

CASE STUDY 5

DC-10 Crash¹

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Introductory Note by W.M.E. and M.M.: On March 3, 1974, the rear cargo door of a Turkish Airlines DC-10 blew open minutes after take-off from Paris, killing all 346 persons aboard. At the time it was the worst crash in the history of commercial aviation. The cause of the crash was attributed to basic design flaws, including the latch and lock mechanism of the rear cargo door. The tragedy of the disaster was made all the worse when it was discovered that senior engineers were aware of the design flaws in the rear cargo doors and even attempted to warn management of the imminent dangers if nothing was done to repair the problems. Most noteworthy in the case was the seeming negligence on the part of both managers and regulators to act on the problem, given an identical incident some months before when the rear cargo doors blew open on a DC-10 over Windsor, Ontario. Fortunately, no one was hurt in that case.

This technological disaster of the Second Industrial Revolution was caused by technical design factors.

... In August 1968, McDonnell Douglas awarded Convair a contract to build the DC-10 fuselage and doors. The lower cargo doors became the subject of immediate discussion. These doors were to be outward-hinging, tension-latch doors, with latches driven by hydraulic cylinders—a design already adequately tested by DC-8 and DC-9 models. In addition, each cargo door was designed to be linked to hydraulically actuated flight controls and was to have a manual locking system designed so that the handle or latch lever could not be stowed away unless the door was properly closed and latched. McDonnell Douglas, however, decided to separate the cargo door actuation system from the hydraulically actuated primary flight controls.

This involved using electric actuators to close the cargo doors rather than the hydraulic actuators originally called for. Fewer moving parts in the electric actuators presumably made for easier maintenance, and each door would weigh 28 pounds less.

However, the Convair engineers had considered the hydraulic actuators critical to safety. They were not satisfied with these changes, and they remained dissatisfied after further modifications were introduced. As Convair engineers viewed the situation, the critical difference between the two actuator systems invoked the way each would respond to the buildup of forces caused by increasing pressure. If a hydraulic latch was not secured properly, the latches would smoothly slide open

when only a small amount of pressure had built up in the cabin. Although the doors would be ripped off their hinges, this would occur at a low altitude, so that the shock from decompression would be small enough to land the plane safely. By contrast, if an electric latch failed to catch, it would not gently slide open due to increasing pressure. Rather, it would be abruptly and violently forced open, most likely at a higher altitude where rapid decompression would dangerously impair the structure of the plane.

Convair's Director of Product Engineering, F. D. "Dan" Applegate, was adamant that a hydraulic system was more satisfactory. However, McDonnell Douglas did not yield to Convair's reservations about the DC-10 cargo door design.

Once a decision had been made to use an electrical system, it was necessary to devise a new and foolproof backup system of checking and locking. In the summer of 1969 McDonnell Douglas asked Convair to draft a Failure Mode and Effects Analysis, or FMEA, for the cargo door system. A FMEA's purpose is to assess the likelihood and consequences of a failure in the system. In August 1969, Convair engineers found nine possible failure sequences that could result in destruction of the craft, with loss of human lives. A major problem focused on the warning and locking-pin systems. The door could close and latch, but without being safely locked. The warning indicator lights were prone to failure, in which case a door malfunction could go undetected. The FMEA also concluded that the door design was potentially dangerous and lacked a reliable failsafe locking system. It could open in flight, presenting considerable danger to passengers (Eddy, Potter, & Page, 1976; Curd & May, 1984; French, 1982).

The Federal Aviation Administration (FAA) requires that it be given an FMEA covering all systems critical to safety, but no mention was made of this hazard to the FAA prior to "certification" of the DC-10 model. McDonnell Douglas maintains that no such report was filed because this cargo door design was not implemented until all defects expressed in the FMEA were removed. The FMEA *submitted*, they contend, was the final FMEA, and did not discuss past defects because they had been removed. As lead manufacturer, McDonnell Douglas made itself entirely responsible for the certification of the aircraft and, in seeking the certification, was expressing its position that all defects had been removed. Convair, by contrast, was not formally responsible because its contract with McDonnell Douglas forbade Convair from reporting directly to the FAA. During a model test run in May 1970, the DC-10 blew its forward lower cargo door, and the plane's cabin floor collapsed. Because the vital electric and hydraulic subsystems of the plane are located under the cabin floor (unlike in the 747, where they are above the ceiling), this collapse was doubly incapacitating (Sewell, 1982: 18).

A spokesperson at McDonnell Douglas placed the blame for this particular malfunction on the "human failure" of a mechanic who had incorrectly sealed the door. Although no serious design problems were contemplated, there were some ensuing modifications in design for the door, purportedly to provide better checks on the locking pins. As modified, the cargo door design was properly certified and authorities at McDonnell Douglas believed it safe. Five DC-10s were flight tested for over 1,500 hours prior to certification of the craft.

Certification processes are carried out in the name of the FAA, but the actual work is often performed by the manufacturers. As a regulatory agency, the FAA is charged with overseeing commercial products and regulating them in the public interest. However, the FAA is often not in an independent position. The FAA appoints designated engineering representatives (DERs) to make inspections at company plants. These are company employees chosen for their experience and integrity who have the dual obligations of loyalty to the company that pays them as design engineers and of faithful performance of inspections to see that the company has complied with federal airworthiness regulations. The manufacturers are in this respect policing themselves, and it is generally acknowledged that conflicts of interest arise in this dual-obligation system (Eddy, Potter, & Page, 1976).

During the months surrounding November 1970, a number of internal memos were written at both McDonnell Douglas and Convair that cited old and new design problems with the cargo door. New structural proposals were made, but none were implemented. McDonnell Douglas and Convair quarreled about cost accounting and about pinning fault for remaining design flaws. The FAA finally certified the DC-10 on July 29, 1971, and by late 1971 the plane had received praise for its performance at virtually all levels. Under rigorous conditions its performance ratings were excellent. The company vigorously promoted the new aircraft.

But on June 12, 1972, an aft bulk cargo door of a DC-10 in flight from Los Angeles to New York separated from the body of the aircraft at about 11,750 feet over Windsor, Ontario. Rapid cabin decompression occurred as a result, causing structural damage to the cabin floor immediately above the cargo compartment. Nine passengers and two stewardesses were injured. A National Transportation Safety Board (NTSB) investigation found that the probable cause of the malfunction was the latching mechanism in the cargo door and recommended changes in the locking system. The NTSB's specific recommendations were the following: (1) Require a modification to the DC-10 cargo door locking system to make it physically impossible to position the external locking handle and vent door to their normal locked positions unless the locking pins are fully engaged; and (2) require the installation of relief vents between the cabin and aft cargo compartment to minimize the pressure loading on the cabin

flooring in the event of sudden depressurization of the compartment (National Traffic Safety Board, 1973).

The administrator of the FAA, John Shaffer, could have issued an airworthiness directive that required immediate repairs. He elected not to issue the directive, choosing instead a "gentleman's agreement" with McDonnell Douglas that allowed the company to make the necessary modifications and recommend new procedures to affected airlines. All actions by the company were to be voluntary. Fifteen days subsequent to the blowout over Windsor (June 27, 1972), Dan Applegate wrote a stern memo to his superior at Convair that expressed his doubts about the entire project and offered some reflections on "future accident liability." The following excerpts from the memo reveal Applegate's anguish and concerns:

The potential for long-term Convair liability on the DC-10 has caused me increasing concern for several reasons:

1. The fundamental safety of the cargo door latching system has been progressively degraded since the program began in 1968.
2. The airplane demonstrated an inherent susceptibility to catastrophic failure when exposed to explosive decompression of the cargo compartment in 1970 ground tests.
3. Douglas has taken an increasingly "hard-line" with regards to the relative division of design responsibility between Douglas and Convair during change cost negotiations.
4. The growing "consumerism" environment indicates increasing Convair exposure to accident liability claims in the years ahead. . . .

I can only say that our contract with Douglas provided that Douglas would furnish all desired criteria and loads (which in fact they did) and that we would design to satisfy these design criteria and loads (which in fact we did). There is nothing in our experience history which would have led us to expect that the DC-10 cabin floor would be inherently susceptible to catastrophic failure when exposed to explosive decompression of the cargo compartment, and I must presume that there is nothing in Douglas's experience history which would have led them to expect that the airplane would have this inherent characteristic or they would have provided for this in their loads and criteria which they furnished to us.

My only criticism of Douglas in this regard is that once this inherent weakness was demonstrated by the July 1970 test failure, they did not take immediate steps to correct it. It seems to me inevitable that, in the twenty years ahead of us, DC-10

cargo doors will come open and I would expect this to usually result in the loss of the airplane. [Emphasis added.] This fundamental failure mode has been discussed in the past and is being discussed again in the bowels of both the Douglas and Convair organizations. It appears however that Douglas is waiting and hoping for government direction or regulations in the hope of passing costs on to us or their customers.

If you can judge from Douglas' position during ongoing contract change negotiations they may feel that any liability incurred in the meantime for loss of life, property and equipment may be legally passed on to us. It is recommended that overtures be made at the highest management level to persuade Douglas to immediately make a decision to incorporate changes in the DC-10, which will correct the fundamental cabin floor catastrophic failure mode. Correction will take a good bit of time; hopefully there is time before the National Transportation Safety Board (NTSB) or the FAA ground the airplane which would have disastrous effects upon sales and production both near and long term. This corrective action becomes more expensive than the cost of damages resulting from the loss of one plane-load of people.

F. D. Applegate
Director of Product
Engineering

(Eddy, Potter, & Page, 1976, 183-5)

If this memo had reached outside authorities, Applegate conceivably might have been able to prevent the occurrence of events that (to some extent) he correctly foresaw. However, this memo was never sent either to McDonnell Douglas or to the FAA. Applegate received a reply to his memo from his immediate supervisor, J. B. Hurt. By now it was clear to both Applegate and Hurt that such major safety questions would not be addressed further at McDonnell Douglas. Hurt's reply to Applegate pointed out that if further questions were now raised, Convair, not McDonnell Douglas, would most likely have to bear the costs of necessary modifications. Higher management at Convair subsequently agreed with Hurt. Without taking other routes to express his grave misgivings about the DC-10, Applegate filed away his memo.

In July 1972, Ship 29 of the DC-10 line was inspected by three different inspectors at the Long Beach plant of McDonnell Douglas. All three certified that the ship had been successfully altered to meet FAA specifications. Two years later, Ship 29 was owned by Turkish Airlines. This ship crashed near Paris in 1974, killing all 335 passengers and 11 crewmembers—the worst single-plane disaster in aviation history. Experts agreed that the immediate cause of the crash was a

blowout of the rear cargo door, at approximately twelve minutes after lift-off. Decompression of the cargo bay caused a collapse of the cabin floor, thereby severing control cables. It was alleged by Sanford Douglas, President of McDonnell Douglas, that the Turkish airline involved in the crash had attempted to "rework" the door rigging or latching mechanism, was working with an inadequately trained ground crew, and failed to follow specified procedures for proper latching. The Turkish airline denied the charges. Recovery of a flight recorder indicated that there was no explosion, fire, or evident sabotage, and that the cargo door blew because it was not securely sealed. . . .

References

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Endnote

1. From "The DC-10's Defective Doors" prepared by Barbara Himes and Tom L. Beauchamp, and revised by Cathleen Kavepy, John Cuddihy, and Jeff Greene. Taken from *Case Studies in Business, Society, and Ethics*, 4th edition, by Tom Beauchamp. Upper Saddle River, NJ: Prentice Hall, 1998. Copyright © Tom L. Beauchamp. Reproduced by permission of the authors.