SP-20

National Transportation Safety Board

Washington, D.C. 20594

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In reply refer to: A-89-53 through 69

Honorable James B. Busey
Administrator
Federal Aviation Administration
Washington, D.C. 20591

On April 28, 1988, at 1346, a Boeing 737-200, N73711, operated by Aloha Airlines Inc., as flight 243, experienced an explosive decompression and structural failure at 24,000 feet, while en route from Hilo, to Honolulu, Hawaii. Approximately 18 feet from the cabin skin and structure aft of the cabin entrance door and above the passenger floorline separated from the airplane during flight. There were 89 passengers and 6 crewmembers on board. One flight attendant was swept overboard during the decompression and is presumed to have been fatally injured; 7 passengers and 1 flight attendant received serious injuries. The flightcrew performed an emergency descent and landing at Kahului Airport on the Island of Maui.[1]

The Safety Board determined that the accident sequence initiated with the structural separation of the pressurized fuselage skin. As a result of this separation, an explosive decompression occurred, and a large portion of the airplane cabin structure comprising the upper portion of section 43 was lost.

A postaccident examination of N73711 revealed that the remaining structure did not contain the origin of the failure. Since the sea and air search did not locate recoverable structure from the airplane, it was necessary to determine the failure origin by examining and analyzing the remaining structure and the airworthiness history of the airplane.

The Safety Board determined that the fuselage of N73711 most probably failed catastrophically at the lap joint along stringer S-10L, initially near BS 440, allowing the upper fuselage to rip free. The reason for this catastrophic failure, rather than the intended fail-safe "flapping" of the skin as designed, was evaluated by the Safety Board.

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[1]For more detailed information, read Aircraft Accident Report--"Aloha Airlines, Flight 243, Boeing 737-200, N73711, near Maui, Hawaii, April 28, 1988" (NTSB/AAR-89/03).

Multiple site damage (MSD) describes multiple fatigue cracks along a rivet line. MSD can range from a few fatigue cracks among many rivet holes to the worst case of small, visually undetectable fatigue cracks emanating from both sides of rivet holes along a complete row of skin panel fasteners. Numerous areas of MSD were discovered in the fuselage skin of N73711 during postaccident investigation. The presence of MSD also tends to negate the fail-safe capability of the fuselage.

It is probable that numerous small fatigue cracks in the lap joint along S-10L joined to form a large crack (or cracks) similar to the crack at S-10L that a passenger saw when boarding the accident flight. The damage discovered on the accident airplane, damage on other airplanes in the Aloha Airlines fleet, fatigue striation growth rates, and the service history of the B-737 lap joint disbond problem led the Safety Board to conclude that, at the time of the accident, numerous fatigue cracks in the fuselage skin lap joint along S-10L linked up quickly to cause catastrophic failure of a large section of the fuselage.

The Safety Board believes that sufficient fatigue cracking or tear strap disbond (or a combination of both) existed in the lap joint at S-10L to negate the design-intended controlled decompression of the structure.

The Safety Board further believes that Aloha Airlines had sufficient information regarding lap joint problems to have implemented a maintenance program to detect and repair the lap joint damage. The information available to Aloha Airlines on lap joint problems included the following:

- o the B-737s in the Aloha Airlines' fleet were high-cycle airplanes accumulating cycles at a faster rate than any other operator;
- o Aloha Airlines operated in a harsh corrosion environment;
- o Aloha Airlines previously had discovered a 7.5-inch crack along lap joint S-10L on another B-737 airplane;
- o Boeing had issued, and records indicate that Aloha Airlines was aware of, a Service Bulletin (SB) covering lap joint inspection and repair in 1972, revised in 1974, and upgraded to an Alert Service Bulletin (ASB) in 1987; and
- o the FAA had issued an Airworthiness Directive (AD) in 1987 requiring inspections of the lap joints along S-4 and referencing the Boeing ASB, which called for inspection of all other lap joint locations, including along S-10.

The Safety Board identified three factors of concern in the Aloha Airlines maintenance program. They were: a high accumulation of flight cycles between structural inspections, an extended time period between inspections that allowed the related effects of lap joint disbond, corrosion, and fatigue to accumulate, and the manner in which a highly segmented structural inspection program was implemented.

The Aloha Airlines maintenance program did not adequately recognize and consider the effect of the rapid accumulation of flight cycles. The Safety Board notes that flight cycles are the dominant concern in the development of fatigue cracking in pressurized fuselages and the accumulation of damage as a result of flight and landing loads. The Aloha Airlines maintenance program allowed one and one half times the number of flight cycles to accumulate on an airplane before the appropriate inspection. The Safety Board believes Aloha Airlines created a flight-hour based structural maintenance program without sufficient regard to flight cycle accumulation.

The Boeing Maintenance Planning Document (MPD) assumed a 6- to 8-year interval for a complete D check cycle, and the Aloha Airlines D check maintenance program required 8 years to complete a D check cycle. The Safety Board believes that the 8-year inspection intervals in the Aloha Airlines maintenance program was too lengthy to permit early detection of disbond related corrosion, to allow damage repair, and to implement corrosion control/prevention with the maximum use of inhibiting agents.

Of additional concern to the Safety Board was Aloha Airlines' practice of inspecting the airplane in small increments. The Aloha Airlines D check inspection of the B-737 fleet was covered in 52 independent work packages. Limited areas of the airplane were inspected during each work package, and this practice precluded a comprehensive assessment of the overall structural condition of the airplane.

The Safety Board believes that the use of 52 blocks/independent work packages is an inappropriate way to assess the overall condition of an airplane and effect comprehensive repairs because of the potential for air carriers to hurry checks in order to keep airplanes in service. Further, the fact that the FAA found this practice to be acceptable without analysis is a matter of serious concern.

The Safety Board believes that the FAA should reevaluate the criteria and guidance provided to principal inspectors for approving individual operator's maintenance plans that divide structural inspections into a large number of independent work packages (segments) to be spread over the normal D check interval. The Safety Board recognizes the concept that the D check, as outlined in the MPD, for each aircraft is accomplished in a reasonable time period such as 3 to 5 weeks. A true heavy maintenance inspection involves extensive work which may take several days. Comprehensive structural inspections for aging airplanes, likewise, can best be accomplished by a D check in which the entire airplane is inspected and refurbished in one hangar visit. As an alternative, some operators have found it efficient to use yearly block C checks with a phased 1/4 D check inspection. Any deviation from this "full airplane" inspection at "seasonal scheduling intervals" should be evaluated carefully before approval.

Operator initiated changes to maintenance manuals and operations specifications are approved by the Principal Maintenance Inspector (PMI). Many PMI decisions require knowledge of airplane engineering and human performance far beyond the capabilities of any one individual. The Safety Board believes that the PMI should be required to seek additional assistance or input from other divisions of the FAA and, through channels, from the manufacturer and other operators. The types of input, the sources for both airworthiness and flight standards information and the conditions under which such input should be used, need to be reviewed and guidance developed by the FAA so the PMI can perform his duties more effectively. Therefore, the Safety Board believes that the FAA should develop and provide guidance to the PMI for the approval of airline maintenance plans which are modified significantly from that outlined in the MPD.

Another factor that may have affected the performance of Aloha's maintenance and inspection personnel is related to the quality of support provided by Aloha management to assist these persons in the performance of their tasks. Proper training, guidance, and procedures are needed as well as an adequate working environment, sufficient aircraft down time to perform the tasks (i.e. flexible scheduling), and an understanding of the importance of their duties to ensure the airworthiness of the airplanes. Aloha Airlines training records revealed that little formal training was provided in nondestructive inspection (NDI) techniques and methods. The inspector who found the S-4R lap joint cracks requiring repair stated that only on-the-job training (OJT) had been provided since he became an inspector in August 1987; his training records show formal NDI training on September 17, 1987, when a 2-hour training session was given by a Boeing representative. Records indicate the inspector who provided the initial OJT had only 2 hours of formal NDI training, during the same 2-hour training session on September 17, 1987, provided by Boeing. Thus, the Safety Board is concerned about how much knowledge the inspector staff may have possessed about disbonding, corrosion, and fatigue cracking at the time that they were required to perform the critical AD inspection task. In fact, during deposition proceedings, the inspector who performed the first AD inspection on N73711 could not articulate what he should look for when inspecting an airplane for corrosion signs.

The Safety Board believes that exacerbating the difficulty in the inspection tasks of airline maintenance personnel is the fact that FAA approved training for aircraft maintenance technicians contains material that is largely irrelevant to the tasks that licensed personnel will actually perform in an airline environment. For example, 14 CFR 147, which governs the certification of maintenance personnel, requires that students in FAA approved maintenance schools be knowledgeable in such topics as wood airframes, airframe fabric repair, and application of paint and dope. In a time when the FAA is certificating air transport aircraft with fly-by-wire technology, composite materials construction and computer self monitoring capabilities, the words "computer" and "composite" do not appear in the list of required curriculum subjects among airframe systems and components in 14 CFR 147, Appendix C. The Safety Board believes that current requirements for training aviation maintenance personnel fail to address the tasks that such personnel will actually perform following their licensure. The Safety Board is concerned about how well the FAA approved training curricula can address the human performance limitations of a relatively simple visual inspection task when the training that maintenance personnel receive fails to address the basic skills they will be expected to perform on the job. The Safety Board believes that the FAA should examine the regulations governing the certification of aviation maintenance technican schools and the licensure of airframe and powerplant mechanics and revise the regulations to address contemporary developments in airplane maintenance.

Another area of Safety Board concern arises from the fact that there are no FAA requirements for formal training or licensing of NDI personnel. The Safety Board is aware that the United Kingdom Civil Aviation Authorities and those in other countries have formally recognized the importance of NDI skills and have required in-depth training, skill demonstration, licensing and recurrent certification of NDI personnel. While NDI technology and techniques in some industries in the United States are quite advanced and personnel certification follows the American Society for Nondestructive Testing (ASNT) guidelines, the aviation industry has not applied such advanced techniques or practices. For instance, in the current environment, any mechanic, including those designated as inspectors, could be assigned to perform detailed and critical NDI inspections on airplanes with little or no training and with tools that have not been technologically improved for some time.

Because of its criticality and complexity, the Safety Board believes that the NDI maintenance function should be reviewed by the FAA with a view towards requiring formal training, skill demonstration, apprenticeships, and formal licensing and recurrent certificaton for NDI inspectors.

The policies, procedures, and organization of Aloha Airlines aircraft maintenance and inspection program significantly affected the control of corrosion of its airplanes. According to airplane maintenance records, lap joint and other areas of corrosion were detected, but corrective action was frequently deferred without recording the basis for such deferrals. Routine inspection task cards contained the "check for corrosion" instruction for specific areas; however, a programatic approach to corrosion prevention and control of the whole airplane was not evident. It appears that even when Aloha Airlines personnel observed corrosion in the lap joints and tear straps, the significance of the damage and its criticality to lap joint integrity, tear strap function, and overall airplane airworthiness was not recognized by the Aloha Airlines inspectors and maintenance managers. This was particularly noteworthy when one considers that Aloha Airlines indicated that SB 737-53-1039, Revision 2 (1974), was incorporated in their maintenance plan. The overall condition of the Aloha Airlines fleet indicated that pilots and line maintenance personnel came to accept the classic signs of on-going corrosion damage as a normal operating condition.

The Safety Board was also concerned about the uncommanded shutdown of the left engine during the accident sequence. The left engine fuel control was found in the "cutoff" position; the control apparently was positioned there by the residual tension in the intact cable or motion of that cable induced by the cabin floor deflection since the cables are routed through cutouts in the floor beams.

Since the point of maximum upward floor deflection (hence maximum cable deflection) was at BS 440 in the cabin, the actual location of the throttle cable failures (in the wing leading edge) seemed an unlikely one.

Additionally, the broken cable ends lacked the unraveling that is characteristic of cables that fail in tension overload. When the appropriate cable sections were removed from the airplane and inspected more closely, there were indications of corrosion. These observations were confirmed by laboratory examination which concluded that the diameters of many of the individual wires that comprise the cables had been reduced significantly by corrosion damage. This corrosion likely weakened the cables so that they separated at a lower than designed load when placed in tension by the displacement of the left side floor beams. The cables of the right engine also exhibited extensive surface corrosion where they were routed through the leading edge of the wing. These cables may have remained intact during the separation sequence only because of the much smaller amount of floor beam deflection that occurred on the right side of the cabin.

The damage to the throttle cables appears much the same as the type of corrosion described in Boeing Service Letter (SL) 737-SL-76-2-A issued on August 25, 1977. This SL was issued as a result of the discovery by Aloha Airlines that a carbon steel thrust control cable had corroded and frayed. Only five of the seven strands of the cable were reported intact. The remaining five strands were also corroded, and the corrosion was present on the entire length of that portion of the cable routed through the wing leading edge.

The Boeing recommended action following this discovery was to replace the carbon steel engine control cables with corrosion resistant stainless steel cables on the production line beginning with production line number 503 which was delivered in September 1977. Boeing recommended that operators of existing airplanes replace the original carbon steel cables on production line numbers 1 through 502 as required. At this date, the number of aircraft modified in accordance with the applicable SL has not been established accurately. Laboratory examination of the separated cables from N73711 confirmed that they were the original carbon steel type. The Safety Board is concerned that Aloha Airlines did not take advantage of the manufacturer's corrective action for these cables, especially in light of their initial discovery of the problem and recognition of their own harsh operating environment.

Even though the corrosion problems with the carbon steel engine control cables have been known for quite some time, the Safety Board believes that it would be beneficial to once again address this area in light of the cable condition on the accident airplane and the fact that some portions of the cables can be difficult to inspect. The Safety Board believes that the FAA *should issue an Airworthiness Directive to the operators of the affected* B-737 airplanes advising them of the corrosion potential of carbon steel engine control cables and directing them to the information contained in 737-SL-76-2-A regarding cable replacement.

The condition of high cycle B-737s in the Aloha Airlines fleet with respect to lap joint corrosion, multiple repairs, and detection of fatigue cracking is an example of what can occur in the absence of regular and knowledgeable evaluations of aircraft condition by qualified engineering staff.

The Safety Board believes that the continued airworthiness of airplanes as they age would be enhanced by including qualified engineers in the operator's organization. While the Safety Board recognizes that situation may be economically unrealistic for all operators, it believes that an equivalent level of safety can be achieved only by using engineering representatives from some other source. Qualified engineers could evaluate service information and airworthiness directives with particular respect to the fleet aircraft and operating conditions. The assistance of these qualified engineers may be available through an industry group or the manufacturer. The Safety Board believes that the Aloha Airlines maintenance department did not have sufficient manpower, the technical knowledge, or the required programs to meet its responsibility to ensure the continued structural integrity of its airplanes. The Safety Board, therefore, recommends that the FAA require airline operators that do not have a functioning engineering department to maintain a formal alternative to provide engineering services.

The Safety Board reviewed FAA responsibilities regarding the issuance and clarity of Airworthiness Directives. In-service fatigue cracking in a disbonded area of a B-737 lap joint was first reported in 1984 (by Aloha Airlines). Then in April 1987, a foreign operator reported several cases within his fleet. Boeing acted by revising the existing lap joint disbond information, SB 737-53-1039, Revision 2 (which had advised that prolonged operation with disbonded areas would result in fatigue cracks), upgrading the SB to Alert status, and notifying the FAA. In October 1987, multiple site cracking was discovered during the manufacturer's continued fatigue testing of a B-737 aft body section. Within the same time frame, the FAA issued AD 87-21-08 which required mandatory inspection for fatigue cracking.

The Safety Board considers it unfortunate that the Boeing Alert SB to inspect all lap joints was not issued after the first instance of cracking, and that the intent of the Alert SB was altered significantly by the FAA to reduce the scope of the inspection when the AD was released. The Safety Board believes that had a full inspection of all lap joints been mandated, the likelihood of this accident occurring may have been reduced. Therefore, the limited AD requirements imposed by the FAA precluded the continuing airworthiness of the aging B-737s and the reduced inspection criteria is considered a contributing factor to the cause of this accident.

When Aloha Airlines accomplished the inspections and repairs associated with the AD, they omitted inspections of lap joints other than those along S-4 and they did not replace the remaining fasteners in the upper row of the S-4R lap joint with universal head ("button head" or protruding head) rivets, as outlined in Boeing ASB 737-53A1039. The AD pertaining to the lap joint inspections states, in part:

> Repair all cracks and tearstrap delaminations found as a result of the above inspections prior to further flight in accordance with Boeing Alert Service Bulletin 737-53A109, Revision 3, dated August 20, or later FAA-approved revisions.

The appropriate section of the ASB states, in part:

Repair fatigue cracks using a repair similar to that shown in 737 Structural Repair Manual Subject 53-30-3, Figure 16, and replace all remaining upper row flush joint-fasteners in that panel joint with oversized protruding head solid fasteners per Part IV - Repair Data.

While operators have interpreted the repair instructions listed in the AD note as requiring the installation of the protruding head rivets as a part of the repair, the FAA personnel stated that its intent was to have protruding head fasteners installed throughout the skin panel joint where cracking was found.

Repairs of the S-4 joint by Aloha Airlines were accomplished using the procedure in the Structural Repair Manual and excluded replacing the remaining flush joint-fastners. The Safety Board believes that the instructions contained in the AD were inexact and subject to misinterpretation.

Such confusion illustrates the difficulty inherent in attempting to present technical information so that it can be interpreted properly by the users of the information. In the case of this AD, it is believed that the repair instructions could have been presented more explicity. This was, in fact, done in subsequent ADs pertaining to the same subject.

The Safety Board is satisfied that the terminating action for the disbonding of B-737 lap joints and tear straps requiring replacement of the upper rivet row is an effective measure to correct this recognized B-737 deficiency.

However, laboratory examination of the S-4R lap joint sample from the accident airplane revealed another area of concern with early line number B-737 airplanes. Fatigue cracks were found emanating from the fastener holes of a significant number of rivets in the middle row of the lap joint. The Safety Board is concerned that because of the extended lifetime of the B-737 afforded by the terminating action mandated for the upper rivet row, the lower rivet row on the inner (lower) skin panel eventually will be a location for fatigue cracks to develop. These cracks, if they occur, cannot be detected externally by visual means since they are covered by the outer skin panel. The FAA and Boeing should continue to evaluate the early model B-737 airplanes to determine the types of inspections, inspection intervals, and corrective actions to be instituted if a significant fatigue cracking problem develops in the middle and lower row of lap joint fasteners.

The investigation has revealed that staffing levels in some FSDOs are insufficient. The Principal Maintenance Inspector (PMI) responsible for Aloha Airlines indicated that he was also assigned as the PMI for nine other operators and seven repair stations throughout the Pacific rim area. He also was assigned out of his geographic area of responsibility to participate in a NASIP inspection. The Safety Board believes that the PMI's workload was too extensive for him to be adequately effective.

As a result of the FAA sponsored Safety Activity Functional Evaluation (Project SAFE) in 1984, the FAA Flight Standards System is now in a 5-year program to improve inspection guidance, field surveillance, and standardization. The FAA has been allocated additional hiring authority and funds to increase the number of air carrier inspectors. While additional personnel will improve the staffing situation, the Safety Board is concerned about the qualifications of the newly hired inspectors and the training of the inspector force. Because there are a limited number of candidates who have extensive air carrier backgrounds, the FAA has had to hire people with general aviation or military backgrounds or transfer inspectors from general aviation assigments. As a result, the new inspectors are not fully familiar with air carrier maintenance programs and practices. Although the FAA provides a 6-week indoctrination for the new inspectors, it requires several years of on-the-job experience to make the inspectors most effective. Then they progress on a career path that leads toward being appointed as a PMI. There is no specific formal training course for PMIs. Additionally, recurrent training is sporadic and difficult to attain, resulting in a work force that must try very hard to stay ahead of the operators and quickly advancing aircraft technology.

The Safety Board sought to identify existing boundaries of responsibility of the PMI regarding regulatory compliance and the level of maintenance quality demonstrated by the assigned air carrier. Evidence of accountability of the PMI and district office for the performance of the assigned carrier(s) was not apparent. Evidence suggests that FAA surveillance and inspection programs are directed toward the air carrier, and the in-house evaluation of PMI performance is oriented toward quantity of work and the ability to handle approvals smoothly and directly. The Safety Board is concerned that the PMI has the authority to approve critical areas of air carrier maintenance programs without being held responsible for those approvals. There does not appear to be an effective method in place for FAA management to make recurring qualitative assessments of PMI approvals.

Followup of the NASIP findings is also indicative of a lack of PMI accountability. The negative findings of an airline maintenance program are placed into the oversight of the PMI to promote and monitor corrective action. That is, a negative situation may occur under the jurisdiction and surveillance of a PMI and yet he is responsible to evaluate and follow up on corrective action. Therefore, the accountability for the on-going quality of the PMIs work performance does not appear to exist.

It appears that the current surveillance system can lead to "rubber stamp" approvals and endorsement of an air carrier's operations and maintenance programs. Improvements are needed to encourage and support the PMIs' efforts to secure compliance and to promote upgraded levels of performance by the assigned air carrier in both safety and reliability areas. Without such improvements, the system of program approval can be driven by the momentum and interests of the air carrier. It appears the present system is sustained by the personal integrity and dedication of the concerned FAA inspector personnel rather than by an FAA system that includes adequate oversight and internal review. With the current environment, only the most motivated PMIs will maintain their sense of responsibility to ensure maximum efficiency and safety. The Safety Board recognizes the need for increased FAA management emphasis on the accountability of a PMI's performance. Both regional and headquarters Flight Standards staff should become more involved in assessing and ensuring PMI accountability.

In addition, there is also a need for a program of standardized approvals of air carrier maintenance programs to promote a uniform and acceptable level of safety performance in the current competitive air carrier industry. The Safety Board believes that the authority of the PMI for approval of airlines procedures and operations specifications can be better guided, and overall PMI performance improved, if definitive Flight Standards criteria are provided to those in the field.

The Safety Board also investigated the effectiveness of the National Aviation Safety Inspection Program (NASIP) after the Aloha Airlines accident. A NASIP inspection had been performed at Aloha Airlines in December 1987 and none of the findings and corrective actions addressed airplane structural maintenance. In fact, NASIP looked chiefly at manuals and records with a minimal effort expended to the condition of the fleet. A month earlier, Boeing had performed a maintenance evaluation of the carrier at Aloha Airlines' request. Boeing found several areas of concern including the deteriorated structural condition of the Aloha Airlines' high-cycle airplanes and Aloha Airlines' immediate need for a structures engineer. The Boeing inspection provided a convenient yardstick by which the effectiveness of the NASIP effort can be measured. The Boeing effort concentrated initially on the actual condition of the airplanes, and then it reviewed the paperwork to find out why the maintenance program had resulted in the airplane deterioration. The Safety Board concluded that there are inadequacies in the NASIP objectives and methodology which require a change in the current philosophy of FAA surveillance to include added inspection of fleet airplane condition.

The Safety Board also believes that routine surveillance and the NASIP concept should be adjusted toward a more "safety-oriented" qualitative program to complement the current "Federal regulation compliance" approach. That is, under the current philosophy, the FAA examines airline records for compliance with regulations, and some negative findings (violations) result in enforcement actions for which there are clear guidelines. However, many negative findings are "nonregulatory" matters for which both the local PMIs and the NASIP teams believe corrective actions should be taken. In the preamble to the 1987 NASIP report of Aloha Airlines, the FAA team stated, "Aloha Airlines' Maintenance Management has been remiss in their responsibilities by not being able to recognize their own deficiencies, as this report will indicate." "Responsibilities" apparently refers to regulations under which Aloha Airlines is charged with maintaining its airplane in an airworthy condition (FAR 121.363). "Deficiencies" in this case apparently refers to items which the FAA believes Aloha Airlines should correct to operate safely. There was no national FAA program to evaluate and verify the quality of the corrective actions, nor to determine the timeliness of such actions. For example, the NASIP team found that Aloha Airlines "...does not have an effective internal audit program." Although FAR 121.373 "Continuing analysis and surveillance" addresses an air carrier's responsibility to maintain a system for continuing analysis and surveillance of its inspection and maintenance programs, the FAA NASIP inspectors apparently concluded that the regulation was too subjective to use as a basis for enforcement action to assure that Aloha Airlines corrected deficiencies in their internal audit program.

Technically, as stated by the FAA, if an airline complies with the regulations, it is "safe." However, many regulations are subjective in nature and are subject to interpretation. Consequently, even with several significant negative findings by a NASIP team, as was the case with Aloha Airlines, the airline was allowed to continue operations without making immediate changes and without having to set deadlines for completion on recommended actions. In fact, the oversight and closeout of corrective actions suggested by the NASIP team were left to the Aloha Airlines PMI, under whose jurisdiction and routine surveillance the discrepancies existed.

At the time of the initial certification of the B-737, a consideration for MSD was not a part of the certification requirements, nor is it required now. This is demonstrated by the fact that there is no specific FAA requirement for full-scale fatigue testing to multiple projected service lifetimes of an airplane. Boeing attempted to assure fatigue life by testing the representative half fuselage section to two lifetimes. However, the durability of the lap joint cold bond appears to be the governing factor producing multiple site fatigue cracking in the B-737 lap joints. The Safety Board believes that the Boeing fatigue tests of the fuselage to two lifetimes did not generate fatigue cracking, probably because the lap joint and tear strap bonds on the test article were initially of good quality. Nonetheless, the Safety Board believes in light of the increased knowledge of and concern for the occurrence of MSD, the difficulties that may be encountered in detecting this type of damage and the catastrophic failure that may result from such damage, full-scale fatigue testing to a minimum of two projected service lifetimes should be required for certification of new designs.

The Safety Board believes that full-scale fatigue testing obviously is not a substitute for a comprehensive structural inspection program throughout the airplane's service life. The effectiveness of these inspection programs as the airplane ages would be enhanced by the early identification of areas where MSD does occur and incorporation of the necessary preventive design changes so that MSD is not a significant factor during the airplane's operating lifetime.

The Supplemental Structural Inspection Programs (SSIPs) mandated by the FAA vary by concept and implementation from manufacturer to manufacturer and from model to model. As Boeing devised the SSIP for their existing certificated airplanes, a structural classification system determined which SSIs are included in the supplemental inspections. Because Boeing defined the fuselage skin as "damage obvious or malfuction evident" if it cracks, the fuselage skin was excluded from directed supplemental inspection. Other manufacturers use different criteria and include primary fuselage structure and skin in the structural inspection program.

Boeing believes that their current FAA approved inspection program is adequate for detecting lead cracks resulting from MSD before the damage becomes critical. However, the Aloha Airlines accident illustrates that it is possible to have enough undetected (but technically detectable) damage along a rivet line to negate the controlled decompression mechanism.

The Safety Board recommends that the classification of fuselage minimum gage skin as damage obvious be discontinued and the affected SSIPs be revised accordingly. Additionally, all of the remaining SSIs in the damage obvious category should be reviewed in light of the recent approach for possible inclusion in the SSIP.

The magnitude of the accident was well beyond any anticipated emergency scenario. The flightcrew's actions were consistent with simulator training situations which minimize the exposure to physiological effects. The flightcrew's success in managing the multiple emergency situations and recovering the aircraft to a safe landing speaks well of their training and airmanship.

The cabin crew also performed in a highly commendable manner when faced with a totally unpredicted event. Their bravery in moving about to reassure the passengers and prepare them for landing was exemplary.

It was apparent from crew interviews and the FDR that a rapid descent was initiated shortly after the explosive decompression. The Safety Board notes that speed brakes and 280 to 290 KIAS were used without first assuring the structural integrity of the airplane (the cockpit door was missing and sky was visible overhead). The IAS used in the descent, although it minimized the time at altitude, increased the maneuvering loads and subjected the passengers to flailing and windburn from the effect of exposure. The open fuselage break was also subjected to high dynamic pressure from the wind force.

The Operators Manual, Emergency Descent procedure (and emergency checklist) states that if structural integrity is in doubt, "limit airspeed as much as possible and avoid high maneuvering loads." The Safety Board considers that evaluation of the structural integrity and techniques of emergency descent (target airspeed, configuration changes, and maneuvering loads) can be critical to the success of further flight. The Safety Board therefore suggests that the FAA issue an Air Carrier Operations Bulletin (ACOB) to review the accident scenario and reiterate the need to assess airplane airworthiness as stated in the operators manual before taking any action that may cause further damage or the breakup of a damaged airframe.

Therefore, as a result of its investigation of this accident, the National Transportation Safety Board recommends that the Federal Aviation Administration:

> Provide specific guidance and proper engineering support to Principal Maintenance Inspectors to evaluate modifications of airline maintenance programs and operations specifications

which propose segmenting major maintence inspections. (Class II, Priority Action) (A-89-53)

Identify operators whose airplane use differs significantly from the flight cycle versus flight time relationship upon which the Maintenance Planning Document was predicated, and verify that their maintenance programs provide timely detection of both cycle and time related deficiencies. (Class II, Priority Action) (A-89-54)

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. (Class II, Priority Action) (A-89-55)

Require formal certification and recurrent training of aviation maintenance inspectors performing nondestructive inspection functions. Formal training should include apprenticeship and periodic skill demonstration. (Class II, Priority Action) (A-89-56)

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. (Class II, Priority Action) (A-89-57)

Develop a continuing inspection program for those B-737 airplanes that have incorporated lap joint terminating action (protruding head solid fasteners installed in the upper row of all lap splices) to detect any fatigue cracking that may develop in the middle or lower rows of fuselage lap joint fastener holes (for both the inner and outer skin panels) or in the adjacent tear strap fastener holes, and define the types of inspections, inspection intervals, and corrective actions needed for continuing airworthiness. (Class II, Priority Action) (A-89-58)

Develop a model program for a comprehensive corrosion control program to be included in each operator's approved maintenance program. (Class II, Priority) (A-89-59)

Issue an Airworthiness Directive for B-737 airplanes equipped with carbon steel engine control cables to periodically inspect the cables for evidence of corrosion and if there is such evidence, to accomplish the actions set forth in Boeing Service Letter 737-SL-76-2-A. (Class II, Priority Action) (A-89-60)

Require that air carrier maintenance departments use the engineering services available from the manufacturer or other sources to periodically evaluate their maintenance practices including structural repair, compliance with airworthiness directives and service bulletins, performance of inspection and quality assurance sections and overall effectiveness of continuing airworthiness programs. (Class II, Priority Action) (A-89-61)

Revise the National Aviation Safety Inspection Program objectives to require that inspectors evaluate not only the paperwork trail, but also the actual condition of the fleet airplanes undergoing maintenance and on the operational ramp. (Class II, Priority Action) (A-89-62)

Require National Aviation Safety Inspection Program teams to indicate related systemic deficiencies within an operators maintenance activity when less than satisfactory fleet condition is identified. (Class II, Priority Action) (A-89-63)

Evaluate the quality of FAA surveillance provided by the principal inspectors as part of the National Aviation Safety Inspection Program. (Class II, Priority Action) (A-89-64)

Integrate the National Aviation Safety Inspection Program team leader in the closeout of the team findings. (Class II, Priority Action) (A-89-65)

Enhance the stature and performance of the principal inspectors through; (1) formal management training and guidance, (2) greater encouragement and backing by headquarters of efforts by principal inspectors to secure the implementation by carriers of levels of safety above the regulatory minimums, (3) improved accountability for the quality of the surveillance and (4) additional headquarters assistance in standardizing surveillance activities. (Class II, Priority Action) (A-89-66)

Require that all turbojet transport category airplanes certificated in the future, receive full scale structural fatigue testing to a minimum of two times the projected economic service life. Also require that all currently certificated turbojet transport category airplanes that have not been fatigue tested to two lifetimes, be subjected to such testing. As a result of this testing and subsequent inspection and analysis, require manufacturers to identify structure susceptible to multiple site damage and adopt inspection programs appropriate for the detection of such damage. (Class II, Priority Action) (A-89-67)

Discontinue classification of fuselage skin as "malfunction evident" or "damage obvious" on supplemental structural inspection documents. In addition, review all the remaining structurally significant items in the damage obvious category for possible inclusion in the Supplementary Inspection Program. (Class II, Priority Action) (A-89-68)

Issue an Air Carrier Operations Bulletin for all air carrier flight training departments to review the accident scenario and reiterate the need to assess airplane airworthiness as stated in the operators manual before taking action that may cause further damage or breakup of a damaged airframe. (Class II, Priority Action) (A-89-69)

Also, the Safety Board issued Safety Recommendations A-89-70 through -72 to Aloha Airlines and A-89-73 to the Air Transport Association.

KOLSTAD, Acting Chairman, and BURNETT, LAUBER, NALL, and DICKINSON, Members, concurred in these recommendations.

By: James L. Kolstad
Acting Chairman