03/01/94 Northwest Airlines

Official Accident Report Index Page

Report Title	NORTHWEST AIRLINES FLIGHT 18 BOEING 747-251B, N637US NEW TOKYO INTERNATIONAL AIRPORT NARITA, JAPAN MARCH 1, 1994

Facts of the Accident

Accident NTSB ID	94-02
Airline	Northwest Airlines
Model aircraft	747-251B, N637US
Aircraft manufacturer	Boeing
Date	03/01/94
Time	1340
Location	New Tokyo International Airport, Narita, Japan
Country	JPN
Fire during flight?	N
Fire on the ground?	Y
Probable cause	Maintenance and inspection personnel who worked on the airplane were not adequately trained and qualified to perform the required maintenance and inspection functions.
Contributing causes	The work environment for the heavy maintenance of the airplane was inadequate and contributed to an error-producing situation for the workers.
Report ID	NTSB/SIR-94/02
Pages	61
Day or night?	Day
Flight number	18
Flight origin	Hong Kong
Flight destination	JFK International Airport, Jamaica, NY
Description	The aircraft stopped on a taxiway at Narita, Japan, with the front of the No. 1 engine touching the ground. The lower forward engine nose cowl had been ground away as it dragged along the runway. A fire near the No. 1 engine was rapidly extinguished by local fire fighters.

Abstract

This special investigation report addresses the maintenance activity at Northwest Airlines that led to the accident involving Northwest Airlines flight 18, a B-747, during the airplane's intermediate stop at Narita, Japan, while it was flying from Hong Kong to John F. Kennedy International Airport, Jamaica, New York, on March 1, 1994. Safety issues in the report focused on maintenance operations and maintenance work environments. Safety recommendations concerning these issues were made to the Federal Aviation Administration and to Northwest Airlines.

Executive Summary

On March 1, 1994, about 1340 Japanese Standard Time, Northwest Airlines flight 18, a B-747, flying from Hong Kong to John F. Kennedy International Airport, Jamaica, New York, with an intermediate stop at New Tokyo International Airport, Narita, Japan, stopped on a taxiway at Narita with the front of the No. 1 engine touching the ground. The lower forward engine nose cowl had been ground away as it dragged along the runway. A fire near the No. 1 engine was rapidly extinguished by local fire fighters, and all passengers remained aboard. They were subsequently deplaned about 30 minutes after the airplane came to a stop on the taxiway. There were no injuries.

The Safety Board conducted this special investigation because of the ramifications of the maintenance anomaly that precipitated the accident to the U.S. aviation industry. The report addresses the activity at the Northwest Airlines maintenance facility that led to the accident and only briefly describes the operational aspects of the flight and landing at Narita.

The accident and the events leading up to it are being investigated by the Japanese Aircraft Accident Investigation Commission (JAAIC), in accordance with procedures outlined in Annex 13 to the Chicago Convention on International Civil Aviation. The Safety Board assisted the JAAIC, also in accordance with Annex 13, by gathering data at the Northwest Airlines maintenance base in Minneapolis/St. Paul, Minnesota, on the maintenance activity affecting the airplane.

As a result of this special investigation the Safety Board concluded that maintenance and inspection personnel who worked on the airplane were not adequately trained and qualified to perform the required maintenance and inspection functions. In addition, the work environment for the heavy maintenance of the airplane was inadequate and contributed to an error-producing situation for the workers.

The Safety Board made several recommendations to the Federal Aviation Administration concerning human engineering principles in maintenance operations, and the critical assessment of maintenance work environments. Recommendations were made to Northwest Airlines concerning the same subjects.

1.Factual Information

1.1 Flight Synopsis

On March 1, 1994, Northwest Airlines (NWA) operated flight 18, a B-747-251B, from Hong Kong to John F. Kennedy International Airport, Jamaica, New York, with an intermediate stop at New Tokyo International Airport, Narita, Japan. According to the captain and first officer, the flight, touchdown, and initial landing rollout at Narita, around 1340 Japanese Standard Time, were routine. Engine thrust reversing was normal on all four engines until the flightcrew moved the engine power levers out of reverse thrust at about 90 knots. During the rollout, the No. 1 engine and pylon rotated downward about the midspar pylon-to-wing fittings into a position in which the lower forward part of the engine nose cowl contacted the runway. The primary forward upper link fuse pin was later found fractured within the No. 1 engine pylon.

The airplane was subsequently stopped on a taxiway, with the front of the No. 1 engine still contacting the ground. The lower forward engine nose cowl had been ground away as it slid along the runway. **(See figure 1)**. A fire near the No. 1 engine was rapidly extinguished by local fire fighters, and all passengers remained aboard. They were subsequently deplaned via portable boarding stairs about 30 minutes after the airplane was brought to a stop. There were no injuries.

Figure 1.--No. 1 engine.

1.2 Special Investigation Protocol

The accident that precipitated this special investigation occurred at New Tokyo International Airport, Narita, Japan. The accident and the events leading up to it are being investigated by the Japanese Aircraft Accident Investigation Commission (JAAIC), in accordance with procedures outlined in Annex 13 to the Chicago Convention on International Civil Aviation. The Safety Board assisted the JAAIC, also in accordance with Annex 13, by gathering data at the Northwest Airlines, Inc., (NWA) maintenance base in St. Paul, Minnesota, on maintenance activity regarding the accident airplane. The Safety Board also examined a copy of the cockpit voice and digital flight data recorder tapes. The data gathered by the Safety Board were provided to the JAAIC in June 1994.

The Safety Board performed this special investigation because of the ramifications to the US aviation industry of the maintenance anomaly that precipitated the accident. The Safety Board acknowledges that this report and the Japanese accident investigation report will contain many common elements. However, it should be emphasized that the full report of the investigation will be issued by the government of Japan. This special investigation report addresses the activity at the NWA maintenance facility that led up to the accident and will only briefly describe the operational aspects of the flight and landing at Narita.

As part of the investigation, the Safety Board conducted 18 interviews of NWA maintenance employees, including mechanics, inspectors, and management personnel. The Safety Board also interviewed two Federal Aviation Administration (FAA) maintenance inspectors assigned to oversee the NWA maintenance operations. Appendix B contains summaries of the interviews. The Safety Board also gathered information related to similar maintenance anomalies at airlines other than NWA. Routine Safety Board investigation procedures were followed during this special investigation. Parties involved were the FAA, NWA, the Air Line Pilots Association (ALPA), the Boeing Commercial Airplane Group, and the International Association of Aerospace Workers and Machinists (IAM).

1.3 Failure of the Engine Support Fittings

The fractured forward upper link fuse pin from the No. 1 pylon was recovered in three pieces and was retained by the JAAIC for metallurgical examination. Examination of the pin revealed that it fractured in static overload and that there was no evidence of preexisting fatigue.

Prior to this landing, at some unknown time, the aft fuse pin on the pylon diagonal brace had migrated out of its fitting. The pin was found loose in the pylon structure. It was intact, undamaged, and had no evidence of preexisting defects. The aft diagonal brace fuse pin is normally retained by both a primary retainer (two washer-like retainer caps and a through bolt) and a secondary retention clip (a bolt-on C-shaped bracket).**(See figure 2)**. However, a search of the airplane pylon and engine area, as well as the runway surface at Narita, revealed neither the aft diagonal brace fuse pin primary nor secondary retaining devices.

The March 1, 1994, NWA Fleet Information Register indicates that the airline operates 41 B-747 airplanes of various models. NWA officials stated that 7 airplanes, numbers 6631, 6632, 6636, 6637 (the accident airplane), 6638, 6739 and 6740, of its 31 B-747 aircraft, have the secondary retainers installed on the aft diagonal braces, unless the third generation of pins had been installed. Third generation pins required no secondary retaining devices.(See**figure 2** and **figure 3**).[1]

The airplane had accumulated 14 flight cycles since the most recent "C" check that was completed on February 21,

1994. A takeoff and subsequent landing constitute a flight cycle.

The day after the accident, NWA personnel advised the Safety Board and the JAAIC that a set of diagonal brace fuse pin primary and secondary retainers had been found in the NWA maintenance facility in an unmarked white cloth bag. According to NWA officials, the bag was found between the hand rail and a piece of "2 by 4" wooden board on the left under-wing work stand. This was adjacent to where work had been performed on the No. 1 engine of N637US. Prior to the accident, N637US had undergone a "C" check at that work stand in NWA's maintenance facility. The "C" check had included maintenance and inspection of the diagonal brace fuse pin lugs.

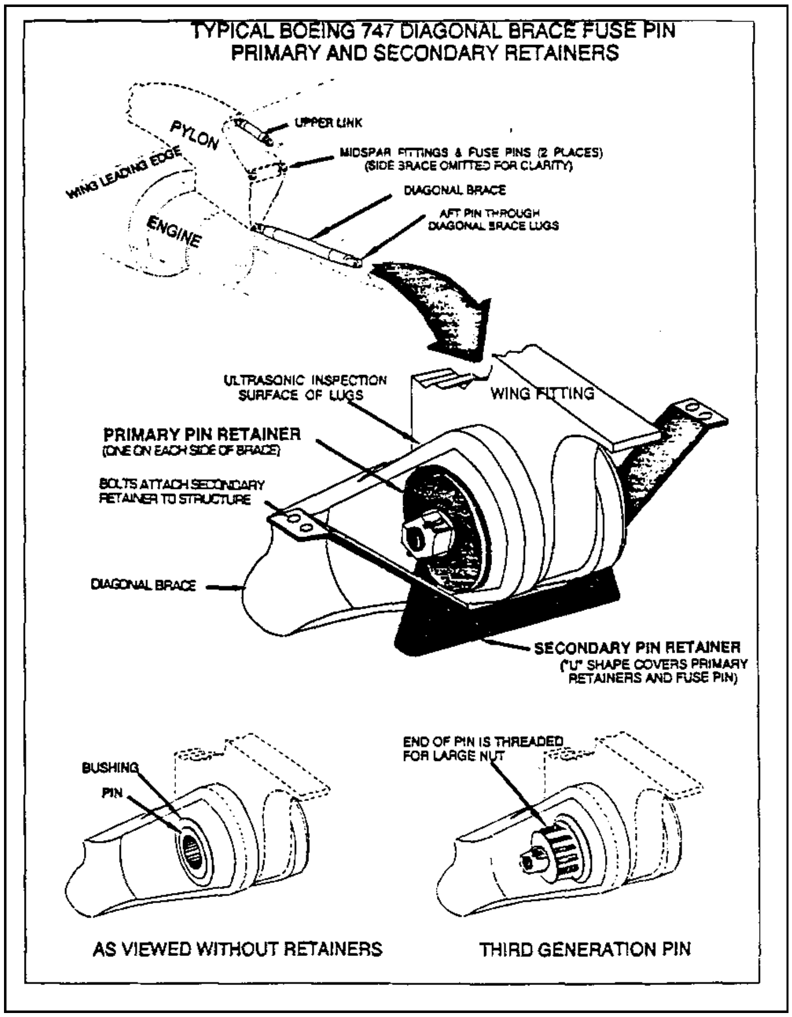

Figure 2.--Diagonal brace attachment details.

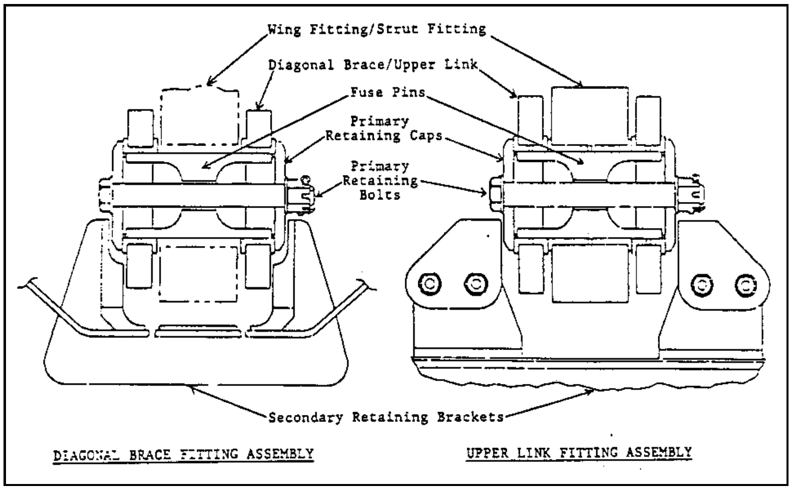

Figure 3.--Diagonal brace and upper link fitting assemblies.

1.4 General NWA Maintenance Procedures

NWA, with the approval of the FAA, had developed overall maintenance-related procedures in the years before the accident. As they relate to this accident, they included:

1. Establishment of a General Engineering and Maintenance Manual (GEMM);
2. The production of work planning instructions through a computerized system known as CITEXT;[2]
3. Monitoring the completion of maintenance actions prescribed by CITEXT.
4. Prominent display of red tags when vital components were disassembled or disconnected; and
5. The requirement for a final inspection of maintenance actions taken, by individuals not involved in performing those maintenance actions, before approval can be given to close a work area.

1.4.1 General Engineering and Maintenance Manual (GEMM)

The GEMM contained the policies and general operating procedures for the NWA maintenance activities. These include work control procedures, policies for handling paperwork in the hangars, and the like.

1.4.2 Citext

According to NWA personnel, the CITEXT system had come to the airline from a merger with Republic Airlines in 1986 and replaced the hard copy, manually generated system then in use at NWA. The CITEXT-generated work cards followed the general instructions contained in the aircraft maintenance manuals. CITEXT policies and procedures are contained in the GEMM. CITEXT cards contain step-by-step instructions for the maintenance activity. NWA personnel estimated that about 95 percent of the routine maintenance procedures performed were generated by CITEXT, with the remainder coming from maintenance manuals or other instructions.

CITEXT work instructions were written as blocks of tasks. For example, a task might describe opening an access panel, performing a maintenance or inspection activity, and closing the panel. Maintenance planners would use a checklist to identify and organize the correct groups of work tasks. The planned activities were informally reviewed by another maintenance planner and signed by the planner's manager. The tasks were then printed as a sequence of work cards, each of which contained the step-by-step instructions for a maintenance or inspection activity, sign-off areas for maintenance and inspection personnel, and locations of reference information in the GEMM, maintenance manuals, or other sources.

The Lead Mechanics on the shop floor would assign work cards to the individual mechanics, who were to follow the steps called out to complete the tasks. Some groups of mechanics had been segregated into crews, such as a dedicated engine crew. When interviewed about receipt of work cards, several people stated that due to the repetition of using the CITEXT work cards, they skimmed the instructions, looking for changes.

Placement of an "R" in the left margin of a CITEXT-generated card denoted a revision. For example, following the accident at Narita, the CITEXT instruction for inspection of the engine pylon diagonal brace strut lugs was revised to add the ship identification of the seven NWA B-747 airplanes that require installation of a secondary retainer in the pylon aft diagonal braces. The "R" was seen in the margin of the revised cards.

The Safety Board investigation identified numerous problems with the CITEXT system. For example, certain tasks were duplicative, and two cards could call for opening a common access panel. When interviewed, mechanics said that they would write "N/A" (for Not Applicable) when work had already been performed. The Director of DC-10/B-747 Maintenance stated that he was aware that many people had a negative opinion of the CITEXT system and cited other problem areas. The most common CITEXT problems mentioned were conflicts with the airplane maintenance manual, and the lack of graphics and charts. Although the CITEXT system was said to have been developed to provide a single set of work instructions, the system required extensive coordination with the airplane maintenance manual.

According to NWA officials, at the time of the accident, the CITEXT system was undergoing modifications and improvements, and the improvements were reviewed by groups of users. Still, more than half of the workers interviewed for this investigation were critical of the CITEXT instructions. Many added that the current system was an improvement over the previous system. The Director of DC-10/B-747 Maintenance noted that since system acquisition, many CITEXT problems had been resolved through an established document change program and that one employee specialized in CITEXT changes. A group composed of managers, lead mechanics, and staff from NWA technical publications and maintenance programs met regularly to improve the system. NWA general inspectors were not included in the task force.

1.4.3 Maintenance Training

NWA maintenance officials stated that regular formal classroom training in NWA general maintenance procedures did not exist. General training was normally informal on-the-job training (OJT), although some employees reported having attended classroom sessions. Lead mechanics were responsible for the instruction of new employees assigned to them. OJT also had been used to teach mechanics and inspectors the subject materials contained in the GEMM for which each individual was responsible.

The airline had seven instructors assigned to B-747 and DC-10 maintenance training. The instructors conducted formal type-specific maintenance training courses for the B-747-100, 747-200, and 747-400. Mechanics assigned to the training were prioritized by training need and time in job assignment. A Director of Training position existed in the maintenance management. The position was vacant at the time of the accident, and the duties had been temporarily reassigned to an acting director.

On July 1, 1992, NWA had modified its maintenance training program and had implemented a program of 1-day familiarization training to be administered to newly hired mechanics. The training included the following topics:

1. Company and maintenance organization; including a GEMM overview;
2. Company rules and regulations;
3. Airplane logbook, manuals, cards and forms;
4. SCEPTRE (computerized maintenance tracking system) orientation;
5. Hazardous materials; and
6. Airframe/Powerplant familiarization.

1.4.4 Nonroutine Discrepancies

During the course of any maintenance activity, including inspections, the NWA maintenance system provided any mechanic or inspector with the ability to identify a "nonroutine" condition or work task. A numbered, red "Unit Inoperative or Removed" (NWA form OM 249) tag could be attached to the airplane in the vicinity of the system affected. The nonroutine card associated with this red tag contains a description of the condition identified, the location on the airplane, and space to record maintenance actions taken to correct the discrepancy. Nonroutine maintenance cards could also be generated for reasons that would not require the generation of red OM 249 tags.

The nonroutine card is comprised of three copies; two copies would be placed on the airplane's "work control board,"[3] and one copy would go into a separate security file. The mechanic taking the work assignment would decide, in accordance with the GEMM, whether the actions should be entered into SCEPTRE. Closure of shop paperwork, prior to return of the airplane to service, required accounting for each nonroutine card. One person noted that the multiple copies prevented missing closure of necessary work items, even though red tags were occasionally lost from the airplane during subsequent maintenance activities, such as airplane washing.

All of the maintenance and inspection personnel interviewed were asked to describe the red OM 249 tags and how to use the forms. The answers were not consistent with respect to how to use the forms, or when to complete them. The majority of mechanics stated that they would complete the form before compromising major components, such as the removal of strut parts. Some mechanics said that although they could do it by themselves, in practice they would bring in an inspector to initiate a red OM 249 tag. Still others said that the red OM 249 tag would be unnecessary if the work could be completed by the end of their shift.

1.5 "C" Check Details Relevant to the Engine Pylon Fittings

Prior to the scheduled nondestructive testing (NDT) inspection of the diagonal brace lugs and other work within the No. 1 pylon, NWA mechanics performing the "C" check were assigned to open the strut aft fairing doors and prepare the diagonal brace and other components for inspection. The written guidance they used for the NDT inspection was a CITEXT work control card titled, "INSP, 66, AD, #1NAC/PYL DIAG B." (See appendix A). Step 4 of this CITEXT card specifies the removal of the U-shaped secondary retention feature from the underside of the wing and the diagonal brace. The procedure does not call for the removal of the primary retention through bolt and washers. Removal of the secondary retention device would allow room to maneuver the transducer of the ultrasonic inspection device. A mechanic accomplished this step and also the next step on the card that specified a thorough cleaning of the diagonal brace lugs. His initials and employee number appear on the sign-off blocks of the CITEXT card for these steps. This individual stated that he did not remove the primary retention devices from the diagonal strut assembly.

The NWA inspector trained in nondestructive testing (NDT) was assigned to ultrasonically inspect both the No. 1 and No. 4 diagonal brace attach point fittings on the accident airplane as part of the "C" check. This inspector used the same CITEXT work cards as used by the mechanic who removed the secondary retainers.

This NDT inspector stated that when he performed his inspection on the airplane's pylon fittings, the primary retainers were installed; however, the secondary retainers had been removed per the CITEXT cards. He did not see a white cloth bag with retainer parts inside, such as the one found later. This individual stated that he had not requested the removal of the primary retainers for any reason in the previous 2 to 3 years because of a change in fitting design. He also stated that he had never experienced a false ultrasonic reading when testing with the primary retainers in place. The NDT inspector stated that he had not recognized that the secondary retainers were required on this airplane. He marked "N/A" in step 10 of the CITEXT instructions that stated, "Reinstall fuse pin secondary retainers at forward and aft lug locations if removed per step 4 above."

Two of the mechanics who closed the No. 4 engine pylon on February 19, 1994, were not experienced with engine and pylon work. Both of these mechanics were certificated airframe and powerplant (A&P) mechanics; however, they were normally assigned to work on the interiors of the airplanes. During the final close-up operation on the airplane, one of these mechanics found a white cloth bag containing the primary and secondary retainers for the No. 4 pylon (as opposed to the No. 1 pylon) attached to the side of the "batwing" door. Neither the mechanics nor their supervisors had considered looking inside the No. 1 pylon, they said.

An examination of the No. 4 engine pylon area by mechanics revealed that the required fuse pin retainers had not been installed on the No. 4 pylon diagonal brace. The retainers found in the cloth bag were then installed, and the airplane was subsequently rolled out for the operational check. The No. 1 engine and pylon had already been inspected and closed before the discovery of the uninstalled retainers on the No. 4 engine pylon. There was no attempt to reinspect the No. 1 pylon diagonal brace or to take long-term corrective actions at that time.

Preparations for the removal of the airplane from the hangar were accomplished on the night of Saturday, February 19, 1994. The "C" check inspection of the airplane was completed 4 days earlier than had been estimated by the work planning group. The airplane was rolled out for an operational check in the early morning hours on Sunday, February 20, 1994, and was released for revenue service on Monday, February 21, 1994.

During the investigation, another airplane undergoing pylon maintenance was examined. Red OM 249 tags were seen in the area of the diagonal brace fuse pins. One was tied to a hydraulic line located near the No. 4 pylon diagonal brace attachment point, and one red tag was also seen near the No. 1 engine access panel (the outboard batwing door). Most of the maintenance and inspection personnel interviewed reported that they did not remember seeing any red tags attached to the No. 1 pylon area on the accident airplane.

The work planning documents for the "C" check on the accident airplane did not call for removal of any diagonal brace aft fuse pin primary retainers. The NDT inspector stated that the primary retainer for the No. 1 diagonal brace was in place when the NDT inspection occurred. The Safety Board also learned that the No. 1 diagonal brace aft fuse pin (as opposed to the primary retainer) was removed during maintenance activity following the NDT inspection of the diagonal brace lugs. The mechanic that related this to the Safety Board stated that he was assigned to check for and remove rust in the area around the No. 1 pylon upper link. Although he found no rust in this area, he did note a migrated upper link bushing and generated a nonroutine work card for rework of the bushing. The discovery of the migrated bushing necessitated the removal of the No. 1 engine and then the upper link, so work on the upper link bushing could be accomplished. During reinstallation of the upper link, the aft diagonal brace fuse pin was removed to facilitate refitting of the upper link to the pylon, because of weight distribution within the pylon.[4] He said that neither the primary or secondary retention devices were in place when he removed and subsequently reinstalled the No. 1 pylon aft diagonal brace fuse pin. He closed by stating that because the diagonal brace fitting/pin system was only compromised by him for a few minutes, no nonroutine paperwork or red OM 249 tags need be generated. None of the mechanics interviewed stated that any maintenance of this sort was done on the No. 4 pylon upper link, or the No. 4 pylon aft diagonal brace.

1.6 Maintenance Personnel Information

1.6.1 Maintenance Personnel Hierarchy

The maintenance personnel in the NWA wide-body hangars have three intermediate levels of supervision. The first level of supervision is that of the lead mechanic (formally called a crew chief). They make specific job assignments and directly oversee the work of mechanics. Maintenance managers, the second level of supervision, supervise and oversee the work by one or more of the lead mechanics. The Director of B-747 and DC-10 Maintenance is in charge of the hangar maintenance staff, which includes the mechanics, lead mechanics and managers, but he has no authority over inspection personnel. The Director of B-747 and DC-10 Maintenance is also responsible for employee training, shop safety, and maintaining an acceptable level of performance of his subordinates and reports to the Vice President of Maintenance Operations. A Vice President of Technical Operations is above the Vice President of Maintenance Operations.

1.6.1.1 NWA Inspection Organization

NWA has a Vice President of Engineering, Inspection, and Quality Assurance. The Director of Central Inspection/Chief Inspector reports to the Vice President and is responsible for the inspection managers and individual inspectors.

1.6.2 Shop Shifts and Staffing Levels

NWA's hangars 5 and 6 at the Minneapolis/St. Paul International Airport (MSP) were dedicated to NWA's B-747 maintenance operations. Aircraft maintenance procedures were performed 7 days a week on three 8-hour shifts. The first shift started at 0648 and ended at 1548; the second shift operated from 1548 to 2248; and the third shift from 2248 to 0648. Maintenance technicians (mechanics) were permitted by union seniority to bid on the shifts they wanted to work.

The Director of B-747 and DC-10 Maintenance stated that 545 people work under his control. He said that 252 of the 545 people were assigned to the first shift. Concerning weekend shifts, he stated that there have been some shift coverage problems, and that on weekends 250 people work the first shift, 130 work the second shift, and 34 work the third shift. He also stated that overtime for personnel in January 1994 was 14 1/2 percent over a 40-hour work week, February 1994 was 20 percent, and, for the first 6 days of March, it was 6 percent. Due to less desire for weekend work, the maintenance and inspection staffs frequently did not work in their usual functions. Individuals worked with constantly changing crews and worked in different settings than they were accustomed.

1.7 The Physical Environment of Hangars 5 and 6

The Safety Board examined the physical environment of hangars 5 and 6. Both hangars have work stands (known as wing docks) located under the wings of B-747s, under the tail surfaces, and at other locations around the airplane. The wing docks in hangar 6 were constructed of scaffolding with plywood decking that provided openings for wing jacks and other maintenance equipment. Loose wooden planks were on the wing docks, some of which were laid across open areas to connect the wing dock to the engine stands, more than 8 feet above the concrete floor. At least one inspector expressed personal safety concerns when he had to rely on the wood planks between the docks to perform his inspections. He said that after becoming tired of climbing down from the wing dock and back up the engine stand, he reluctantly used the temporary wood bridges between the docks.

There were fixed lights on the wing docks to illuminate the underside of the wings and the airplane; however, many of the light fixtures were either covered with paint overspray and provided poor illumination, or were not in use. Mechanics were observed using portable work lights and flashlights when they were working on the undersides of the airplanes. One employee stated that hangar 6 had previously been used for painting airplanes, and that it resulted in paint overspray on the light covers. In contrast, the wing docks in hangar 5 were permanent fixtures that permitted the use of space below the stands. Light levels in the work areas of hangar 5 were higher than in hangar 6.

During the inspection of hangar 6 by Safety Board investigators, a No. 4 engine pylon from a B-747-400 undergoing maintenance had been removed and was placed on a floor stand located under the No. 4 engine position. Other parts removed from the airplane were also placed in racks for parts and on the hangar floor. A ladder stand was adjacent to the No. 4 pylon with a partitioned wooden box on the top step that contained fuse pins and retainers from the No. 4 pylon. The parts overfilled the partitioned areas, and the fuse pin bearing surfaces were resting against each other. On two separate shop visits, investigators observed this box in the same location.

Other stored parts were located on racks located in the hangar area. Part storage was different in different work areas. Some areas were neat, with parts clearly placed in an orderly fashion on the racks. However, as with the wooden box containing fuse pins from the subsequent airplane, storage of vital components was not the same in all areas.

1.8 Other Incidents and the Boeing Response

Migrations of upper link fuse pins or diagonal brace fuse pins have been reported on five occasions by several airlines prior to the NWA Narita accident. One of these resulted in an accident similar to this accident. The other four were discovered during routine maintenance. One other instance of pylon fuse pin migration has occurred since the Narita accident. All of these incidents were attributed to the improper assembly of the components during maintenance.

The pin migration incident that caused the earlier accident involved Air India flight 132 on May 7, 1990. In this incident, an upper link fuse pin fractured immediately after a harder-than-normal touchdown. The engine also rotated to the runway surface around the midspar fitting, as seen at Narita. In this instance, prior to the accident, the aft fuse pin on the diagonal brace had also migrated out of its fitting. According to the Indian investigation report, the fuse pin was found intact at the side of the landing runway with the retaining bolt and nut installed; however, the primary retaining caps were not installed. The Government of India presented the following cause of the accident in its final investigation report:

The accident was caused due to the migration of the improperly installed diagonal-brace aft fuse-pin of the No. 1 engine from its fitting which substantially reduced the load carrying capability of the engine fittings resulting in failure of the upper-link forward fuse pin due to excessive loads on account of probably improper landing leading to a partial separation of engine and fire.

On July 5, 1990, following the Air India accident, Boeing issued Service Letter 747-SL-54-35, suggesting operators ensure that fuse pins are correctly assembled and recommended incorporation of the secondary retention devices at the earliest maintenance opportunity. Following the Narita accident, Boeing issued a revision to the earlier service letter (Service Letter 747-SL-54-35-A). This document stated:

While the 747 nacelle strut upper link and diagonal brace load paths are redundant, the struts were not designed to be fully fail-safe with a member disconnected. The struts were designed for safe separation under conditions exceeding ultimate design loads. The struts have limited fail-safe capability for a detached upper link or diagonal brace. This capability exceeds normal operating loads. However, the fatigue life of the remaining member may be significantly reduced.

The service letter included advice to customers that all fuse pin installations must be correctly assembled and that established maintenance procedures should be adequate to account for all removals and reinstallations of the pins and retention hardware. It also recommended that operators incorporate the secondary retention devices at the earliest maintenance opportunity. No other corrective actions were initiated by Boeing or the FAA at that time.

Following the discovery of one more migrated fuse pin after the Narita accident, on August 26, 1994, Boeing issued Service Letter 747-SL-54-35-C.[5] This service letter reiterated the information contained in the earlier service bulletins on this issue. It also stated that the service bulletin requiring the inspection and replacement of diagonal brace fuse pins (SB 747-54-2153) will be revised by the first quarter of 1995 to include the part number callout in the removal and installation steps. This, Boeing states, will ensure parts accountability during installation.

1.9 FAA Oversight

The principal maintenance inspector (PMI) for NWA has held that position since 1985. He was not responsible for the maintenance oversight of other operators, and he was assisted by two assistant PMIs and six partial program managers (PPMs), one for each type of airplane in NWA's fleet. The PMI stated that he believed NWA was a "compliance-oriented" airline and that company management was professional and cooperative. He was of the opinion that the CITEXT system has improved overall maintenance at NWA, and that it had also made it easier for the FAA to monitor NWA maintenance activity.

The PPM for the NWA B-747 fleet had held that position for 5 months at the time of the accident. For approximately 5 years before he became the PPM for B-747s, he was the PPM for the NWA Airbus A-320 fleet of 50 airplanes. He stated that he often visits NWA hangars 5 and 6 to observe various maintenance operations, and, in fact, attempted to do so at least one night a week. He said that his surveillance also included weekend activity when he observes work accomplished during the inspections. He then followed the paperwork generated by the maintenance to compare work performed against work required. Part of this surveillance procedure was to compare the contents of the CITEXT-generated work cards with GEMM and maintenance manual requirements. There was, however, no formal program (outside of his real-time shop observations and comparisons) to compare a general, random sampling of CITEXT-generated work cards with GEMM and maintenance manual procedures. He also stated that most of his inspections took place after a particular maintenance operation had been completed. In addition, he said that the FAA regional office established his work program, and required that at least 35 percent of his time be dedicated to actual airplane surveillance.

According to FAA personnel, routine surveillance, unless it was required for compliance with airworthiness directives or other specific tasks, did not include monitoring the preparation of work instructions, storage and the documentation of parts removed from airplanes (housekeeping), or audits of completed work.

1.10 Actions Taken by NWA Since the Accident

Since the accident at Narita, NWA has taken the following actions to preclude recurrence of the maintenance anomaly.

1. The NWA Central Engineering Division has revised all engineering orders that require the removal of engine strut fuse pin components. These engineering orders now contain a step that requires inspection signoff and that specifically address reinstallation of all fuse pin retention hardware.
2. The NWS Production Planning Division has accelerated accomplishment of the Boeing service bulletin concerning engine strut third generation fuse pin installation. All B-747 airplanes will have third generation pins installed by April 1, 1995.
3. The NWA Systems and Automation Division is in the process of replacing the CITEXT system with the AMI-Task system job instruction cards that include graphics. AMI-Task will be ready for B-747 periodic maintenance checks by September, 1995.
4. The NWA Technical Publications Division has revised OM-249 red tag procedures via a revision to the CITEXT cards concerning pylon strut removal, installation, and opening and closing of the pylon to insure midspar fuse pin retainer installation.
5. The NWA Technical Operations Training Division has intensified technical training of mechanics throughout the NWA maintenance system. Also, in conjunction with the FAA, Boeing, and the IAM, NWA is implementing a Maintenance Error Decision Aid concept that addresses human factors principles in hangar work procedures.

2. Analysis

2.1 General

The Safety Board examined NWA's overall maintenance practices and procedures, reviewed the airplane's "C" check records, and analyzed why the airplane was returned to service without the primary and secondary aft diagonal brace fuse pin retainers installed on the No. 1 engine pylon.

The Safety Board determined that the secondary retainer for the aft fuse pin on the No. 1 and No. 4 engine pylon diagonal brace had been removed, as required and directed by the CITEXT system, to permit NDT of the diagonal brace end fittings. The inspector who performed the NDT stated that he signed the paperwork, indicating that he performed the required tests, then further stated that he also signed N/A (not applicable) in the blocks that direct the reinstallation of the secondary retainers. The person(s), who removed the primary retainers, and the reasons for their removal, were not identified. The Safety Board could not determine why there were no nonroutine work cards generated or red OM 249 tags applied to the aircraft structure in the vicinity of the primary retainer, after its removal, as required by the GEMM. Although a red OM 249 tag could have been accidentally lost by washing the airplane or other maintenance, a mechanic performing nonroutine parts removal should have generated the nonroutine card paperwork to ensure that the removed parts (in this case the primary and secondary retainer set) were reinstalled and that the area was inspected. The security copy of both the nonroutine work card and the red OM 249 tag, in addition to redundant copies of both forms contained in the work control package, should have precluded the closing of the paperwork prior to the release of the airplane.

The evidence indicates that several important maintenance procedures were either not followed or were followed incorrectly during the maintenance and inspection of the airplane. On February 20, 1994, after all "C" check maintenance actions were considered to have been completed, the airplane was dispatched for revenue flights. After the airplane was returned to service, it completed 14 cycles without incident, prior to the accident flight. The diagonal brace aft fuse pin migrated out of the fitting at some point during the 14 flights, and the upper link fuse pin failed in overload during rollout at Narita.

2.2 Maintenance Procedures

2.2.1 General

The evidence indicates that several of the previously established procedures were either not followed or were followed improperly. They include:

GEMM procedures;

Organizing, describing, and tracking the performance of maintenance actions through a computerized system known as CITEXT;

Monitoring with CITEXT the completion of maintenance actions taken;

Application and prominent display of red OM 249 tags when systems were rendered inoperative or unserviceable; and

Requiring a general visual zonal inspection of the work area before closure.

2.2.2 Fuse Pin Retainers

A given B-747-200 airplane could have two different types of pylon retention fuse pins installed on the four engine pylons. The mechanic performing maintenance on the pylons would be unable to determine the particular pin installed by looking at the CITEXT card. Only by close inspection of the pin could he or she determine the particular generation of pin installed. In addition, only the second generation fuse pins had secondary retainers installed and required removal for inspection.

2.2.3 Citext Procedures

The CITEXT card relevant to this accident specified steps to be carried out to perform the ultrasonic inspection of the engine strut diagonal brace aft lugs to ascertain if crack indications were present. Step 4 of the procedure called for the removal of the secondary fuse pin retainer to allow access for the ultrasonic inspection. The CITEXT card did not direct the removal of the primary fuse pin. However, the evidence suggests that both the secondary and primary fuse pin retainers were removed from the No. 1 and No. 4 engine pylons at some point. Only the last minute fortuitous finding of the fuse pin retainers near the No.4 engine pylon prompted their reinstallation on that pylon.

None of the maintenance personnel that Safety Board investigators interviewed, including all who had worked on the No. 1 or No. 4 pylon diagonal braces, had knowledge of the person who had removed the primary fuse pin retainers from either diagonal brace. Consequently, the Safety Board was unable to identify the individual who had removed either primary retainer, the mechanic who had failed to reinstall the No. 1 diagonal brace primary or secondary retainer, or the specific reason why the primary fuse pin retainers were removed when such action was not specified in the CITEXT instructions. Neither could it be determined why red OM 249 work tags were not placed on the diagonal brace to indicate that a system was compromised.

The Safety Board noted the apparent compartmentalization of maintenance tasking in a large maintenance organization such as that of NWA. The mechanic, who removed the No. 1 pylon aft diagonal brace fuse pin for several minutes to facilitate reinstallation of the No. 1 pylon upper link, was not concerned that the pin was not retained in its fitting in any manner. He believed that the retaining device or devices had conveniently been removed for some valid reason by other mechanics already, that the brace/fitting/pin system was only compromised for a few minutes, and that he would return the system to its exact previous state. Therefore, in his mind, no nonroutine card needed to be generated, and no red OM 249 card needed to be attached in the diagonal brace area. Had he, or any one of his various supervisors, been more aware of the overall maintenance plan for the No. 1 pylon area, the existence of a retainerless fuse pin so late in the "C" check process might have been recognized as an anomaly, and this accident might not have occurred.

The Safety Board examined the quality of the instructions on the CITEXT card to determine how the wording on the CITEXT might have played a part in the accident. Although the relevant card in this accident was created for the maintenance to be performed on the airplane, as well as the particular day in which the maintenance actions were to be carried out, it did not specify the type of fuse pin present on the particular pylon or whether secondary fuse pin retainers were required to be present. Step 4 of the procedure called for the removal of the fuse pin secondary retainer "if installed."

This step is straightforward. If secondary retainers are present when the airplane arrives for maintenance, then they must be removed before NDT inspection of the fitting. However, the necessity for the reinstallation of the secondary retaining devices is not as obvious. The mechanic is required to perform several actions as part of step 10 of the CITEXT card. Nevertheless, these relatively simple actions required the application of different skills. The mechanic first had to examine the pin to determine the type that was installed. Based on this examination, the mechanic then had to perform the necessary maintenance action, as appropriate to the type of fuse pin retainer installed. No guidance was present on the card to help the mechanic determine the potential need for the secondary fuse pin retainer, or to assist in identifying which generation fuse pin was installed. Perhaps more important, no feedback was available to the mechanic to indicate whether his or her determination had been correct.

The mechanic who removed the No. 1 engine secondary fuse pin retainer prior to the NDT estimated that he had performed that task 50 to 100 times over a period of about 4 years. He had previously been employed 22 years performing aircraft maintenance in the U.S. Navy. He also displayed competence in the documentation of work and in the use of "nonroutine" documents. The Safety Board believes that his experience with the airline and with the Navy was sufficient to provide him with an appreciation for the need for full adherence to required maintenance action directions. His experience would not support the type of carelessness in reading and applying instructions that led to this accident, if indeed he removed and failed to reinstall the relevant fuse pin retainers.

NWA mechanics performed their maintenance according to directions on the CITEXT cards. According to NWA, information on the cards originated in the approved airplane maintenance manual and was tailored to the records of previous maintenance actions taken on each airplane. The CITEXT cards were meant to be used as work cards that "translated" procedures referenced in the airplane maintenance manual into a series of maintenance-related actions.

All of the mechanics that the Safety Board interviewed indicated that with CITEXT, they continued to refer to the maintenance manual. The potential for confusion was high among mechanics who were attempting to adhere to the GEMM, coordinate with the maintenance manual, and follow the CITEXT directions.

The Safety Board believes that NWA could have eliminated the potential for confusion among mechanics by clarifying the instructions on the CITEXT card in question. This could have been accomplished by stating on the card that the removal of the secondary fuse pin retainers is necessary only on specific pylons equipped with second generation fuse pins and supplying graphics on the card. Since the accident, NWA has addressed the potential for confusion over retainer types by modifying the text in the CITEXT according to the type of pin installed. Nevertheless, the Safety Board is concerned that the potential for confusion from unclear CITEXT directions may exist elsewhere in the NWA maintenance system. If so, mechanics could become confused by required maintenance actions and might perform an unnecessary action, as a mechanic did on the accident airplane. Therefore, the Safety Board believes that NWA and the FAA should review the NWA CITEXT system, and, where practical, require the modification of sections that refer to actions, components, or systems that are specific to particular airplanes to ensure that the maintenance action requested conforms to the maintenance action required for the specific airplane.

The No. 1 pylon aft diagonal brace primary fuse pin retainer was removed for some unknown reason, at some unknown time, during the "C" check. It was not reinstalled. The secondary retainer was removed in accordance with step 4 of the CITEXT card, but was not reinstalled, as required by step 10 of that card. Specifically, the mechanic was instructed, in part, to: "Reinstall fuse pin secondary retainer at forward and aft lug locations if removed per step 4 above." The Safety Board believes that the failure to reinstall the primary and secondary fuse pin retainers on the pylon of engine No. 1 was the result of a series of errors.

2.2.4 Red OM 249 Tag Procedures

NWA had implemented a procedure to prevent the very errors that led to this accident, but the procedure was not followed. Red OM 249 tags were to be prominently posted in the area in which systems were compromised. The red OM 249 tags were to be removed after the components had been reinstalled or the wiring or tubing had been reconnected. In this manner, mechanics and inspectors had a visual means to alert them when components were not in place and when work was not complete. The Safety Board believes that the red tag procedure is an excellent method, if used properly and consistently, to prevent the type of error that occurred on this accident. It can serve as an additional and highly visible method of alerting mechanics to the fact that maintenance action on a critical component had not been completed.

The investigation revealed several flaws in the application of the airline's red OM 249 tag procedures. Personnel had differing interpretations of the airline's red tag policy. Most of them appeared to understand that a red tag was to be displayed when a major or vital component or system had been compromised. However, the mechanic tasked with removing the secondary fuse pin retainer believed that the red tag was to be posted when specified on the CITEXT. Since the CITEXT card for this action did not call for posting a red tag, he did not post one. Further, it was unclear whether different mechanics would have considered the fuse pin retainers sufficiently critical to warrant the red tags. The evidence suggests that if a red OM 249 tag had been posted following the removal of the fuse pin retainers, someone would have noticed that the maintenance action had not been completed (at least the absence of the primary pin retainer would have been noted) and the accident could have been avoided. Therefore, the Safety Board believes that the failure of the mechanics to use red OM 249 tags following the removal of the fuse pin primary and secondary retainers, as well as the inadequacy of red tag training, was another in the series of errors.

The Safety Board notes that the OM 249 tags are red, a meaningful color in aviation. Red is primarily used to alert pilots or maintenance personnel to an unusual condition, and it stands out within the predominantly green, silver, and brown colors inside the B-747 engine pylon. Investigators noted that a few high strength fasteners within the pylon were highly conspicuous due to small areas of red, and that a prominent color might have stood out for the "OK to Close" inspector who stated that he was looking for obvious discrepancies.

The Safety Board also notes that the incident that occurred since the Narita accident indicate that the potential exists for the omission of both the primary and secondary retainers on reassembly, in spite of the warning message issued by Boeing to operators. The common element between the accidents and incidents has been the maintenance personnel involved. Since the primary retainers independently hold the fuse pins by covering them, the Safety Board believes that making the semi-hollow fuse pin interiors that are normally covered by the primary retainers conspicuously red (or some other conspicuous color such as dayglo orange) would alert maintenance personnel to the omission of the retainers. This would not require the removal of fuse pins from the airplane and could be accomplished as access becomes available. Although the third generation pins are supposed to eliminate the need for secondary retainers, the Safety Board believes that an interim addition of red paint would add a level of safety and that it should be recommended to all operators of B-747 airplanes.

2.2.5 Nondestructive Testing

CITEXT step 6 called for an ultrasonic or NDT inspection of the diagonal brace lugs to ascertain the presence of crack indications. If evidence of cracks were found, step 7 directed the inspector to proceed to step 8. If no cracks were found, the inspector was to put "N/A" (not applicable) in the appropriate boxes of steps 8 and 9, and the mechanic was to go to step 10. The inspector who performed the ultrasonic inspection found no cracks, and appropriately marked N/A adjacent to steps 8 and 9. However, the evidence indicates that he then proceeded to inappropriately mark N/A adjacent to the remaining steps 10 and 11. Step 10 called for the reinstallation of the secondary fuse pin retainer. Consequently, the Safety Board believes that the inspector's inappropriate completion of the CITEXT card was another in the series of errors.

The inspector who performed the ultrasonic inspection performed such inspections almost exclusively. The evidence from this accident suggests that in this routine, he properly focused on the item to be ultrasonically tested but paid less attention to the accompanying paperwork. As a result, he did not notice, and he was not expected to notice, whether the secondary fuse pin retainer had been removed. Following his inspection, his routine was, again appropriately, to mark the CITEXT cards according to what he had found.

The NDT inspector told Safety Board investigators that he marked N/A for steps 8 and 9. He made no mention of marking N/A for the remaining steps, although the marking on the card was clearly similar. The Safety Board was unable to determine why he inappropriately marked N/A adjacent to those steps of the CITEXT card. The evidence does suggest that the inspector merely completed the card inattentively. Overlapping work tasks identified on multiple cards were normally marked out with an "N/A". Therefore, an unquestioning acceptance of the NDT inspector's N/A marks (in the wrong blocks) could have gone unnoticed. The circumstances of this accident illustrate the importance of devoting the necessary attention to accompanying "paperwork" as well as performing the tasks specified by such paperwork. Because of similar occurrences of fuse pin migrations at other airlines, one of which was subsequent to the Narita incident and the Boeing service letter, the Safety Board is concerned that similar problems continue to exist at other airlines. Therefore, the Safety Board believes that the FAA should inform other airlines operating under 14 Code of Federal Regulations (CFR) Part 121 of the circumstances of this accident, and urge them to implement corrective actions, where necessary, to prevent the maintenance program deficiencies that were noted in this accident.

2.2.6 The "OK to Close" Inspection

NWA had implemented a final means to identify disassembled components or systems that had not been reassembled. The "OK to Close" inspection was performed before open doors or panels could be closed. In this inspection, open doors or panels could not be closed until an inspector performed a general, visual, and zonal inspection of the work area.

The inspector stated that signing off of the "OK to Close" inspection indicated that he had examined the work area, found no red OM 249 tags, or any other obvious discrepancies, and signed off on the work that had been performed on that pylon as completed. He qualified his description of the "OK to Close" inspection by stating that it was a quick area inspection for rags and previously identified problem areas. Then, as he was about to approve the work on the No. 4 engine, maintenance personnel found the No. 4 engine fuse pin retainers. Neither he, the maintenance personnel, nor the on-site maintenance managers believed that finding these components near, but not in, the pylon suggested that similar retainers could have been missing from the No. 1 pylon. After the reinstallation of the retainers on the No. 4 pylon, the work on the airplane was considered completed, and the airplane was placed into service. If the inspector or a maintenance manager had gone back and noticed that the fuse pin retainers were missing from the pylon of the No. 1 engine, it is likely that the retainers would have been correctly installed.

The inspector completed and approved the "OK to Close" inspection of the pylon about 0600 on February 20, 1994, at the end of a night shift, on the sixth full night of work, following what was to have been a regularly scheduled 5-day week. NWA personnel indicated that on that night of the week, the number of maintenance personnel on duty was at its lowest for the week. NWA mechanics were consistent in denying that they felt pressure to rush a maintenance action or inspection. Maintenance personnel were aware, however, that the company was expecting the work on the airplane to be completed that night. He indicated that he worked about twice as hard that night, or performed about twice the inspections, in comparison with what he normally did during the week. Moreover, because of the shortage of personnel, he and one other inspector were expected to work on two B-747 airplanes in both hangars 5 and 6. He indicated that on that night, he constantly shifted between the two hangers. This most likely added to his sense of feeling pressured, and possibly to some fatigue by the end of the shift, when he performed the inspection in question.

2.3 Maintenance Training

The evidence indicates that NWA's method of training in the GEMM, CITEXT, and application of the red OM 249 tag procedure was less than systematic. The mechanics who worked on the airplane learned the method informally, through OJT from more experienced maintenance personnel. As a result, the level of understanding of the red tag procedure was largely influenced by the quality of training a mechanic had received from his or her OJT instructor. Consequently, multiple interpretations of the system, including some that were not in accordance with the GEMM, prevailed.

Airlines operating under the provisions of 14 CFR Part 121 are required to adhere to Part 121.375, which states:

Each certificate holder or person performing maintenance or preventive maintenance functions for it shall have a training program to ensure that each person (including inspection personnel) who determines the adequacy of work done is fully informed about procedures and techniques and new equipment in use and is competent to perform his duties.

On July 1, 1992, NWA had modified its maintenance training program and had implemented a program of 1-day familiarization training to be administered to newly hired mechanics. The training included the following topics:

GEMM orientation;

Company and maintenance organization;

Company rules and regulations;

Aircraft logbook, manuals, cards and forms;

SCEPTRE (computerized maintenance tracking system) orientation;

Hazardous materials; and

Airframe/powerplant familiarization.

According to NWA, red tag procedures were to be discussed during the session on aircraft logbook training. With one exception, the mechanics who were interviewed had been hired before this training was initiated. Therefore, nearly all of them had been taught about red OM 249 tags through OJT. As a result, NWA maintenance personnel, who worked on the accident airplane, did not uniformly understand the conditions under which the red tags were to be used and had a variety of interpretations of the procedure. A common perception was that the red tags were an available, but not a required, procedure.

Nevertheless, the Safety Board believes that this procedure, irrespective of its perceived informality, was an important part of the process of ensuring that critical maintenance procedures were performed and completed without error. Because of its importance, the Safety Board believes that NWA should have formalized the red OM 249 tag procedure and ensured that all mechanics understood it and implemented it properly and consistently.

The Safety Board has previously expressed its views on the importance of proper aviation maintenance training in its investigation of the accident involving an Aloha Airlines B-737-200,[6] that lost part of its fuselage in flight. As a result of that investigation, the Safety Board recommended that the FAA:

A-89-55

Revise the regulations governing the certification of aviation maintenance technician schools and the licensing of airframe and powerplant mechanics to require that the curriculum and testing requirements include modern aviation industry technology.

In response to that recommendation, the FAA substantially revised and modernized the curricula required of schools certificated under Federal Aviation Regulations (FAR) Part 147, where many aviation maintenance technician students are being trained. The final rule for this revision of curricula is dated June 29, 1992. Based on these amendments to the regulations for certificating aviation maintenance technician schools, on February 22, 1994, the Board classified A-89-55 "Closed--Acceptable Action."

During its investigation of this accident, the Safety Board has learned that the FAA also intends to modify the requirements for the certification of airframe and powerplant (A&P) mechanics to create a separate category of A&P certificate to be required of mechanics who perform maintenance on aircraft certificated under 14 CFR Part 25. A Notice of Proposed Rulemaking (NPRM) was promulgated to that effect, and comments were due on October 12, 1994.

2.4 Maintenance Working Environment

The Safety Board believes that the "OK to Close" inspector was hindered considerably by the environment of the pylon area. He indicated, for example, that the combination of location of the scaffolding (at a level just below the underside of the wing that forced him into unusual and uncomfortable physical positions) and inadequate lighting from the base of the scaffolding up toward the pylon, hampered his inspection efforts. Moreover, the underside of the pylon was illuminated by portable fluorescent lights that had been placed along the floor of the scaffolding. These lights had previously been used in areas where airplanes were painted, and, as a result, had been covered with the residue of numerous paint applications that diminished their brightness. These factors combined to cause the inspector to view the fuse pin retainers by holding onto the airplane structure with one hand, leaning under the bat wing doors at an angle of at least 30°, holding a flashlight with the other hand pointing to the area, and moving his head awkwardly to face up into the pylon area. Concerning other work areas around the airplane, the inspector admitted that he felt apprehensive because of the lack of protection against a person falling from the scaffolding, a height of about 8 feet above the concrete floor.

In its investigation of the previously cited accident involving the Aloha Airlines Boeing 737-200, the Safety Board addressed human factors-related deficiencies similar to those noted in this accident; that is, in the environment in which visual inspections were being carried out. In that investigation, the Safety Board noted the challenges that these deficiencies presented to the performance of visual inspections and the resultant diminished effectiveness in detecting "errors" during such inspections. As a result of its investigation of that accident, the Safety Board recommended that the FAA:

A-89-57

Require operators to provide specific training programs for maintenance and inspection personnel about the conditions under which visual inspections must be conducted. Require operators to periodically test personnel on their ability to detect the defined defects.

In partial response to that recommendation, the FAA's Office of Aviation Medicine performed a human factors evaluation of maintenance-related issues, such as lighting in maintenance work areas and the scheduling of rest time for mechanics. The final report was entitled "Human Factors Evaluation of the Work Environment of Operators Engaged in the Inspection and Repair of Aging Aircraft."

The Safety Board believes that many of the FAA's efforts in response to the maintenance and inspection issues identified in the Aloha Airlines accident were positive and served to increase the understanding of contemporary human factors issues that affect the quality of aircraft maintenance. For example, following the completion of the final report noted above, the FAA sponsored an on-going effort to address human factors issues in maintenance. Part of that effort was a multiphase study[7] that directly addressed many of the issues relevant to this accident. For example, Phase I of the report, in identifying factors that affect the ability of inspectors to detect defects, stated:

The factors affecting the conspicuity of a defect are defect size, defect/background contrast, and lighting intensity. The latter two are functions of the lighting and can be improved without changing the aircraft design. Defect/background contrast is a function of the angles between the inspector's eye, the defect, and any light sources. In general, an adequate level of illumination needs to be provided at the inspection point, with levels of 500 to 1000 lux typically recommended. However, the distribution of light is at least as important as its intensity. Of particular concern is that in inspecting partially hidden areas (e.g., inside door panels), the lighting used to illuminate the defect may cause glare from surrounding surfaces. Carefully designed combinations of general area lighting, portable area task lighting, and localized spotlighting need to be produced.

The evidence indicates that the human factors-related impediments to the effective performance of maintenance/inspection procedures that the Safety Board found nearly 6 years ago in its investigation of the Aloha Airlines accident, and that the FAA identified 2 1/2 years after the accident in its study of human factors issues in aviation maintenance, were also present in the NWA maintenance program.

In addition to its response to Safety Recommendation A-89-57, the FAA also stated that it would issue an airworthiness bulletin to its principal maintenance inspectors (PMIs) to require them to ensure that their assigned operators include specific training and testing in maintenance/inspector training programs that address the problems associated with performing visual inspections. Pending receipt of the published airworthiness bulletin, the Safety Board classified the FAA's response "Open--Acceptable Response" on February 22, 1994.

The circumstances of this accident suggest that the FAA has adequately studied many of the critical human factors issues in aviation maintenance but that the implementation of many of the positive findings from these studies have not yet been accomplished. Additional training of maintenance and inspection personnel, while beneficial, will not mitigate the problems of inadequate lighting and potentially hazardous scaffolding where visual contact with the area to be inspected is difficult or the immediate environment carries with it personal risk. Therefore, the Safety Board believes that the FAA should issue a directive to 14 CFR Part 121 and Part 135 air carrier PMIs instructing them to have their assigned carrier(s) conduct inspections to identify human factors-related impediments to the effective performance of maintenance and inspections, such as inadequate lighting and potentially hazardous scaffolding, and require the carriers to correct those deficiencies.

In addition, the lack of an organized method of storing parts removed from airplanes prevented the physical presence of the pins from alerting personnel to an error. The storage of parts was largely left to the lead mechanics, some of whom were more fastidious than others. If a location had been provided and habitually used for the No. 1 pylon retainers, they would have been visible after closure of the pylon. Instead, the parts were found behind a board on the wing dock. In hangars and work areas that perform repetitive inspections or other maintenance activities, the Safety Board believes that an organized means of storage must be provided to maintenance personnel and that personnel must use those facilities.

3.Conclusions

3.1 Findings

1. Maintenance and inspection personnel who worked on the airplane were properly certificated to perform the required maintenance and inspections.
2. Maintenance and inspection personnel who worked on the airplane were not adequately trained and qualified to perform the required maintenance and inspection functions. Critical functions had been taught by on-the-job training and were not standardized or formalized in an initial or recurrent training program.
3. The mechanic who removed and failed to reinstall the No. 1 pylon aft diagonal brace primary retainer could not be identified.
4. The inspector who performed the nondestructive testing inspection of the No. 1 pylon diagonal brace fitting properly completed the inspection, but he improperly signed off on

several subsequent steps of the centralized interactive text system (CITEXT) instruction card. This could have led other maintenance and inspection personnel to interpret that the maintenance actions on the fuse pin retainers on engine No. 1 had been completed when they had not.

5. The "OK to Close" inspection of the pylon area was hampered by inadequate lighting and perceived dangers of the scaffolding.
6. The CITEXT used by Northwest Airlines was inadequate because it lacked the pertinent information contained in the FAA-approved maintenance manual, it did not follow Northwest Airlines' GEMM policy, and it did not contain specific instructions for actions, components, or systems that were specific to the B-747 No. 1 engine pylon.
7. Mechanics and inspectors of Northwest Airlines did not adequately understand the application of the CITEXT and red OM 249 tag systems for critical maintenance items.
8. Maintenance supervisors and managers of Northwest Airlines failed to ensure that the work practices of the mechanics and inspectors were conducted in accordance with the approved maintenance manual.
9. The work environment for the heavy maintenance of the airplane was inadequate and contributed to an error-producing situation for the workers.
10. The lack of adequate and organized storage of removed parts contributed to the failure to reinstall the fuse pin retainers.
11. FAA oversight of the maintenance facility at Northwest Airlines failed to detect deviations in red OM 249 tag procedures.
12. FAA inspectors failed to apply FAA-developed human factors elements and allowed an inadequate work environment in the hangar to exist.

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:

Review the Northwest Airlines CITEXT system, and, where practical, require modification of those sections that refer to actions, components, or systems that are specific to particular airplanes to ensure that the maintenance action requested conforms to the maintenance action required for the specific airplane. (Class II, Priority Action) (A-94-218)

Apply human engineering principles to the evaluation of computer-generated work card systems to ensure that they include all of the critical information contained in, and are consistent with, the FAA-approved maintenance manuals. (Class II, Priority Action) (A-94-219)

Inform other airlines operating in the U.S., and foreign airworthiness authorities, of the circumstances of this accident and require them to implement corrective actions, where necessary, to prevent the maintenance program deficiencies noted in this accident. (Class II, Priority Action) (A-94-220)

Assess the work environments in which carriers operating under 14 Code of Federal Regulations Part 121 perform their maintenance to identify human factors-related impediments to the effective performance of maintenance and inspections, such as inadequate lighting, potentially hazardous scaffolding, and inadequate and unorganized parts storage during maintenance activity, and require those carriers to correct the deficiencies. (Class II, Priority Action) (A-94-221)

Direct operators of Boeing 747 airplanes to paint the inside surfaces of the engine pylon fuse pins a conspicuous color such as red. (Class II, Priority Action) (A-94-222)

--to Northwest Airlines:

Review the CITEXT system, and, where necessary, require the modification of sections that refer to actions, components, or systems that are specific to particular airplanes to ensure that the maintenance action requested conforms to the maintenance action required for the specific airplane. (Class II, Priority Action) (A-94-223)

Apply human factors engineering principles to the evaluation of the CITEXT system and implement revisions, as necessary, to ensure that the computer-generated work cards are consistent with the material contained in the FAA-approved maintenance manuals and that the specified work or inspection requirements are clearly stated. (Class II, Priority Action) (A-94-224)

Review the maintenance training curricula for mechanics and inspectors to ensure that all critical airline maintenance policies and procedures are addressed during initial and recurrent training, and, in cases in which they are found deficient, incorporate such maintenance policies and procedures in the curricula. (Class II, Priority Action) (A-94-225)

Review the training records of personnel engaged in the maintenance and inspection of air carrier aircraft to ensure that such personnel have received the formal training required under 14 CFR 121.375. (Class II, Priority Action)(A-94-226)

BY THE NATIONAL TRANSPORTATION SAFETY BOARD

James E. Hall
Chairman

John Hammerschmidt
Member

Member Lauber did not participate.

December 20, 1994

5.Appendixes

Appendix A "Insp, 66, ad, #1Nac/Pyl Diag B." Citext Card Instructions

Step	Job Description
01.	This procedure accomplishes an ultrasonic inspection of the number ____ (enter engine strut position from header card) engine strut diagonal brace forward and aft lugs for cracks. This inspection is per Boeing SB 747-54-2126 and FAA AD 89-07-15.
02.	Gain access to the engine strut diagonal brace by opening the strut aft fairing doors. On inboard struts, the fixed fairing aft of the strut aft fairing doors must also be removed.
03.	Check the side of the diagonal brace for stenciling of EM5441-01009. If stenciling is found, this brace has been previously modified and the inspection specified in this work procedure is not required. Advise MSP Technical Records by message switching (/FOR JAR), include employee clock number ____, to MSPCTIPA and MSAPCTIPE. State that terminating action per EM 5441-01009 was accomplished on aircraft number ____, strut position ____. Assign Complied with Inspection No. ____ for strut ____ as applicable: No. 1 Strut Complied with Inspection No. 66-0554-8-0037 No. 2 Strut Complied with Inspection No. 66-0554-8-0038 No. 3 Strut Complied with Inspection No. 66-0554-8-0039 No. 4 Strut Complied with Inspection No. 66-0554-8-0040 If stenciling of EM 5441-01009 is not found on the diagonal brace, proceed to step 04, otherwise enter N/A for all remaining steps.
04.	Remove fuse pin secondary retention (if installed) by the forward and aft diagonal brace lugs to allow traducer [sic] positioner access.
05.	Clean the diagonal brace forward and aft lugs thoroughly to allow for an accurate ultrasonic inspection of the lugs.
06.	Ultrasonically inspect all four diagonal brace lugs for cracking as specified in 747 NDT manual D6-7170, Part 4, Subject 54-04-05. Indicate inspection results below: A. Aft Outboard Lug:____Cracked____No Cracks B. Aft Inboard Lug:____Cracked____No Cracks C. Fwd Outboard Lug:____Cracked____No Cracks D. Fwd Inboard Lug:____Cracked____No Cracks
07.	If any cracks are indicated in step 6 above, proceed to step 8; otherwise N/A steps 8 and 9 and proceed to step 10.

08. Remove the engine strut diagonal brace as specified in 747 MM Subject 54-10-03. If brace is removed from strut positions 1 or 4, mark aircraft number ____, strut position ____, P/N 65B90326 and Stk No. 66-5400-4-0003 on repairable parts tag and route diagonal brace to stores. If brace is removed from strut positions 2 or 3, mark aircraft number ____, strut position ____, P/N 65B90430 and Stk No. 66-5400-4-0002 on repairable parts tag and route diagonal brace to stores.Installation of adjustable static diagonal brace tool (Stk N 00-5742-0-0002) will provide static engine support (if needed) until serviceable diagonal brace is available.

09. Install a serviceable diagonal brace as specified in 747 MM Subject 54-10-03. For strut positions 1 and 4, install Stk No. 66-5400-4-0003.
For strut positions 2 and 3, install Stk No. 66-5400-4-0002.
N/A step 10 and proceed to step 11.

10. If sealant was removed for inspection, reapply fillet sealant around diagonal brace forward and aft lug bushing flanges. Use BMS 5-95 sealant. Reinstall fuse pin secondary retainers at forward and aft lug locations if removed per step 04 above. Restore access and enter N/A in step 11.

11. Send this JAR message only if diagonal brace was replaced. Advise MSP Technical Records by Message ____, to MSPCTIPA and MSPCTIPE. State that terminating action per EM 5441-01009 was accomplished on aircraft number ____, strut position ____. Assign Complied with Inspection No. as applicable:
No. 1 Strut Complied with Inspection No. 66-0554-8-037
No. 2 Strut Complied with Inspection No. 66-0554-8-038
No. 3 Strut Complied with Inspection No. 66-0554-8-039
No. 4 Strut Complied with Inspection No. 66-0554-8-040

Appendix B Maintenance Personnel Interview Summaries

On March 8 and 9, 1994, the Safety Board interviewed 16 NWA employees and 2 FAA inspectors who were directly or indirectly involved in the maintenance of the accident airplane. Interview summaries of these individuals are as follows:

1. Northwest Airlines B-747 Production Planner

This individual's job title was B-747 Production Planner. He has been with NWA for 12 years, since 1982, and in his present position for 6 years, since 1988.

As a production planner, the individual stated that he did not plan the "C" check on aircraft 6637 but that his cubicle mate did. If one planner does the package to a checklist, then the opposite person checks over the package to ensure its completeness. Production planners were responsible for the entire airplane, and were not divided into specialties, such as powerplants, and structures. It takes about 1 week to build the entire package. In his 12 years of service at NWA, he was never aware of an FAA inspection of his work.

This person stated that the size of a "C" check package will vary depending on such factors as aircraft age and number of cycles on the airframe. The planned interval between "C" checks is 1,000 flight cycles, 5,290 flight hours, or 450 days. The duration of a "C" check varies from 14 to 35 days. The work tasks are taken directly from the maintenance manual, while the engineering department decides what items will be included in the "C" check. The planning for each airplane incorporates basic routine items, engineering authorizations (EAs), and engineering orders (EOs).

This interviewee stated that a particular package might change after he had completed his work. For example, an area that is not scheduled to be opened up during this inspection may enclose an item that requires a mandatory inspection. If this particular item still has operating time remaining before a required inspection, it could be decided to accomplished the inspection at a later date.

2. Northwest Airlines A&P Mechanic

This individual's job title is Mechanic, and he has been with NWA for 27 years, since 1966. He has been in his present position for 2 months.

The interviewee said that he did not work on the No. 1 pylon area on the accident airplane. However, he did perform work on the No. 4 engine pylon area. His work on the No. 4 engine pylon area included installing the ADP (air driven pump), hydraulic lines and other nonroutine items. He stated that at the time he worked in this area, the No. 4 engine was attached to its pylon.

On March 1, 1994, at approximately 0900, this individual found a small, unidentified, white cloth bag near a safety hand rail on the under-wing scaffolding. He did not open the bag, but felt what was inside with his hands. In the bag was a set of diagonal brace fuse pin primary retainers (two washer shaped objects on a bolt and nut) with the fuse pin secondary retainer attached to the bag by a piece of wire. This bag had no identifying tag attached to it. Although parts bags, in general, were normally tagged with what was inside, there apparently was no requirement to do so, according to this individual. Because he was not sure of what these parts were, and had only worked in the hangar for about 2 months, the interviewee asked a co-worker for help in their identity. He stated that he did not remember who this co-worker was, but that the co-worker identified the parts as "engine parts" and placed them on a "rotating parts" table. The interviewee's initial assumption was that these parts had been removed from the B-747-400 currently occupying bay 6. When he was asked how the parts he found on March 1 could have remained undiscovered since February 21, 1994, the date that the accident airplane was rolled out of bay 6, the interviewee stated that it might be because the bag and its contents were hidden by a "2 × 4" wooden board (part of the under-wing scaffolding). He further stated that it was unusual for people to leave airplane parts on the wing docks.

In responding to questions on CITEXT, the interviewee stated that he had seen CITEXT errors when he worked in the component shop, but not on the hangar floor. His training in the use of nonroutine cards called for the attachment of a red tag to the airplane before the removal of parts.

3. Northwest Airlines A&P Mechanic

This individual's job title is Engine Crew Mechanic; he has been with NWA since 1986, and in his present position since 1987.

The interviewee stated that he was assigned to work on the No. 2 engine of the accident airplane and that he did not do any work on the No. 1 or No. 4 engines. He has been involved with the removal of the secondary retention devices for the diagonal brace on other airplanes. He said that the primary retention washers may be removed when checking the diagonal brace fuse pins. Sometimes, both the primary and secondary retention devices are removed to do a diagonal brace aft lug inspection because of old habits developed during the earlier fuse pin inspections required by various earlier service bulletins. He would ask for a nonroutine card if parts were removed and no other paperwork was available. He would bag removed parts and put them on the "parts cart." He has not been asked by inspectors to remove primary retention devices but had removed the primary retainers in the past, working to the requirements of nonroutine cards.

When the white cloth bag was found, this individual was working on the No. 1 engine of airplane 6302, the airplane then in the maintenance dock. He stated that he took the white cloth bag from the mechanic that discovered it, and identified the parts inside as the primary and secondary retention devices. He then put the parts on the "parts cart," assuming they were from the airplane in the maintenance dock at the time. After he was informed of the event on the accident airplane, he looked at the airplane in the dock and saw that the primary and secondary retention devices were installed. He then assumed that they were from the accident airplane. He also stated that when fuse pins are removed from a pylon assembly, they are put in a special, marked box. He said that the retention devices may be put on top of the pins or placed on the parts cart.

This individual was involved with the upper link change on the No. 1 position on the accident airplane. He stated that it is customary to remove one of the two diagonal brace fuse pins to make the installation of the upper link easier.

Other comments made by this mechanic included:

The CITEXT system does not issue work cards for more than one pylon at a time. Usually, if a specific task is started and completed on a particular shift, a mechanic would not create a red tag unless the part compromises the safety of flight. He stated that he does not know who is responsible for ensuring that the GEMM is followed. Both routine and nonroutine work is done that does not have any associated paperwork. He estimates this happens 4 to 5 times out of every 100 maintenance actions. Generally, there are more instances of this occurring when the work is done by inexperienced people. There is very little briefing between mechanics at shift change. The shift change briefings that do occur are mostly between lead mechanics.

This individual closed by stating that he had received no formal basic training on the GEMM or SCEPTRE. What he learned about the systems, he learned from his crew chief.

4. Northwest Airlines A&P Mechanic

This individual's job title is Mechanic, and he has been with NWA since mid-1989. He has been in his present position since mid-1989.

He stated that he worked on the No. 1 engine upper link of the accident airplane. He had a nonroutine work card for rust in the area of upper link fuse pin. He cleaned the area and found no rust, but he did find a migrated bushing. He said that he then had a nonroutine card written for the bushing. The bushings were removed and the upper link was reamed oversize. The No. 1 engine was removed before the start of upper link rework. New bushings were installed in the upper link, and the link was replaced. However, during installation, it was necessary to disconnect the No. 1 diagonal brace so that the upper link could be aligned with the attachment fitting and the upper link fuse pin installed. He stated that the aft diagonal brace fuse pin was removed because the primary and secondary retention devices were not installed. The diagonal brace fuse pin was reinstalled after the very few minutes that it took to install the upper link fuse pin.

He said that he did not see any red tags and that he did not remove the primary and secondary retention devices of the aft diagonal brace fuse pin. He stated that any red tags may have been installed on the outside of the bat wing doors and, therefore, hidden from view. He signed off both nonroutine cards for the No. 1 upper link.

He stated that he worked the No. 1 engine and pylon and was unaware of the No. 1 bat wing door closure or "OK to close" inspection since these two items occurred on his days off. He was off on Saturday and Sunday at that time. Normal days off were Friday and Saturday. His red tag training and CITEXT training were by OJT. He estimated that he would write one nonroutine card per week.

He was temporary manager for all week. As a manager, he supervises six lead mechanics. He had been a temporary manager for a 5-week period during late 1993 and early 1994. As a manager, he supervised others with more seniority than he had.

Normal progression for mechanics would be: mechanic; lead mechanic; and manager. If an individual wants IAM (union) progression he would be a mechanic, lead mechanic, inspector, and finally a lead inspector. The current IAM contract has a limit for the length of time that a contract employee may serve as temporary manager and still hold his union seniority.

5. Northwest Airlines A&P Mechanic

This individual's job position is as an aircraft mechanic on the second shift. He has been in this position with NWA for about 4 years. He has been through B-747-100/-200/-400 avionics, and engine and aircraft familiarization training. He served in the U.S. Navy for 22 years in the airplane maintenance and overhaul field.

On the accident airplane, this individual removed the No. 1 pylon secondary retainer prior to ultrasonic inspection of the fuse pin by an inspector. He may also have removed the secondary retainer from the No. 4 pylon, but he does not remember if he actually did so. Normally, he gets more than one CITEXT card to do the same job on different engines. CITEXT cards require the removal of the diagonal strut pin secondary retainer prior to any NDT inspection of the fuse pin. He does not know if the primary retainers were ever removed. There is usually no need to remove sealant in the pin area for NDT inspection. This individual stated that he was unaware of who was supposed to reinstall the retainers following his NDT inspection. He stated that he has done this particular inspection 50 to 100 times. He related that the NWA procedure is to obtain the CITEXT card, open the bat wing doors, remove the secondary retainer, then put the CITEXT card on the work control counter. He said that CITEXT does not call for red tagging the cowl when the secondary retainer is removed, but that it does require a red tag if the primary pin retainers are removed. He would then put the secondary retainer on the parts stand in front of the engine. The NDT ultrasonic inspection would then be performed by an inspector.

This individual remembered working on the accident airplane. He stated that he helped reassemble the mid-spar fittings, including the primary retaining caps and bolts, during the reassembly of the No. 1 pylon components. He stated that he had nothing to do with the No. 1 pylon upper link. At the time he was taking off the secondary retainers prior to the NDT inspection, the inspector was checking the canoe fairings. He said that the inspector commented that the secondary retainers "looked good." The interviewee stated that he then cleaned the lugs at both ends of the diagonal brace. All of the fuse pins were of the same type.

This individual stated that he may have been given multiple CITEXT cards that call for opening the same panels or exposing the same work areas. He believes that several CITEXT cards may specify removing the same panel to provide access for different jobs. Normally, the first mechanic to remove the panels initials the CITEXT card. If this work had already been done on a different card, the mechanic would initial the card assigned to him.

He said there were red tags on the pylon for the work accomplished on the mid-spar fittings on the one side. The isolation valve red tags were on the other side of the pylon. This interviewee noticed no red tags for the aft end of the diagonal strut, and said that these red tags should have been on the bat wing doors.

This individual further stated that he had no training on when to use red tags, or when not to use red tags, but that red tags should be used when "opening up" a hydraulic, electrical, or other safety of flight system, or when CITEXT cards require red tags. He also stated that red tags are mandatory, even if the job can be finished by the end of the shift. If a red tag comes off, such as when washing an area of the airplane, or when the cards get wet, he said that he would refer to the red tag copy on the nonroutine card.

If an inspector would ask for the removal of the diagonal brace pin primary retainers prior to an NDT inspection, he stated that he would be required to write, or ask for, a nonroutine card. This individual stated that, in his opinion, the system does not break down very often. He closed by saying that he had, on occasion, been asked to disassemble some airplane component without the required documenting by an inspector, knowing that it would be put back.

6. Northwest Airlines A&P Mechanic

This individual's position is as a mechanic on the third shift. He has been with NWA since 1992, was laid off in October 1992, and rehired on February 5, 1994.

He said that ordinarily he works on airplane structures, primarily inside the cabins of airplanes. On the accident airplane, however, he safety wired the hydraulic and pressurization valves on engine No. 2. He also closed up the No. 1 engine bat wing doors with two other mechanics. The inspector had approved the "OK to close" checklist on the No. 1 engine bat wing doors.

He said that the same inspector had approved the closing of engine No. 4's bat wing doors before he approved closing those on engine No. 1. The interviewee stated that he stood around while the inspector completed the inspection, which took 4 to 5 minutes. He believes that the lighting for the scaffolding under the wings was inadequate. The inspector used a flashlight to complete his inspection. Often, mechanics have to bring their flashlights to help them see the areas they are working on. He believes this does seem to hinder the work. He did not remember seeing any red tags for the No. 1 engine bat wing doors, but he did remember one red tag on the left side of the pylon.

He did not notice any significant changes in maintenance procedures from the time he was first laid off until his return to NWA 15 months later. He believed that he had "some" training in nonroutine procedures, CITEXT, and the GEMM.

7. Northwest Airlines General Inspector

This individual is a general inspector specializing in nondestructive testing (NDT), and he performs most of the ultrasonic inspections for NWA. He holds an FAA Airframe and Powerplant (A&P) license, and he has been employed by NWA for 15 years. He also is certified by ASNT Level II for NDT.

This interviewee stated that he performed an ultrasonic inspection on both end fittings of the diagonal brace on the No. 1 and No. 4 pylons on the accident airplane. Engines No. 2 and No. 3 were off of the airplane, and engines No. 1 and No. 4 were still attached at the time. He performed his inspection of the No. 1 diagonal brace in the afternoon and the No. 4 brace in the morning. He stated that when he performed his inspection on these pylon fittings, the primary retainers were installed and in place; however, the secondary retainers had been removed per the CITEXT card. He did not see white cloth bags with the parts inside. This individual stated that he had not requested the removal of the primary retainers in the previous 2 to 3 years, due to the change in fitting design, and had never requested that the primary retainers be removed for this inspection. He also stated that he had never experienced a false reading from having the primary retainers in place. He remembered that the primary retainers did have the required sealant around the end caps and over the castle nut.

This individual said that he had not recognized that the secondary retainers were required on this airplane. He marked "N/A" in the blocks of the CITEXT instructions that pertained to crack indication detection and installation of the secondary retainers.

He stated that he had received some RII (required inspection item) training during the past 2 years and initial inspection training when he was first hired by NWA. A 1-day recurrent inspection training session was completed yearly. He also stated that the paperwork concerning airplane maintenance was not always up to date.

He was also qualified as a general inspector and described some duties not related to NDT. In his terms, a zonal inspection of the aft strut area is to detect unwanted rags and glaring discrepancies.

8. A&P Mechanic

This individual holds a position as an aircraft mechanic at NWA. He holds an FAA-certified Airframe and Powerplant (A&P) license, and he has been with NWA for 6 years. He was a line maintenance manager at Logan Airport, (BOS) Boston, Massachusetts, for 3 years before transferring to NWA's heavy maintenance facility in Minneapolis, Minnesota. This individual also has military experience and was a Beechcraft field service representative for 9 years before joining NWA.

This interviewee normally worked with the interior cabin maintenance crew, but he was assigned to an engine maintenance crew when he reported to work on Saturday, February 19, 1994. While he and other mechanics were installing the engine cowl for the No. 4 engine, somebody (he does not remember who) noticed a white bag hanging on the bat wing doors that contained some airplane parts. He believes that seeing the bag of parts hanging from the airplane was not considered unusual, but, in retrospect, not to have the paperwork was strange. A secondary fuse pin retainer was on the outside of the bag; and inside were the primary fuse pin retainers for the No. 4 pylon diagonal brace end fittings.

On February 19, he worked with about six people, but only two of them were normally assigned to engine work. The interviewee stated that an examination of the No. 4 pylon revealed that the diagonal brace end fittings had their fuse pins installed but that both sets of the fuse pin retainers were missing. A second bag contained the retainers for the forward diagonal brace. He and another mechanic took reassembly (installing the pin retainers) upon themselves for the forward and aft diagonal brace primary and secondary retainers. This interviewee stated that they obtained the maintenance manual reference paperwork, and other necessary items, before they installed the retainers.

This individual also worked on the accident airplane on Saturday, February 20, 1994, but stated that he did not work on the No. 1 engine or pylon. He did say, however, that he was present when the No. 1 pylon bat wing doors were closed.

When he was questioned about his training on the GEMM, he stated that he had not received any formal training on either the GEMM or the CITEXT system, but rather had received only OJT. He stated that CITEXT is not "user friendly" and that he occasionally had to consult experienced people to resolve differences between CITEXT and the maintenance manual. He had to refer to the maintenance manual frequently. In his previous work at BOS (a line, rather than a heavy maintenance station), he said that red tags were only used for turnover items,[8] especially if the work would be completed by shift end. He estimated that Boston would use 100 red tags per month, whereas Minneapolis/St. Paul could use 100 per night.

He stated that he was happy at NWA and was treated "fairly well," but commented that some management actions were unsettling. When he was asked if the weekend shifts were short of people, he replied that there was a lot of "borrowing of people" on Saturday nights and that they are usually less experienced. He believed that the overtime working conditions could lead to confusion when strangers worked together in areas that they had not previously worked.

9. Northwest Airlines Director DC-10 And B-747 Maintenance

The Director of B-747 and DC-10 Maintenance at NWA has been employed by NWA for more than 11 years and is responsible for three aircraft maintenance hangars, including hangars 5 and 6.

This individual stated, in part, that initial formal training is virtually nonexistent and that any training is usually OJT. He stated that he reviews each employee's training records. He also stated that crew chiefs instruct new employees. Concerning job bidding, he said that under the new labor management agreement of August 1993, mechanics can now bid not only for specific jobs but for specific crews.

This interviewee stated that he has 545 NWA employees working for him, with 252 on the first shift. He has no control over inspection personnel. He stated that the overtime percentage in January was 14 1/2 percent, in February 20 percent, and, at the time of the interview in March 1994, it was 6 percent.

GEMM training is accomplished through the OJT process, although the individual mechanics and inspectors are responsible for knowledge of the GEMM. New mechanics are trained by OJT. Formal training in NWA general maintenance procedures is "nonexistent." NWA does provide formal training on specific airplane types, such as initial B-747-100, B-747-200 and B-747-400 training. NWA has seven instructors for the B-747 and DC-10 airplane maintenance classes. Airplane training is geared toward the aircraft mechanics, as determined by their training needs and union seniority. There is currently no permanent Director of Training for maintenance. This position is being filled on an acting basis.

With the signing of a new labor/management contract in August 1993, and with the completion of the ARMAR-Program (aging aircraft program), there has been "constant movement" of mechanics across hangars and between hangars and shops, which, apparently, has caused some confusion on the hangar floor. Inspection service was described by this interviewee as "pretty good," although, on weekends, the mechanics might have to look for an inspector following the completion of a specific job.

CITEXT training is also accomplished via OJT. The system was inherited in the merger with Republic Airlines and was dedicated to replacing the old maintenance action tracking system. He was aware that many people had a negative opinion of the CITEXT system. The system has many problems, such as conflicts with the airplane maintenance manual and a lack of visual graphics. Floor mechanics were made aware of CITEXT changes by the placement of notices in an "alert" book that they were supposed to read.

NWA maintenance personnel are trying to modify and improve the CITEXT system, and depending on where the originating item is, such as GEMM or other source, different specialists will review modifications to CITEXT. A group composed of managers, lead mechanics, and people from NWA technical publications and maintenance programs has been formed and meets regularly to improve the system. Line mechanics are not included in this task force, but their immediate supervisors (lead mechanics) are included.

This interviewee stated that CITEXT does not contain specific information on if or when it is necessary to "red tag" an item. For the most part, NWA procedures expect the mechanic to recognize when a red tag is needed. He stated that red tags are required any time a system or component is disturbed, although implementation depended on the individual. He will occasionally hear of someone not using a red tag when he should. This individual believes that this may occur once in 6 months. When that happens, he will counsel the particular managers involved. He constantly hears of procedures not being followed. He has written to managers on procedures to follow on documenting parts and using red tag procedures.

This interviewee stated that on this particular incident, the CITEXT card was completed correctly up to step 9. Steps 10, 11, and 12 were stamped N/A and should not have been. Because the CITEXT card was completed, albeit incorrectly, it was filed as completed. If someone had attempted to file the card with steps not stamped, as should have been the case, the error would have been discovered because it would have been noted that the actions were not completed. Nevertheless, verification of completing the steps could have been done by the mechanic, lead mechanic, inspector, or manager. He believes that the "OK to close" inspection should have been the "second line of defense." His perception of the "OK to close" inspection was that it was for red tags, loose hardware, and rags.

This interviewee said that the scaffolding in bay 6 is temporary and, perhaps because aircraft had been painted there up to 1 year ago, the fluorescent lights at the base of the scaffolding may have become dim from ambient paint spray. Hangar 5 is used for "C" checks that are known to involve more maintenance activity and will, therefore, take longer. Hangar 6 is used for faster "C" checks.

The interviewee acknowledged that there have been manning problems on weekends and that he has been addressing this by creating new schedules to increase the shift coverage during weekend periods. Currently, 250 people work the first shift, 130 work the second shift, and 34 are assigned to the third shift on weekends. There is little overlap among the shifts, although the new labor contract allows lead mechanics to come in 18 minutes early to be briefed by the mechanics of the previous shift. No formal checklist or procedure exists on items to be briefed.

This individual stated that he meets with managers weekly. He also meets with lead mechanics daily to learn about the status of aircraft. In addition, shift managers have monthly crew meetings to discuss safety issues. He stated that he was aware that some employees had expressed a fear of reprisals for bringing maintenance problems up, but he was working to allay this.

The interviewee was not aware of the No. 4 pylon problem until after he heard about the No. 1 engine incident at Narita, Japan.

10. Northwest Airlines General Inspector

This individual's position is that of a general inspector. He has been with NWA for 8 1/2 years, and in his current position for 5 years.

He stated that he performed inspections on several areas on the accident airplane. However, he stated that he did not inspect engines, pylons or anything specifically related to the diagonal braces. This interviewee stated that mechanics usually walk over and ask for an inspector to check the mechanics work. He said that 99 percent of his inspections are completed with his signature or stamp placed on the proper document. When inspections are completed, the inspector usually enters the status into the computer. Maintenance personnel enter nonroutine items into the computer also, and items annotated "OK to close" are always on computerized work cards (CITEXT). This individual stated that inspectors do not help with any maintenance and do not keep hand tools at work.

This inspector indicated that only two inspectors were assigned to hangars 5 and 6 on the Saturday third shift prior to the event. The work was constant on this night, which was the sixth day of his work week. He was given the CITEXT cards for all four engine pylon areas at the same time. Initially, he did not approve of ("buy off") the maintenance accomplished on the No. 1 hydraulic reservoir in the strut area. Otherwise he did not remember anything unusual about the No. 1 or No. 4 pylon and strut area maintenance. He saw no red tags or items hanging in the area of pylon No. 1. Eventually, he approved the No. 2, No. 1, then NO. 4 pylon area for "OK to close." The NWA maintenance procedure calls for a crew chief to initial "OK to close," then to stamp the paperwork (CITEXT) "OK to close." However, he said that this is not always done, but that the third shift crew chief initialed off the "OK to close." This inspector stated that he has no specific routine for checking the pylon area. Usually, he will look for previous problem areas, such as foreign objects hanging down from the pylon, loose hydraulic connectors, loose ADP attach bolts, bat wing door hinge problems and disconnected cannon plugs. However, in this case, he does not remember looking at the fuse pin retainers and did not think the secondary retainer was required. He said that if he had known the secondary retainer should have been installed, he would have considered it important.

This inspector stated that when he is asked to perform a closure inspection of the pylons, 50 to 75 percent of the time they were not ready for closure. He also indicated that he has been criticized for being too critical of mechanics concerning closure, but he believed that "OK to close" items are important and should be perused carefully. He did not see or write "N/A" or "OK to close" on the CITEXT work sheet, and he completed his inspection of the No. 1 strut area in about 5 minutes. He said that work center control boards are typically checked for zone final inspections, but not "OK to close" items.

This interviewee mentioned several times during his interview that the possibility of fatigue bothered him. First, fatigue was a factor with working all night without a break. He was physically tired on this "push out" night which was "100 percent" more active than other shifts. In addition, the first time he went to the No. 1 pylon strut area, he came back down to cross to the engine stand because he considered the wooden boards between stands to be unsafe and insufficient in the inspection area. He eventually used the boards at the to No. 1 pylon area to perform his inspections.

He reported that he received training as an inspector in 1990. The class taught him that at that time, he was lax in some of his procedures. He did not mean necessarily that he overlooked maintenance anomalies, but rather that he was not trained to access areas of the airplane effectively. He cited one example of having been informed that he overlooked corrosion on a shear tie in a belly skin on an airplane. This NWA inspector stated that he has never had an FAA inspector follow him during the course of his work. Finally, he discussed his shift and sleeping pattern and indicated that he would keep the same daily pattern of sleeping between 0800 and 1600. On his days off, he would normally sleep the same time, but might get up at 1300.

11. Lead Mechanic

This individual's present position is as a Lead Mechanic, and he has been with NWA since 1988.

He stated that he was a Lead Mechanic on the third shift in hangar 6, building C, at NWA's heavy maintenance facility, Minneapolis, Minnesota. On Saturday, February 19, 1994, he worked on the accident airplane during its "C" check. His crew was a structures crew, which on weekdays work mostly on the interior section of B-747 airplanes. However, on Saturday and Sunday, his crew functioned as a utility crew and worked on any portion of the airplane that was assigned to it. He stated that it was the job of his crew to do whatever was required to ensure a timely release of the airplane back to service.

He said that on weekends his crew is made up of people from all different crews. He does not personally know many of the people he worked with on the weekend, nor is he familiar with their maintenance qualifications. He believes that the average seniority of his weekend crewmembers is approximately 1 year. There were no engine mechanics on his crew.

On February 19, 1994, he assigned several of his mechanics to work on the "close up" of the engines on the accident airplane. He requested approvals to close up on engines No. 1 and No. 4 from his mechanics. He was also aware of the work being done on the No. 4 pylon, but not the specific details of those work assignments. He did not notice any red tags in the pylon area. He stated that he also checked the nonroutine log and there were no open cards.

During the interview, he said that he believed that some of the problems that may have led to the accident were:

1. The low level of experience of the mechanics who work on the weekend shifts. This is usually when airplanes enter and leave the hangar.
2. CITEXT cards that are often wrong or unclear, and not specific enough (especially for junior mechanics).
3. NWA has no formal training on the use of red tags.
4. NWA has no formal training on the GEMM.
5. Weekend maintenance crewmembers do not normally work together and are not familiar with each other's qualifications.
6. There are only two lead mechanics and two inspectors assigned to the third shift on weekends, and they must provide support for both hangars No. 5 and 6.
7. Management is usually anxious to dispatch airplanes out of the hangar on weekends.

12. FAA Principal Maintenance Inspector (Pmi)

This individual is the FAA Principle Maintenance Inspector (PMI) for NWA. He has held this position since 1985. He is not responsible for other commercial aviation company operating certificates, nor does he have responsibility for any other FAR 135 or FAR 121 airline. Before assuming his present position, he served in the Minneapolis (MSP) General Aviation District Office (GADO) for 3 years; before that he was a flight safety inspector at MSP. Prior to joining the FAA, he was a civilian employee of the US Air Force where he supervised an NDT laboratory, and was also a maintenance instructor. The interviewee served 7 years in US Air Force. He holds the following FAA certificates: Pilot, Aircraft Single Engine Land (ASEL), and Airframe and Powerplant Mechanic (A&P) with Inspection Authorization (IA). His responsibilities as a PMI are to oversee and ensure that NWA is complying with the FAA's rules and regulations governing the maintenance of its airplanes.

The interviewee said that he made the decision to switch the FAA Partial Program Manager (PPM) from the A-320 fleet to the B-747 fleet to enable the PPM who had been assigned to the B-747 fleet to gain experience on the A-320 airplane. This provided the office with PPMs who were experienced in two of NWA's major airplanes.

This individual stated that NWA is "compliance oriented," and that company management is professional and cooperative. To illustrate this, he noted that in 1989, within a few weeks after his request, management provided his office with a SCEPTRE terminal and, therefore, direct access to records and other information on maintenance and inspection programs. He also noted that he has not detected a pattern of noncompliance in the enforcement actions that have been initiated against NWA. Most of the enforcement actions pertain to inadequate documentation, maintenance deferral of repairs, etc. The interviewee further stated that all required inspections items "get done."

It is this individual's opinion that the CITEXT system has improved overall maintenance at NWA and also made it easier for the FAA to monitor the airline's maintenance activity. Because of the size of the airplane fleet, a PPM is assigned to oversee each aircraft model.

He stated that he has two assistant PMIs; one assigned to hangar maintenance while the other concentrates on line maintenance. He also has six PPMs assigned to the different NWA aircraft fleets.

He said that NWA is very involved in the FAA's voluntary disclosure program for operational and maintenance issues.

13. FAA Partial Program Manager (PPM)

This individual is the FAA's Partial Program Manager (PPM) of NWA's B-747 fleet. As the PPM he oversees NWA's compliance with FAA rules governing the maintenance of its B-747 fleet. He has been in this position for about 5 months. Prior to this, for approximately 5 years, he served as the PPM of NWA's A-320 fleet. This interviewee joined the FAA in June 1988. Before joining the FAA, he served in the US Air Force for 25 years. He holds an FAA A&P Mechanics Certificate with IA authority.

This individual said that FAA Headquarters provides guidance and lists on the required work program. The FAA Regional office then establishes a work program, which requires that at least 35 percent of the PPM's time be dedicated to actual airplane surveillance. He stated that he meets or exceeds this minimum in his planned maintenance surveillance activities, including night and weekend surveillance. He further stated that he dedicates about 4 to 6 hours a week on inservice inspections of such operations as early morning B-747 departures. In these cases, he inspects the airplane before it is loaded and boarded.

The interviewee stated that most of his inspections take place after the maintenance has been completed. However, on occasion, he will take an engineering order (EO) and personally observe how the resulting maintenance is being performed. He has also visited one overseas station, an initial B-747 flight to Sydney, Australia (SYD), to observe the maintenance operation. He has not yet visited Narita, Japan (NRT), where the majority of the Asian operations are carried out. He also stated that since his visit, SYD has been discontinued as a destination.

The interviewee said that he often makes visits to the NWA hangars to observe the various maintenance operations. He did this 8 days prior to this interview between 1630 and 1815. He tries to visit the hangar 1 night a week. He stated that during a hangar visit, he observes the work accomplished during the inspection, then follows the paperwork generated by the maintenance task and required by the inspection items. This allows him to compare the actual work performed against the work required, to determine if the actual maintenance is meeting the company and FAA requirements. When questioned about personal inspection equipment, he stated that he carries a flashlight, inspection mirror and tire depth gauge with him on his inspections. He will observe inspections, but will not request that items be opened once the inspection has been completed. In the morning, this individual will check minimum equipment list (MEL) items. He also monitors MEL compliance.

14. Northwest Airlines A&P Mechanic

This individual's position is that of a mechanic; he has been with NWA for 5 years, and in his current position also for 5 years.

The interviewee stated that he helped two other mechanics install the upper link forward fuse pin on the No. 1 pylon of the accident airplane. He also stated that the crew removed the diagonal brace aft fuse pin to facilitate installation of the upper link fuse pin. This was because the engine was not installed (it was frequently stated by interviewees that a diagonal brace fuse pin was removed to facilitate installation of the upper link pins). There were no primary retainer caps on the aft diagonal brace fuse pins at that time. He also stated that he did not see any red tags for the removed retainers, but since the retainers were already removed, he did not believe that red tags needed to be written. This work was done on third shift with interviewee numbers 4 and 18. This individual then stated that he assumed the red tags had been prepared, but could not check all the paperwork. He also stated that the primary retainer was not reinstalled since he did not remove it. This individual also stated that if they have to pull a diagonal brace to align the upper link, they will prepare a red tag for removal of fuse pin retainers since they have had problems with these pins before. There was, however, a nonroutine red tag for a cracked hydraulic reservoir bracket. The retainer caps were still off, but it was not necessary to remove the No. 1 diagonal brace to facilitate access to the hydraulic reservoir.

He stated that third shift mechanics do not stay on one pylon or with a particular engine. Instead, the mechanics would float to whatever crew needed the help. This interviewee was not sure, but he believed that work on the upper link had been accomplished on February 15, 1994. He stated that he did not recall seeing any red tags on bat wing doors and indicated that they are usually placed on the pylon. He also stated that the retainers are put on stands in boxes in front of the particular engine.

This interviewee stated that the GEMM and procedures for nonroutine cards are learned by shop practice and OJT. He also indicated that he had read part of the GEMM. When asked about CITEXT, he indicated that procedures were working well now, and that many of the problems were being worked out.

15. Northwest Airlines Lead Mechanic

This individual's position is Lead Mechanic of the B-747, and he has been with NWA since 1969. He had worked as an inspector for 2 years at NWA and had previously worked on US Navy and general aviation airplanes.

He said the lead mechanic would assign duties to the individual mechanics. The first day shift would have the heaviest staffing. The first day shift would also initiate work projects, which were then passed to the second and third shifts for completion. Although he was on vacation when the No. 4 pylon retainers were found, at the time that the accident airplane was being prepared for shop completion, this interviewee was the lead mechanic for all three engines on the second shift. Second shift mechanics are not kept continuously working on any particular engine or position. He stated that he had 11 people working for him and should ideally have had 12. Management generally did not pressure this individual, or rush him, and he considers labor relations at NWA to be good. The majority of the second shift staff have 5 years of experience or less.

This interviewee stated that turnovers (shift changes) to subsequent shifts are generally informal. In the past, more overtime was permitted, although there currently was an overlap of crew chiefs. This individual stated that he would receive a verbal description of work being accomplished from the previous crew chief, possibly walking to the work area being discussed. He would then examine the turnover log book.

This interviewee said that he had been involved with work on the No. 1 and No. 4 engines of the accident airplane. He recalled that the No. 1 engine upper link work was not accomplished until late in the "C" check, possibly even after the engine had been off and reinstalled. The work was to correct migrated upper link bushings. He did not remember whether he had seen red tags. He went on vacation on February 18, 1994.

This interviewee stated that mechanics could be handed multiple CITEXT job cards for accomplishment. Some CITEXT cards were confusing, and he had recently experienced one with incomplete work instructions. He said that a mechanic could not determine if a CITEXT card had been revised unless the card was carefully and completely examined, and he noted that this had created problems in the past. The most common problems that he could identify were incorrect part numbers and serial numbers. The more experienced mechanics were more likely to identify CITEXT errors, and he believed that the system had problems. If the GEMM and CITEXT had differences, they would use the instructions contained in the GEMM and later notify the person responsible for CITEXT changes. Mechanics can, and do refer to the GEMM document available on the shop floor.

Concerning red tags and nonroutine cards, this individual said that to remove the fuse pin retainers, he would remove the parts, then fill out and attach the red tags. He was aware that some people would complete and attach the red tag first. He was asked how often he became aware of work accomplished without red tags. He stated that this occasionally occurred, and that his last experience was during the previous week.

16. Northwest Airline Mechanic

This individual's position with NWA is that of mechanic. He has been in his present position since 1988. Prior to 1988, this interviewee was employed by Republic Airlines from 1980 to 1988. During this time, he worked as a cleaner from 1980 to 1984 and then in the auto shop from 1984 to 1988.

He stated that on Thursday morning, February 17, 1994, he completed installing a repaired hydraulic reservoir on the No. 1 pylon, which was protected by a nonroutine work card. He further stated that he had previously removed the end "caps" (primary retainers) and the seal material in order to clean the fuse pins for ultrasonic inspection, based on a routine CITEXT instruction. The lugs and bushings were NDT checked. The inspector then notified the crew chief, and the crew chief had the components reinstalled. He said that a different mechanic, rather than the one who removed them, might reinstall the components.

He said that he did not have to remove the retainers to complete his work on the hydraulic reservoir bracket of the No. 1 pylon on the accident airplane. He said that he did not remember anything about the primary or secondary retainers on the No. 1 diagonal brace. He further stated that he does not know why retainers would have been removed on the accident airplane.

This individual stated that the No. 1 and No. 2 pylon areas are physically similar, but that they are worked by separate crews. There are usually three mechanics assigned to each engine and strut, and work is done independent of each of the other crews. As nonroutine maintenance needs arise, the mechanics must write up paperwork before removing the part. They must complete a red tag or a C copy on CITEXT card as appropriate. Pins and retainers would require two separate red tags.

This interviewee described problems with the CITEXT system. He indicated that when a problem is discovered, it is brought to the attention of the crew chief, who, in turn, discusses the anomaly with the manager or work planner. The CITEXT anomalies most commonly encountered are with test sequences and errors concerning the maintenance manual or EO references.

17. Northwest Airlines A&P Mechanic

This individual's position is as an A&P Mechanic. He has been with NWA since 1984 and in his present position since hangars 5 and 6 opened.

He worked in hangar 6 on the first shift on February 19, 1994. He was performing the duties of acting lead mechanic. During the time the accident airplane was in hangar 6 for the "C" check, he worked on the No. 1 pylon forward upper link, where his crew replaced the bushings in the forward end fitting. He stated that he did not work on the aft diagonal brace.

On the evening of February 19, 1994, he worked overtime because of a shortage of engine mechanics. He quit work for the evening at 2148. About 2100, another mechanic found the primary retaining caps off on No. 4 diagonal brace forward and aft ends. He checked the paperwork and found no red tags or any nonroutine cards to cover these items.

This individual stated that when his crew found the primary caps missing from the No. 4 diagonal brace with no associated paperwork, he told the shift manager about the problem, and the shift manager stated that he would take care of it. This interviewee also told a mechanic to ensure that the work was being done. As he left the hangar to go home, he noted that work was being done on the No. 4 pylon.

This individual stated that on March 1, 1994, the Director of DC-10 and B-747 Maintenance (interviewee No. 9) told him of a problem with the accident airplane at Narita, Japan. The Director asked if any of the mechanics present had any idea what might have happened.

This interviewee then stated that earlier, on March 1, 1994, interviewees number 2 and 3 (both mechanics) had found a set of primary retainers in a bag tied to the secondary retainer on the wing dock in the No. 1 engine position and placed them on a parts cart by the No. 1 engine.

The individual then said that after the Director told his group about the accident airplane in Japan, he went to the cart and retrieved the retainers. He then checked to be sure that they were not off of the airplane now in the hangar. They were not, so he gave the parts to the Director.

This interviewee could think of no reason for the primary diagonal brace fuse pin retainers to be removed. He stated that the NDT inspection done on the diagonal braces did not require their removal, and that there were no red tags or paperwork covering the removal on the No. 1 or No. 4 pylon.

18. Northwest Airlines A&P Mechanic

This individual stated that he is a licensed FAA A&P mechanic, and that he works as a mechanic for NWA. He has been with NWA for 4 years and has been working in his present position since hangar 5 & 6 opened. Prior to joining NWA, he worked in the general aviation field as an A&P mechanic.

He stated that he worked on removing the No. 1 engine from the wing because it makes the fuse pin-related jobs a little easier when the weight of the engine is off the pylon. Furthermore, it releases a hoist for use in other maintenance areas. He also stated that he was assigned to work the No. 1 engine upper forward link to replace the bushings. He further said that the No. 1 engine upper link was already out of the pylon when he arrived, but that he did put the upper link forward bushing shaft and fuse pin in. This individual also reported that he participated in removing the No. 2 engine to allow for a change of the No. 2 engine mid-spar bushings. He clearly stated that he did not work on the No. 1 engine pylon diagonal brace during this period. This interviewee stated that he did not see anybody working on the diagonal brace on the No. 1 engine, nor did he see the parts bag that was recovered after the accident airplane had returned to service.

When he was questioned about his training, he stated that he did not receive any formal training on the GEMM and that he only had OJT on the red tag procedure.

[1]Because of the limited availability of the new third generation pins, the airline was installing the parts based on availability. As a result, any particular NWA B-747 airplane could have two different types of pins installed on the four engine pylons.

[2]A computer-generated maintenance instruction system. CITEXT (Centralized Interactive Text System) is a European-developed software system.

[3]A work control board is a pin-on/grease pencil log board devoted to the airplane in work. The board allows control of the shop floor work flow, providing visibility to tasks in progress.

[4]This mechanic stated that normally the closer, forward diagonal brace pylon fuse pin would have been removed, but that in this case, the aft primary and secondary retainers had already been removed by someone else, thus simplifying his job.

[5]Service Letter 747-SL-54-35-B corrected two references in Service Letter 747-SL-54-35-A.

[6]Aircraft Accident Report--"Aloha Airlines, Flight 243, Boeing 737-200, N73711, Near Maui, Hawaii, April 28, 1988." (NTSB/AAR-89/03)

[7]"Human Factors in Aviation Maintenance Phase I: Progress Report." Galaxy Scientific Corporation, 1991 (FAA report No. DOT/FAA/AM-91/16, pp. 78 and 79).

[8]A turnover item is a maintenance item that is carried over from one shift to the following shift or "turned over."