Serious Incident

Aircraft Type and Registration:	Boeing 737-4K5, G-JMCV	
No & Type of Engines:	2 CFM56-3C1 turbofan engines	
Year of Manufacture:	1989 (Serial no: 24128)	
Date & Time (UTC):	1 December 2023 at 0613 hrs	
Location:	East Midlands Airport	
Type of Flight:	Commercial Air Transport (Cargo)	
Persons on Board:	Crew - 2	Passengers - None
Injuries:	Crew - None	Passengers - N/A
Nature of Damage:	Damage to tail skid and drainage mast	
Commander's Licence:	Airline Transport Pilot's Licence	
Commander's Age:	44 years	
Commander's Flying Experience:	7,649 hours (of which 2,720 were on type) Last 90 days - 39 hours Last 28 days - 10 hours	
Information Source:	Aircraft Accident Report Form submitted by the commander and subsequent enquiries by the AAIB	

Synopsis

The aircraft was operating a cargo flight from East Midlands Airport to Aberdeen Airport. During the departure preparations, an incorrect load sheet was used to input figures for the takeoff performance calculation and so the aircraft was approximately 10 tonnes heavier than anticipated. During the takeoff the aircraft tail struck the ground damaging the tail skid and a drainage mast. No personnel were injured.

History of the flight

The crew arrived at the aircraft at 0430 hrs and the commander decided that it required de-icing. This was carried out by two separate vehicles each of which provided receipts to the commander. Both receipts contained errors, which the commander asked the dispatcher to have corrected. When the dispatcher returned, he gave the commander some forms including the load sheet for the flight, the de-icing receipts and Notifications to Captain, which contain essential information related to the cargo. During this time the aircraft was being loaded. The load sheet for the flight was checked, found to be correct and acknowledged by the commander in accordance with the operator's Operations Manual.

The sheaf of papers given to the crew also contained a load sheet for the same aircraft on a previous flight. Although not recognising this at the time, the crew used the figures from this incorrect load sheet to calculate the takeoff performance figures using the

manufacturers Onboard Performance Tool (OPT). The OPT calculates thrust settings, stabiliser trim setting and takeoff speeds. The incorrect load sheet was for an aircraft mass approximately 10 tonnes lighter than the incident flight, so the aircraft dispatched with inappropriate performance settings.

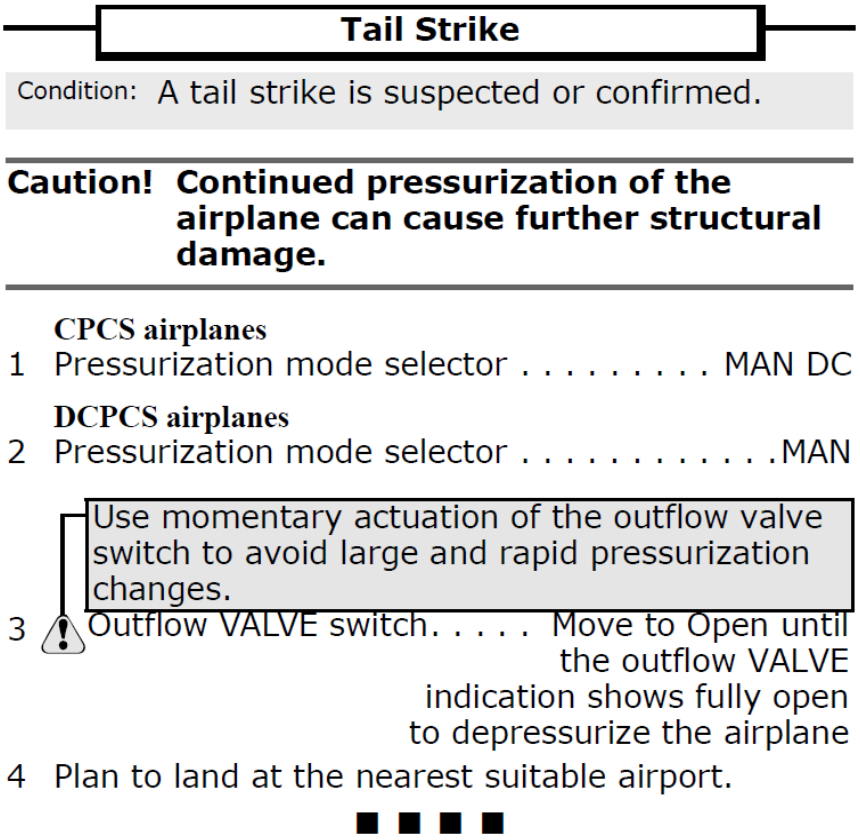
The taxi out was uneventful and after an engine run up check due to the low temperature, the commander, as PF, commenced the takeoff run. The commander described the rotation as normal but stated that both crew members felt a "small bump." The crew checked engine parameters and warnings, but no issues were apparent. They then completed the after takeoff check list. They discussed possible causes of the "bump", considering a tail strike or a possible load shift. However, as there were no abnormal indications and the aircraft was handling normally, the commander decided to continue the climb to the cruising level of FL240. The co-pilot was inexperienced and under training, so the commander stated his workload was now higher than normal.

The Operations Manual Part B (OMB) contains the following guidance in the event of a loadshift:

> *'Should a load come loose, there is a serious risk to the aircraft. The deck angle must be maintained as stable as possible to avoid further movement.'*

Once in the cruise the commander asked the co-pilot to visually check the cargo hold to eliminate any concerns regarding unsecured freight. The load bay is in three sectors designated A, B and C from front to back. Bay B was empty for this flight so the commander was concerned cargo from Bay A could have moved aft. The co-pilot was only able to see the cargo in Bay A and that appeared secure. The crew then revisited the possibility of a tail strike and consulted the aircraft's Quick Reference Handbook (QRH). The checklist for a tail strike is shown at Figure 1.

Though the aircraft was handling normally and there were no abnormal indications, given the absence of any other explanation for the 'bump' at takeoff, the commander decided to action the tail strike checklist in the QRH. The checklist directed the crew to depressurise the aircraft but, due to the inexperience of the co-pilot, the commander decided to descend to FL90 before actioning the depressurisation. He checked the fuel figures before descent to confirm sufficient fuel remained to reach Aberdeen at the reduced flight level.



Tail Strike

Condition: A tail strike is suspected or confirmed.

Caution! Continued pressurization of the airplane can cause further structural damage.

CPCS airplanes

1 Pressurization mode selector . . . . . MAN DC

DCPCS airplanes

2 Pressurization mode selector . . . . . .MAN

Use momentary actuation of the outflow valve switch to avoid large and rapid pressurization changes.

3 Outflow VALVE switch. . . . . Move to Open until the outflow VALVE indication shows fully open to depressurize the airplane

4 Plan to land at the nearest suitable airport.

■ ■ ■ ■

Figure 1

QRH Tail Strike Checklist

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The crew carried out an ILS approach to Aberdeen and the aircraft landed without further incident. After the aircraft was parked and shut down the commander carried out a walk round check which revealed damage to the tail skid and a drainage mast.

Aircraft performance

The crew calculated the takeoff performance using the OPT application. Aircraft mass, centre of gravity position, runway in use and meteorological data are entered into the application and it calculates speeds, thrust settings and stabiliser trim position for each takeoff. Both crew members make the calculations using their own OPT to trap any errors made in data entry. In this case both crewmembers used information from a previous flight to enter the figures into the OPT. The calculation for the actual aircraft mass is shown at Figure 2.

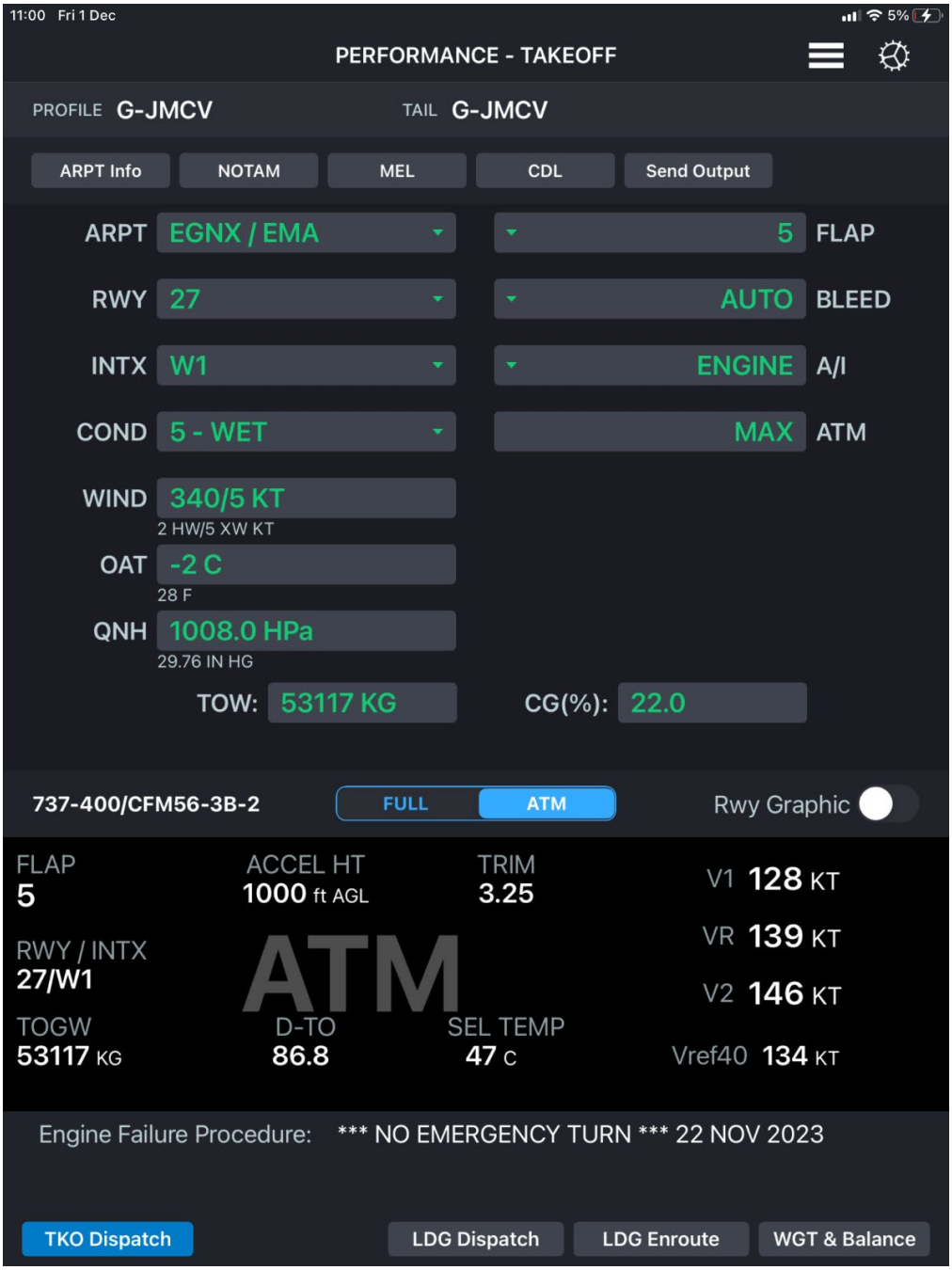

Figure 2

Performance calculation with actual aircraft mass

The calculation used by the crew on the incident flight is shown at Figure 3.

Figure 3

Performance calculation with mass from previous flight

The PF commences the rotation at V_R[1], which was 139 kt for the correct mass but only 124 kt for the calculation used by the crew. Calculated thrust setting was also lower on the calculation used for the flight with N_1 calculated at 81.9% against 86.8% for the actual mass. The OPT also outputs a setting for the stabiliser trim, intended to give consistent handling of the aircraft at takeoff. In this event the setting used by the crew gave a slightly more nose-up trim than the actual mass figures.

Footnote

[1] V_R is defined as the speed at which the rotation of the aircraft toward takeoff attitude should be initiated.

Recorded information

The FDR information was not recovered but information from the Quick Access Recorder (QAR) was downloaded and analysed by the manufacturer. An extract from the information is shown at Figure 4.

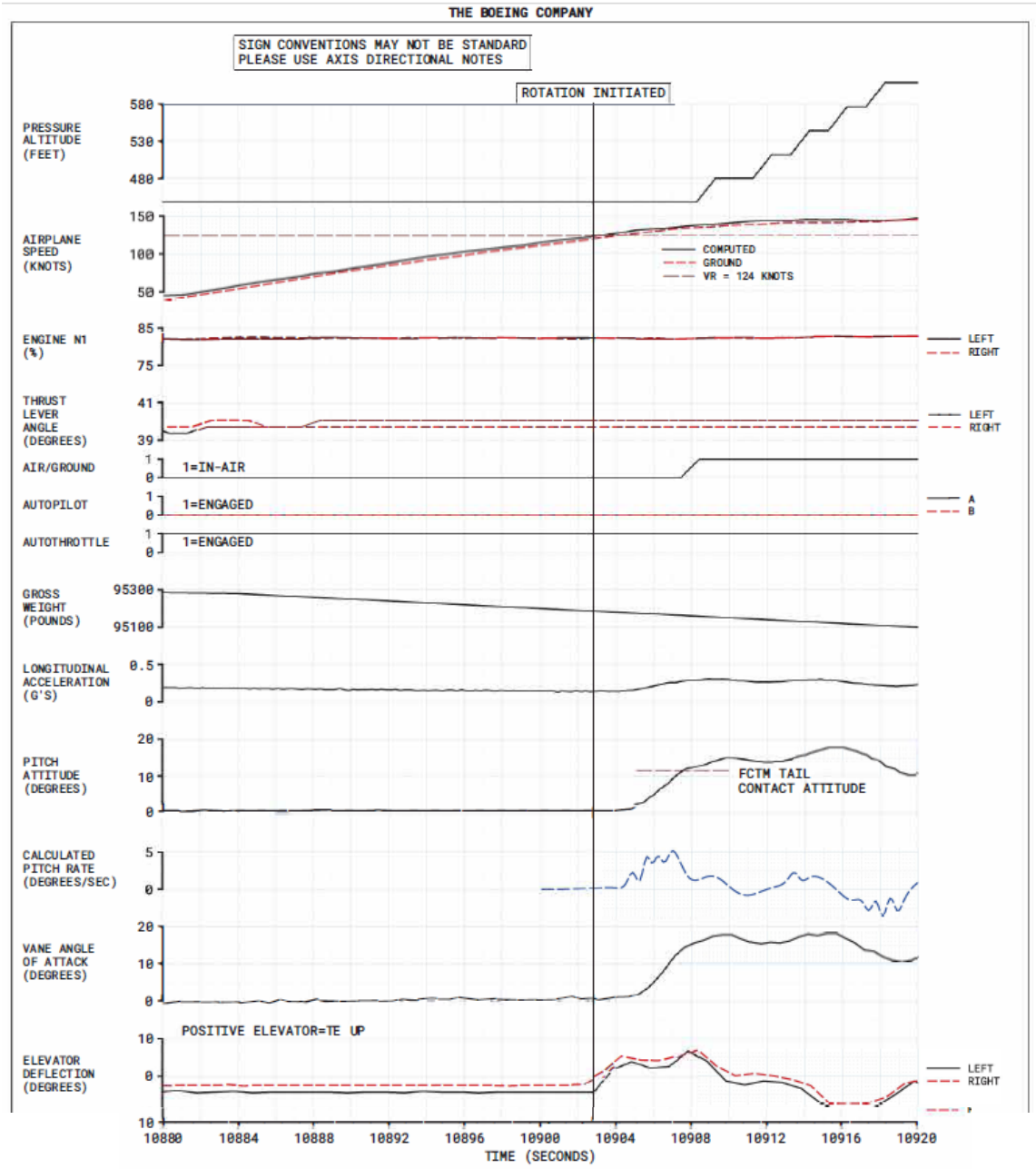

Figure 4

Extract of QAR information.
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The QAR data shows that the elevator deflected trailing edge up to commence the takeoff rotation at an airspeed of approximately 123 kt which is consistent with the V_R calculated by the crew. The V_R for the actual mass of the aircraft was 139 kt. The aircraft's attitude

started to increase approximately 2 seconds after rotation was initiated. Around 4 seconds after rotation was initiated the calculated instantaneous pitch rate peaked at 5°/s just prior to liftoff. The air/ground discrete parameter indicated liftoff occurred at a computed airspeed of around 137 kt, approximately 5 seconds after rotation was initiated. Pitch attitude was then 12.3° which exceeded the pitch attitude for a tail strike (11.4°).

Manufacturer's information

The Flight Crew Training Manual (FCTM) for the B737 contains guidance for takeoff techniques and tail clearance during rotation. For the rotation phase the FCTM states:

> '*Above 80 knots, relax the forward control column pressure to the neutral position. For optimum takeoff and initial climb performance, initiate a smooth continuous rotation at VR toward 15° of pitch attitude. However, takeoffs at low thrust setting (low excess energy) will result in a lower initial pitch attitude target to achieve the desired climb speed.'*

A note on the guidance states:

> *'Using the technique above, resultant rotation rates vary from 2° to 3° per second, with rates being lowest on longer airplanes. Liftoff attitude is achieved in approximately 3 to 4 seconds depending on airplane weight and thrust setting.'*

The FCTM contains the image at Figure 5 for a typical takeoff which shows that the lowest tail clearance will occur close to lift off speed (V_{LOF}).

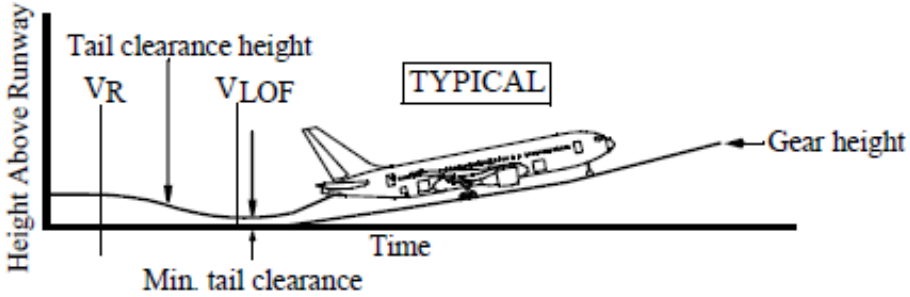

Figure 5

Typical takeoff profile for B737 FCTM
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The actual tail clearance distance and the pitch attitude for a tail strike varies with the length of the aircraft. G-JMCV is a B737-400 and the FCTM states that for a takeoff with flap 5 set, lift off should occur at 9.1° pitch attitude, the minimum tail clearance will be 23 inches and the tail strike attitude will be 11.4° with the main wheels on the ground.

The FCTM lists five factors that are liable to increase the risk of a tail strike as follows:

'Mis-trimmed Stabiliser
Rotation at Improper Speed
Trimming during Rotation
Excessive Rotation Rate
Improper Use of the Flight Director'

In amplification of the mis-trimmed stabiliser the FCTM notes that this usually results from the use of erroneous takeoff data. Should a tail strike be suspected the FCTM contains the following guidance:

'Any one of the following conditions can be an indication of a tail strike during rotation or flare:

- *a noticeable bump or jolt*
- *a scraping noise from the tail of the airplane*
- *pitch rate stopping momentarily*

Note: Anytime fuselage contact is suspected or confirmed, accomplish the appropriate NNC (Non Normal Checklist) without delay.'

Analysis

The crew used the data from a loadsheet for a previous flight to calculate the takeoff performance figures for the aircraft. This led to the takeoff performance being calculated for a mass 10,082 kg less than the actual mass of the aircraft at departure. Therefore, the commander, as PF commenced the takeoff rotation at 123 kt as opposed to the 139 kt required for the aircraft's actual mass. The FCTM advises that pilots should make a smooth continuous rotation at V_R towards a pitch attitude of 15° nose-up. The stabiliser trim setting was more nose-up than for the correct mass resulting in pitch control forces being lighter than anticipated by the PF, possibly contributing to the pitch rate peaking at 5°/s just prior to the tail striking the ground. As the aircraft rotated the airspeed was too low to generate sufficient lift for the actual mass of the aircraft. The aircraft did not therefore lift off at the point in the rotation anticipated by the crew but, instead, lifted off as the PF continued the rotation. As described in the FCTM the aircraft tail struck the ground damaging the tail skid and a drainage mast.

The commander recalled feeling a small bump during the takeoff but saw no other abnormal indications. Once the after takeoff checklist was complete the crew discussed the possibility of a tail strike or a load shift as being the cause of the bump. The commander was confident

that the rotation and lift off had been normal, with no abnormal indications or flight parameters he considered liable to cause a tail strike. His workload was high due to the inexperience of the co-pilot so with the aircraft handling normally the commander decided to continue the planned departure as this also kept the deck angle stable in accordance with the load shift guidance in the OMB. Continuing the planned departure and climb also avoided the increased workload of an immediate diversion.

In the cruise at FL240 with the workload much reduced, the commander revisited the symptoms after the co-pilot had visually checked the cargo. With the suggestion of a load shift excluded the commander decided to action the Tail Strike QRH procedure out of an abundance of caution. Concerned about exposing the co-pilot to the very unusual task of depressurising the aircraft at high altitude the commander decided to first descend and then complete the QRH actions. Sufficient fuel remained to carry on to the destination which, in considering the workload, the commander decided to do. The sector was short and so comparatively little time would have been saved by diverting.

The aircraft then flew an uneventful approach to Aberdeen and, after landing, was checked by the commander and the damage identified. The crew reviewed their paperwork and realised that the loadsheet signed by the commander was not the one they had used for calculating takeoff performance.

Conclusion

The crew used incorrect loading figures to calculate the aircraft performance at departure. The aircraft was approximately 10 tonnes heavier than anticipated and the PF therefore commenced the takeoff rotation 15 kt too slow. Due to the lower speed the wing did not develop sufficient lift for the aircraft to takeoff as expected and the tail struck the ground.