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Tragic lessons

The final investigation report on the crash of Alaska Airlines Flight 261 finds fault with maintenance procedures and design.

Martin Aubury

"Ah here we go," the captain said immediately before the McDonnell Douglas MD-83 crashed into the Pacific Ocean just north of Anacapa Island, California. Two pilots, three cabin crew members and 83 passengers on board died in the crash, on 31 January 2000.

The US National Transportation Safety Board's final investigation report found that the probable cause of the accident was a loss of aeroplane pitch control due to the failure of the gimbal nut threads of the horizontal stabiliser trim system jackscrew assembly.

"The thread failure was caused by excessive wear resulting from Alaska Airlines' insufficient lubrication of the jackscrew assembly," the report said.

However a single maintenance failure should not lead to the loss of an aircraft and all people on board.

One of the key contributing factors identified by the NTSB was the certification standards that allowed a stabiliser attachment configuration that was not fail safe – a deficiency that remained hidden for almost 40 years. On the stabiliser trim jackscrew assembly, approved extensions of lubrication intervals increased the likelihood that an unperformed or inadequate lubrication would result in excessive thread wear.

The excessive wear was at the maximum limit, and went unaddressed, according to the Alaska Airlines lead mechanic, "because it was within the allowable limits on the work card".

An MD-83, similar to the Alaska Airlines aircraft that plunged into the sea off the California coast in 2000.

Alaska Airlines officials told the NTSB that the jackscrew assemblies were not stocked as inventory items at the time of the C-check and were only available through third-party vendors.

More than two years later, when the jackscrew jammed in flight, the aircraft was still controllable. However, attempts to free the jammed screw led to complete failure. The front of the stabiliser came loose and pivoted up causing the aircraft to dive.

How did the accident happen, and what can we learn from it?

The aircraft, operating as Alaska Airlines Flight 261, had departed Puerto Vallarta, Mexico, and was bound for Seattle via San Francisco. During climb, pitch trim jammed. The crew did not know why but continued the flight. About 70 minutes later, at 1549 (local time), the crew contacted its maintenance control in Seattle to discuss diverting to Los Angeles.

A Los Angeles based maintenance employee called back and asked the crew if they had tried to rectify the problem by using the "pickle switches and the suitcase handles", (switches that control trim by tilting the horizontal stabiliser).

Following a discussion of primary and alternate trim indications the pilot reported that the stabiliser still did not seem to move.

After the exchange, the cockpit voice recording suggests that the crew again tried to free the trim. The pilot said, "let's do that". There was a click, then the statement, "this'll click it off", followed by another click and two faint thumps.

The aircraft's aural warning system began indicating "stabiliser motion" and the CVR and flight data recorder show that the aircraft dived from FL310 until the flight crew regained control at FL240. About 1612, the crew called Alaska maintenance in Los Angeles to report:

"We did both the pickle switch and the suitcase handles and it ran away full nose trim down."

The exchange ended optimistically with, "… see you at the gate".

A minute later, before descent the crew again commanded a nose-up trim. The aircraft again responded in the opposite direction, nose-down and the pilot told ATC: "I need to uh get down about 10, change my configuration make sure I can control the jet and I'd like to do that out here over the bay if I may."

At 1617 while trying to descend and configure the aircraft for landing the crew spoke of "like a big bang back there". Two minutes later the CVR recorded a faint thump and, at 1619:36, an extremely loud noise followed by increased background noise until the recording ended at 1620:57.

Wreckage: Among the debris retrieved from the ocean were the horizontal stabiliser and its attachments that join it to the top of the vertical tail.

There are only three attachments, one of which is the trim jackscrew at the front spar. The jackscrew is about 60cm long and runs in a nut, mounted in gimbals that are attached to the vertical tail.

Threads in the gimbal nut had sheared off and remnants were found as spirals wrapped around the jackscrew. There was no lubricant on the jackscrew. An end stop on the jackscrew assembly did not prevent the jackscrew from sliding out of the gimbal nut, nor was it designed to do so once the threads had stripped. There was no mechanical back-up restraint or stop.

Investigation determined that threads in the gimbal nut were worn badly before the accident. During the accident sequence the threads initially jammed in the screw. It is deduced that the crew's efforts to free the jam caused the threads to shear off completely.

The jackscrew pulled partly out of the nut, causing the first dive. Later, the jackscrew assembly failed completely, releasing the only attachment at the front of the horizontal stabiliser. The tail pivoted nose up and the aircraft entered a dive from which recovery was impossible.

Design and certification: The accident aircraft was a successor to the Douglas DC-9 that entered production in 1963 and has been further developed as the Boeing B-717. On all of these aircraft, the horizontal stabiliser is mounted on top of the vertical stabiliser by two pivot points about mid-chord and by an electrically driven jackscrew assembly connecting the front of the horizontal stabiliser to the vertical stabiliser.

When the flight crew adjusts pitch trim or when the autopilot commands an adjustment, the assembly's motors, operating through a gearbox, rotate a titanium torque tube that is inside and splined to a hardened steel acme screw. In turn, the screw rotates in a gimbal nut attached to the vertical stabiliser, raising or lowering the leading edge of the horizontal stabiliser.

The captain of a private diving boat passes an Alaska Airlines seat cushion to US Coast Guard workers collecting debris from Flight 261 in the Pacific Ocean near Port Hueneme, California on Tuesday, 1 February 2000.

The configuration of the horizontal stabiliser, its attachments and control system, were originally certificated to US Civil Aeronautics Rule (CAR) 4b effective March 1962 and have remained essentially the same.

The rules required that "all control systems shall be provided with stops which positively limit the range of motion of the control surface" and that "control system stops shall be capable of withstanding loads corresponding with the design conditions for the control systems".

Also "...catastrophic failure…[is] not probable after fatigue failure or obvious partial failure of a single principal structural element". However, none of the rules exactly addressed the failure that happened on Flight 261.

Apparently the design not only complies with the original rules, but with current Federal Aviation Regulations Part 25.

Boeing contends that the concentric torque tube and acme screw achieve fail-safety by providing dual load paths strong enough should either fail. Within the acme nut, structural redundancy takes the form of dual independent threads that provide protection if either thread fails or cracks along its root. What actually happened was that both threads failed because they were so badly worn. There was no truly independent load path.

Maintenance: From the outset, safety of the stabiliser attachment depended on maintenance of the screw assembly, especially its correct lubrication.

The nut was made from relatively soft aluminium bronze alloy, so it was expected to wear and was inspected periodically for excessive wear. That was done by a "go/no-go" check of end play in the assembly: wear rate trends were not monitored.

Because the MD-80 series was a derivative of the much older DC-9, its maintenance requirements and procedures had developed through many stages. Some underlying concepts of maintenance had changed.

The original On Aircraft Maintenance Program (OAMP) recommends that the jackscrew be lubricated at between 600 and 900 flight hours. A later one recommends lubrication at every "C" check, nominally 3,600 flight hours.

Over the years, the manufacturer recommended several changes to procedures for lubrication and the end-play check.

Alaska Airlines scheduled jackscrew lubrication every eight months, about 2,500 flight hours, more often than the industry norm. End-play was checked at alternate "C" checks.

"C" check escalation was not subject to

Gimbal nut from Flight 261, shown attached to the front spar of the fin.

The jackscrew from the horizontal stabiliser of Alaska Airlines flight 261, recovered from main wreckage site.

task-by-task evaluation. In retrospect, this led to Alaska and other airlines servicing the jackscrew far less often than originally envisaged and contributed to the risk of inadequate lubrication, undetected wear and eventual failure.

NTSB findings: The NTSB attributes the loss of Flight 261 to insufficient lubrication of the stabiliser jackscrew. However there were mitigating factors. "Contributing to the accident was (1) Alaska Airlines' extended lubrication interval, and the FAA's approval of that extension, which increased the likelihood that an unperformed or inadequate lubrication would result in excessive wear of the gimbal nut threads; and (2) Alaska Airlines' extended end-play check interval, and FAA approval of that extension, which allowed the excessive wear of the gimbal nut threads to progress to failure without the opportunity for detection.

"Contributing also to the accident was the absence on the MD-80 of a fail-safe mechanism to prevent the catastrophic effects of total gimbal nut thread loss."

Moreover, lubrication and the end-play check were difficult. Access was through a small panel near the top of the tail, eight metres up. Procedures for both tasks were imprecise before the accident.

NTSB does not investigate accidents to lay blame, only to identify factors that jeopardise safety.

From Flight 261 the NTSB has made 16 recommendations including:

- Instruct pilots facing a faulty flight control system to complete only the applicable checklist procedures, and not to attempt any other corrective actions. If checklist procedures are not effective, they should land at the nearest suitable airport.
- Require an inspector's sign-off for (DC-9, MD-80/90, and Boeing 717) jackscrew assembly lubrication.
- Review intervals for critical maintenance tasks that have been extended without adequate engineering justification.
- Pending the incorporation of a fail-safe mechanism in the design of DC-9, MD-80/90, and Boeing 717 horizontal stabiliser jackscrew assembly, establish an end-play check interval that (1) accounts for the possibility of higher-than-expected wear rates and measurement error and (2) provides for at least two opportunities to detect excessive wear before wear becomes catastrophic.
- Modify certification regulations to ensure that new horizontal stabiliser trim control system designs do not have a single-point catastrophic failure mode.
- Revise certification regulations to ensure that wear-related failures are fully considered and will not be catastrophic.

Lessons for Australia: The NTSB primarily addresses its recommendations to the US Federal Aviation Administration for action. In time, changes to FAA design rules and maintenance practices enhance safety worldwide.

Meanwhile some lessons are clear and immediate:

- Do every maintenance task meticulously and on time; carelessness kills.
- Beware extending maintenance intervals without sound engineering justification.
- When a failure happens in flight, follow the checklist. If that does not solve the problem, land. It is always safer to fix a defect on the ground.

Adapted from NTSB aircraft accident report - 02/01. Martin Aubury, formerly head of Structures at CAA now teaches at the UNSW School of Aerospace and Mechanical Engineering at the Australian Defence Force Academy.