot.		
1252:06	{30:50}		
CAM-3	OK, comin down three and four. --- power's coming off.		
1252:10	{30:54}		
INT-7	copy that. you guys did a good job gettin' it in here.		
1252:12	{30:56}		
CAM-2	number one radio can be on.		
1252:13	{30:57}		
INT-1	well, I didn't think it'd make it.		

END of TRANSCRIPT

END of RECORDING

APPENDIX C

MINISTRY OF TRANSPORT, JAPAN

COMMENTS ON DRAFT OF FINAL REPORT

*Aircraft Accident Investigation Commission
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KUI-CHO No. 058
1 October, 1993

Mr. Thomas E. Haueter
Deputy Chief
Major Investigations Division
National Transportation Safety Board
Washington D.C. 20594, U.S.A.

ref; B747-121, N473EV, ANCHORAGE, 31 MARCH 1993

Dear Mr. Haueter,

In reply to your letter which afforded us an opportunity of reviewing the draft final report of the above accident, as a result of consultation with Japan Airlines and Civil Aviation Bureau of Japan, the Aircraft Accident Investigation Commission as the state of operator in Annex 13 has no comment on the draft final report.

We appreciate your faithful mind to this matter and look forward to the final report.

Very truly yours,



M. Matsumoto
Chief Investigator
Secretariat, Aircraft accident
Investigation Commission

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