Log 2179

National Transportation Safety Board

Washington, D.C. 20594

Safety Recommendation

Date: August 23, 1989

In reply refer to: A-89-92 through -94

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

On February 24, 1989, United Airlines, Inc., (UAL), Flight 811, a Boeing 747-122, N4713U, with 3 flight crewmembers, 15 cabin crewmembers, and 337 passengers on board, experienced an explosive decompression as a result of the in-flight loss of the right forward lower lobe cargo compartment door and a part of the right cabin fuselage.

Flight 811 was en route from Los Angeles, California, to Sydney, Australia (SYD) with intermediate stops in Honolulu, Hawaii (HNL) and Auckland, New Zealand (AKL). It was a regularly scheduled flight conducted under the provisions of 14 Code of Federal Regulations (CFR) Part 121.

The captain was at the controls when Flight 811 was cleared for takeoff on HNL runway 8R at 0152:49, Honolulu standard time (HST). The flightcrew reported the operation of the airplane as normal during takeoff and the initial climbout. The first indication of a problem occurred while the airplane was climbing between 22,000 and 23,000 feet, at an indicated airspeed (IAS) of 300 knots. The flightcrew heard a sound they described as a thump which shook the airplane. This was followed immediately by, what was described as, a tremendous explosion. The airplane had experienced an explosive decompression.

The captain immediately initiated an emergency descent and proceeded toward HNL. The flightcrew declared an emergency with Honolulu Combined Center Radar Approach Control (CERAP) at approximately 0210 HST. The number 3 engine was shut down shortly after commencing the descent due to heavy vibration, no N1 indication, low exhaust gas temperature (EGT), and low engine pressure ratio (EPR). The captain subsequently shut down the number 4 engine due to high EGT and no N1 indication accompanied by flashes of fire.

The airplane was cleared for an approach to HNL runway 8L. The final approach was flown at 190-200 knots with engines 1 and 2 operating. The crew noted that the right outboard leading edge flaps did not extend, so they elected to use a 10^{0} flap position for landing. There was a slight asymmetry. The aircraft touched down approximately 1,000 feet from the approach end of the runway at about 170 knots. The captain applied idle reverse thrust and used minimum braking to stop the airplane. HNL tower was notified, at 0234, that the airplane was stopped and an evacuation had commenced on the runway.

Nine passengers were lost in flight. Twenty-two passengers (including 1 flight attendant flying as a passenger), 15 cabin crewmembers, and 1 flight crewmember were injured. Some were injured during the decompression and others during the evacuation.

Examination of the airplane indicated that the primary damage consisted of an approximate 10- by 15-foot-hole on the right side in the area of the forward lower lobe cargo door. The cargo door bottom and side frames were intact but the door was missing. An additional 5-6 feet of the fuselage skin had separated from the airplane at a location above the cargo door extending to the upper deck windows. Debris had damaged portions of the right wing, the right horizontal stabilizer, the vertical stabilizer, and engines 3 and 4. No structural damage to the left side of the aircraft was noted. On-scene visual examinations of all fractures disclosed no evidence of pre-existing cracks or corrosion. All fractures were typical of fresh overstress breaks.

The investigation is continuing and the National Transportation Safety Board has not determined the probable cause(s) of the accident; however, the investigation has raised certain safety concerns about which the Safety Board believes the Federal Aviation Administration (FAA) should take immediate actions.

The investigation has revealed no evidence that failure of the structure surrounding the forward lower lobe cargo door was the precipitating event. The evidence strongly suggests that the forward cargo door opened in flight and led to the subsequent damage. The precise reason for the cargo door opening is yet to be determined. However, the investigation has established a few possibilities which match the evidence gathered thus far. That is, the door was not latched at all, or was only partially latched, before takeoff, and as the pressure differential increased during the climbout, the door could no longer sustain the pressurization loads. Or, it is possible that the door was properly closed and latched before takeoff and it then became unlatched, for some reason.

Boeing 747 cargo door operations, in the normal (electrical) mode, involve the actuation of three electrical motors during the door opening and closing sequence. The door closing sequence commences as the door control switch is actuated to the "close" position and an electrical motor moves the door to a near closed position. At this point, a switch actuates the door "pull in hook" motor which pulls the door to a fully closed position. A second switch actuates the motor which drives the latch cams (eight across the bottom of the doorsill and two at the mid-span sides of the door frame) to the latched position. The final step is the manual positioning of the master latch lock handle to its flush position on the door. This action positions the master latch lock sectors to lock the latch cams while moving the two pressure relief doors, located on the cargo door to the closed position. A micro switch on the forward pressure relief door is depressed when the pressure doors close. This action turns the cargo door warning light off on the second officer's warning light annunciator panel in the cockpit.

Door closing in the manual mode performs the same sequence of events by manually driving the door mechanisms to a closed and latched position with the use of a one-half inch socket drive. The opening sequence also can be accomplished by use of the manual drive system.

The cargo door was designed to preclude a false visual indication of a fully locked condition. The design intent was to prevent the lock sectors from moving to the locked position because of the mechanical interference between the locking sectors and the latch cams when the cams are not in the fully latched position. The external manual handle could not move to the flush closed position in this configuration and the pressure relief doors would remain open. In this condition, the cockpit warning light would remain on and the airplane could not be pressurized in flight. However, operation of the mechanisms as intended is dependent upon undamaged latching and locking components.

The investigation of the accident involving UAL flight 811 has revealed at least two possible failure modes which would allow a cargo door to be partially or fully unlatched, even though the manual door lock handle and the pressure relief doors are in the closed position. First, if the lock sectors are damaged (bent out of their proper position), it may be possible to force the manual door lock handle to the closed position without breaking the handle shear pin, even though the latch cams are not rotated to their fully closed position. Or, it is possible to drive the latch cams, either electrically or mechanically, toward the open position, even though the lock sectors are properly engaged. That is, the mechanical drive system and electrical motor could drive the cams toward the open position by bending the latch sectors out of the way.

A previous incident in which the cargo door manual lock handle was in the closed position, but the latch cams were not fully engaged, occurred on March 10, 1987. In that incident, Pan American World Airways (PAA) Flight 125, a Boeing 747-122, N740PA, was climbing out of London, England, when pressurization problems were encountered. After the flight returned to London, it was found that the forward cargo door was slightly open, even though the manual lock handle was closed. Examination of the door mechanisms revealed that the latches were fully unlatched, that the manual lock handle was closed, and the pressure relief doors were closed. Although not proven conclusively, the circumstances suggest strongly that the latch cams were driven open, probably manually, after the door was closed and the locks were in place. Subsequent investigation revealed that broken or bent latch lock sectors would not restrain the latch cams from being driven open manually or electrically. Damaging the lock sectors by electrical movement of the latch cams would require multiple electrical failures.

The circumstances of the PAA incident led to the issuance of Boeing Alert Service Bulletins (SB) 52A2206 on August 27, 1987, and SB52A2209 on April 14, 1988. The FAA subsequently issued Airworthiness Directive (AD) 88-12-04 on May 13, 1988. In general, the AD required an initial inspection of the cargo door latch locking mechanisms and certain repetitive inspections until terminating action for the AD was taken.

The terminating action for AD 88-12-04 called for strengthening the master latch locking sector mechanisms by installing steel doublers to prevent recurring damage that had been experienced by originally designed latch locking sectors. The respective dates for completion of terminating action, depending on the Boeing 747 model series, were 18 months and 24 months from the issue date of AD 88-12-04. AD 88-12-04 also included provisions by which, if the door could not be operated normally (electrically), a trained and qualified mechanic was required to open and close the door manually. Terminating action for AD 88-12-04 had not been completed on UAL's Boeing 747-122, N4713U, prior to the accident on February 24, 1989. The deadline for compliance with the AD was January 1990.

Following the accident of flight 811, the FAA issued telegraphic (AD) ADT 89-05-54 on March 3, 1989. This AD superseded AD 88-12-04, and required certain procedures to be accomplished when operating the cargo doors. These included: confidence checks of the door mechanical and electrical systems, inspections of the door locking mechanisms, and repairs if necessary. The AD also accelerated the schedule for terminating action to place steel doublers on the latch lock sectors.

The FAA and Boeing Commercial Airplanes Company acknowledged at the Safety Board's public hearing that, during certification of the Boeing 747, the loss of a lower lobe cargo door was not considered to be an "acceptable event," because the fuselage was not designed to withstand such an event. Therefore, redundant mechanical devices and operational procedures were incorporated to insure against an inadvertent loss of the door in flight. Initial FAA certification of the Boeing cargo door included the use of eight view ports on the door for ground personnel to observe paint stripes on the latch cams and, thereby, meet the requirements of 14 CFR 25.783(e), which require a ". . . provision for direct visual inspection of the door locking mechanism . . ." to determine if the door is closed and locked." Title 14 CFR 25.783(e) also required that the visual means to warn flight crewmembers if a door is not fully closed ". . . must be designed such that any failure or combination of failures that would result in an erroneous closed and locked indication is improbable . . . ."

In correspondence dated November 24, 1969, and May 15, 1970, Boeing requested that the FAA approve the use of a switch mechanism on the cargo door's forward pressure relief door as an alternate method for determining the door's locked condition. This design also provided a visual indication to the flightcrew via the cargo door warning light on the flight engineer's warning light annunciator panel. Boeing's request stated that this means of compliance "... provides a simpler check whereby only the pressure relief doors need to be checked," in lieu of actually observing the latch cams through the eight view ports. Boeing also provided a Failure Analysis to support its request. The conclusion of the Failure Analysis reads: "Any failure, mechanical or electrical, within the latching system which results in open latches will always be indicated by open pressure relief doors." The FAA approved this alternate method on June 18, 1970.

The circumstances of the PAA incident in which the door came open in flight and the circumstances of the UAL accident demonstrate that the original design of the Boeing 747 lower lobe cargo doors does not comply fully with the intent of 14 CFR 25.783(e), and that the FAA's approval of this design does not provide for the "fail safe" features intended. That is, one single failure can lead to the door being apparently closed, latched, and locked, yet it can be unlatched or can become unlatched, and neither the ground personnel nor the flightcrew would be aware of its unsafe condition. Although it is improbable, multiple electrical failures could drive the latch cams open through the engaged sectors. Moreover, the investigation has revealed that a single failure by ground personnel, in manually driving the latch cams open with the latch locking sectors engaged, could lead to damaged lock sectors and the door opening in flight.

Therefore, because the in-flight loss of a Boeing 747 cargo door is unacceptable and can lead to a serious accident, the FAA should take further actions to verify that cargo doors on the Boeing 747, and all other transport category aircraft equipped with non-plug doors, have proper fail-safe design features and operational procedures to prevent an airplane departure with improperly latched and locked cargo doors.

The immediate action taken by the FAA in releasing ADT 89-05-54 and the resultant corrective actions have merit; however, those actions are short term solutions at best. Although this AD reinstituted the procedure of utilizing the view ports for verifying that the latch cams are fully engaged, and the incorporation of steel doublers on the latch locking sectors should preclude electrical or mechanical backing off of the latch cams, other unpredicted failures may occur in the future. For example, latching sectors with steel doublers might be overridden by manual drive units and electrical actuators without torque-limiting devices installed. Therefore, the FAA should require torque-limiting devices on all manual drive units and electrical actuators for B-747 cargo doors.

The continued reliance upon the use of the latch view ports in verifying a properly latched and locked door would take only one human failure (forget to check the view ports) combined with one mechanical failure of the latching and locking mechanisms to initiate another accident sequence. The FAA should require Boeing to install redundant indicating switches which are located to sense directly the position of the latch cams. An external indicator light and a monitoring light on the forward master caution panel in the cockpit, with associated checking procedures, is one means to satisfy this concern.

Therefore, the National Transportation Safety Board recommends that the Federal Aviation Administration:

Issue an Airworthiness Directive (AD) to require that the manual drive units and electrical actuators for Boeing 747 cargo doors have torque-limiting devices to ensure that the lock sectors, modified per AD-88-12-04, cannot be overridden during mechanical or electrical operation of the latch cams. (Class II, Priority Action) (A-89-92)

Issue an Airworthiness Directive for non-plug cargo doors on all transport category airplanes requiring the installation of positive indicators to ground personnel and flightcrews confirming the actual position of both the latch cams and locks, independently. (Class II, Priority Action) (A-89-93)

Require that fail-safe design considerations for non-plug cargo doors on present and future transport category airplanes account for conceivable human errors in addition to electrical and mechanical malfunctions. (Class II, Priority Action) (A-89-94)

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

Lee V. Dickinson

For ~~By~~: James L. Kolstad
Acting Chairman