When instruments lie

The crew of a 737 narrowly averts a fatal accident after their engine instruments malfunction during take-off.

John Laming

THE BEST JOB I ever had was flying a Boeing 737 for a small airline based on a tiny island in the Pacific. On one particular trip I was rostered to fly as a passenger from Nauru to Guam.

I settled into a first-class seat, adjusted my reading glasses, and watched the senior flight attendant brief her cabin crew as the engines started. A few minutes later, at 0130 local time, the aircraft moved onto the runway, back-tracking for take-off to the northwest. The runway on the island was 5600ft long with the overrun area just 100ft from the ocean. There was the very real prospect of fatal damage if the aircraft collided with huge phosphate rock boulders that formed the sea wall.

As the aircraft taxied down the runway the senior hostess informed me that the captain had invited me up front for take-off. Leaving my reading glasses on the seat next to me, I entered the darkened flight deck, sat on the jumpseat, and thanked the captain, whom I had trained for his command some months earlier.

The first officer was to carry out the take-off and I caught the last part of the emergency briefing as we slowly turned to line up. The take-off data card indicated 10 degrees of flap for take-off, a V_1 of 130kt, a V_R of 135kt, and initial climb speed of 145kt (see box, right). Even without reading glasses, I could plainly see the Engine Pressure Ratio (EPR) gauge digital cursors set for 2.18, which meant maximum take-off power was needed.

This was understandable considering the short runway, the hot night, and the extra fuel needed for a long flight. The data card also showed that the crew had worked out that 100% N1 was needed for take-off, and this tied in with the 2.18EPR limit. The N1 gauges were dimly lit and I could not see the needles clearly without my glasses.

From our position on the runway threshold, I could just make out the dark shape of the control tower some two-thirds down the runway. From previous experience, I knew that the indicated airspeed should be about120kt as the aircraft passed abeam the tower, with lift-off speed usually 10 seconds later.

Take-off power: The captain opened the throttles to 1.6EPR with brakes set, checked that both engines spooled up evenly, then quickly advanced the throttles to the planned take-off power of 2.18EPR. The brakes were released and the first officer began to steer the aircraft down the runway centreline.

Acceleration appeared normal, and I could clearly see both EPR gauges steady at 2.18. The airspeed indicator needle began to accelerate past 60kt and I checked the engine gauges in a swift eye scan. Fuel flow, N1, and exhaust gas temperature (EGT) were all

Illustration only. Airport depicted is not Nauru.

pointing in the right area, though somewhat blurred to my vision without my glasses.

Seconds passed and the captain called "eighty knots" at the dual airspeed indicator check. A sixth sense warned me that the acceleration was not the solid kick in the back that I would have expected from 2.18EPR, and at the same instant I noticed the captain begin to glance rapidly from the instruments to the remaining runway ahead. There was no readily discernible problem but I had an uneasy feeling that something was not quite right.

The company procedure was that, apart from the 80kt airspeed check, no calls were to be made by either pilot unless something was seriously amiss. On this occasion, the take-off seemed to be proceeding normally and apart from my vague unease at the perceived lack of marked acceleration, I was unable to pinpoint any impending problem.

The control tower and passenger terminal flashed past the right wing tip as I strained forward against my shoulder straps in an attempt to focus more clearly on the vital N1 gauges. The EPR needles were clear – exactly 2.18 – but I could not get an accurate look at the N1 without glasses. The airspeed reading went through 110kt. From my experience we should have been perhaps 10kt faster and my unease grew stronger. One thing I was sure of was that we were rapidly using up the remaining runway.

Something's wrong: Six runway lights to go, and we were still at least 10kt below V_1, the go/stop decision speed. It was, to say the least, an interesting situation. I hoped the captain would not make a split-second decision to abort the take-off because we could now never pull up in time, even with maximum reverse thrust and braking. Our V_1 speed was useless now, and the invisible sea-swept rocks were only seconds ahead.

My unease had just changed into the cold realisation that we were never going to attain lift-off speed before reaching the end of the runway, when suddenly the captain called "Rotate now!". While hauling back on the control column he pushed both throttles hard against their forward stops. Boeing calls this "firewalling the thrust levers", and it's only be used as a last resort to climb out of trouble.

The last runway light disappeared under us and I felt the reassuring surge of thrust propel the 737 upwards at a deck angle of 20 degrees. I silently thanked God that the captain had made an instant decision to

Jet speak

V_1 (decision speed): V_1 is the maximum speed at which the take-off can be safely aborted in the event of an emergency. If an emergency occurs after V_1 the take-off must be continued.

V_R(rotation speed): V_R is the speed at which the pilot initiates rotation in order to take-off. V_R must not be less than V_1.

EPR (Engine Pressure Ratio): The ratio of turbine pressure divided by compressor inlet pressure. In some jet aircraft, this is used as an indication of the amount of thrust produced by the engine.

N_1: The RPM of the low-pressure compressor.

Nauru airport: **The 737 lifted off 15 knots below the calculated rotation speed, and flew just 19 feet above the sea for several hundred yards before gradually climbing away.**

firewall those Pratt & Whitneys.

The flight data recorder (FDR) later revealed that the aircraft had lifted off 15kt *below* the calculated rotate speed, and had flown just 19 feet above the sea for several hundred yards before gradually climbing away. We never did see the towering metal structure of the phosphate cantilevers that passed above our altitude, 200 yards to the right of the extended runway centreline...

Air Florida: Readers may remember a widely publicised accident involving a Boeing 737 that crashed on take-off from Washington National Airport as it tried to get airborne while covered in snow and ice. The aircraft was unable to hold altitude and, after hitting a bridge, crashed nose first into the frozen Potomac River.

The FDR was recovered and it showed that the engines had not been set to full take-off power during the take-off. The engine power indicators had given false information to the crew, possibly due to ice blocking the air inlet tubes. These tubes, which have an opening the size of a drinking straw, measure the pressure of the air as it is drawn in by the engine compressors, and compare it to the pressure of air as it exits the engine. This provides a measurement of engine power output (indicated on the EPR gauge) which is used for setting engine thrust and monitoring performance.

In simple terms, if the front tube (known as the PT2 sensing tube) is blocked the sensor thinks no air is coming into the front of the engine. The rear sensor, operating normally,

> **“ If [the captain hadn’t firewalled the throttles] it is likely the Potomac accident would have been repeated with equally disastrous results. ”**

senses lots of high-pressure hot air being ejected from the tail pipe and thus the EPR will indicate an abnormally high reading.

The natural tendency to remedy the apparent excessive power indication on the EPR gauges is for the pilot to ease the throttles back in order to keep within perceived engine limits. The engine RPM gauge will, however, show the pilot the real power being produced.

Obviously, if 100% RPM is indicated, the engine is really pushing out lots of power, regardless of a false reading on the EPR gauge caused by a blocked tube. The advantage of the EPR gauge is that accurate power settings can be measured, providing of course that the system works as advertised.

Following the lengthy investigation into the Potomac accident, notices were sent to all operators of Pratt & Whitney JT8D series engines, warning that crews should be on alert for erroneous EPR indications in icing conditions and to rely primarily on the engine RPM gauge for actual indications of power. Typically, the RPM gauge is called an N1 or fan gauge and will usually show 35% N1 while idling, 83% in cruise, and 95-101% on take-off. Blocking of PT2 tubes by substances other than ice was not discussed in the Alert Bulletin.

Boeing recommended that the crew calculate the expected EPR and N1 gauge readings for each take-off. These readings, which are placed on a take-off data card, will vary depending on the take-off weight of the aircraft, length of runway, ambient air temperature, and aerodrome pressure altitude. Also on the card will be the V_1 decision speed, rotation speed, and other information pertaining to the take-off.

The Potomac accident might have been averted if the crew had only hit the throttles wide open to the stops, to prevent their ice-laden Boeing from stalling.

Solving the riddle: Ahead was sheer blackness. The captain locked on to the instruments as the ASI needle crept towards safe flap-retraction speed. The VSI was held at 1000fpm, and the first officer set the climb thrust at 1.93EPR as the flaps were slowly retracted in sequence. It seemed an abnormally long time before the aircraft reached 250kt, the scheduled climb speed that night. The rate of climb was well below normal.

Finally we passed 5,000ft, engaged the autopilot, and called for coffee while we held a round table discussion about what had just happened. A mechanic who had been seated in the cabin came up front and said that a couple of dead-heading pilots down the back sent their respects to the captain, but hoped he had finished playing silly buggers with the aircraft as they were hoping to get some shut eye! They had obviously felt the thrust change through the seat of their pants.

We turned our attention to a detailed scan of the engine instruments and the mechanic remarked that the N1 indications seemed low when compared with the 1.93EPR climb setting. From the back of my mind came the recollections of previous problems that I had experienced several months ago with an over-reading EPR gauge. On one occasion, at 100kt on take-off, the first officer urgently called that the engine was over speeding. He attempted to pull back the throttle on that engine to limit the peak EPR, but I quickly stopped his hand and told him to ignore the faulty reading.

He was convinced however, that the engine was overboosting because of the high EPR reading, although I felt no asymmetric yaw on the flight controls. I again prevented him from dragging the offending EPR back and we continued the take-off using the N1 RPM (which was steady at normal take-off thrust).

Once at a safe altitude, I turned on the hot air bleed system to the engine anti-ice, and almost immediately the offending EPR needle did a few cartwheels and returned to normal. We were not in icing conditions but the hot air used for de-icing had obviously cleared some obstruction in the PT2 tube. The flight continued without further incident.

John Laming at the controls of a Boeing 737-200.

Back to the present situation. On my suggestion, the captain momentarily switched on the engine anti-ice to both engines. This would normally cause a small loss of about 5% N1 and an EPR drop of .08, which reflected the stealing of some hot compressor air for piping to the engine inlet cowls and PT2 tubes.

The N1 dropped obediently but both EPR gauges went crazy, increasing by an unheard of amount, and in the opposite direction to that expected.

My mind went back to a paragraph in the Potomac accident report which mentioned that with the engine anti-ice switched on and the PT2 tube blocked, the EPR needle would indicate a reverse reading to that expected.

The impossible had apparently occurred: an identical erroneous reading on both EPR gauges at the same time. The PT2 tubes were obviously still blocked but we now knew for sure that both engines were operating normally.

ANALYSIS > Reduced thrust

AFTER landing, the cause of the trouble was soon discovered. The PT2 tubes of both engines – the sensors that gave the vital EPR readings for take-off – were blocked, not with ice but with congealed phosphate dust and some other glutinous substance. It was impossible to determine the precise time that the tubes became blocked, or how the substance found its way into the system.

Later calculations showed that the actual power on take-off was around 2.05EPR, even though the EPR needles were steady at 2.18. That power would have been ample for a long runway, and in fact was a setting frequently used for the right combination of runway length and gross take-off weight.

The N1 gauge scale between 91% and 100% is less than 3mm and very difficult to read in dim light, especially at a quick glance. This might explain why the crew was unable to pick the apparent lower-than-normal N1 readings on the take-off run. At night especially, it is also nearly impossible to make any meaningful correlation between rate of acceleration and runway remaining – until it is almost too late.

In my view, the captain demonstrated a high level of airmanship when he made the decision to firewall the throttles. If he had not done so it is likely that the Potomac accident would have been repeated with equally disastrous results.

The chances of an identical double EPR failure at night, causing identical instrument readings, were infinitesimally small. The actual power (EPR) used on that night was similar to that used on an everyday reduced-thrust take-off at longer runways such as Hong Kong, Guam, Nandi or Sydney. The acceleration forces were identical to a planned reduced-thrust take-off, and it was only at a late stage of the take-off at Nauru that it was realised that the take-off run was going to be insufficient to lift off.

Later versions of the Boeing 737 have CFM56 engines which rely on N1 gauges as the primary power indication. EPR gauges still remain on many older jet transports, however.

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