Take-off performance parameters and position errors — large aeroplanes

1. Why we need to amend the rules — issue/rationale

Related safety issue

Incidents and accidents involving large aeroplanes used in commercial air transport have occurred in the past years as a result of:

— the use of erroneous take-off performance parameters due to either errors made during the performance parameters calculation or errors made during the entry in the aeroplane flight management system (FMS) of correctly calculated performance parameters. The following errors appear to be the most common ones:

  — wrong weight values used, from various causes such as: use of a wrong zero fuel weight (ZFW) value for take-off weight (TOW) calculation, use of ZFW value or other value (e.g. empty weight (EW)) instead of TOW, use of previous flight TOW, various errors made when using the electronic flight bags (EFBs), typing errors when entering weight values in the FMS, and errors in the load sheet provided to the flight crew;

  — wrong available runway length used, e.g. not taking into account a notice to airmen (NOTAM) (maintenance work), use of wrong runway chart, error made during re-calculation after a runway change;

  — wrong assumed temperature used for thrust reduction calculation;

  — wrong thrust selection in the FMS (e.g. fix derate);

  — wrong reference speeds entered in the FMS (calculation or typing errors) or no speeds entered;

  — wrong pitch trim setting due to erroneous determination of the centre of gravity (CG) (e.g. in the load sheet) or due to changes in the actual passenger distribution compared to load sheet assumptions; and

— errors in the positioning of the aeroplane for initiation of the take-off: e.g. take-off from a runway position providing a length shorter than that assumed for the take-off performance parameters calculation (i.e. wrong runway, wrong runway intersection), take-off from a wrong runway or from a taxiway.

These errors have resulted in various consequences and safety effects:

— Long take-off roll, failure of the rotation or initial climb, collision with obstacles beyond the runway end (runway excursion), loss of control and fatal crash;

— Take-off performed without the flight crew noticing the abnormal situation and not taking any corrective action but with degraded performance and safety margins (e.g. longer take-off roll, slower rotation, decreased speeds margins). In some cases, should an engine failure have occurred, the flight crew would either not have been able to stop the aeroplane on the runway after a rejected take-off (RTO) or not have been able to clear obstacles during the continued take-off and climb, with potential catastrophic consequences;

— Take-off performed but included a collision with runway end lights or antennas, or a tail strike. A fatal accident (from a high energy runway excursion or loss of control) was sometimes avoided by pure luck. An engine failure during such take-off could be catastrophic;

— Rejected take-off, sometimes preceded by a tail strike;

— Rejected take-off and runway excursion with no fatal consequence.

Safety recommendations addressed to EASA

CAND-2006-007 (accident (fatal) to Boeing 747-244B (SF), reg. 9G-MKJ, on 14 October 2004 in Halifax, Canada, causal factor: use of previous flight TOW in the EFB): 'The Board recommends that the Department of Transport, in conjunction with the International Civil Aviation Organization, the Federal Aviation Administration, the European Aviation Safety Agency, and other regulatory organisations, establish a requirement for transport category aircraft to be equipped with a take-off performance monitoring system that would provide flight crews with an accurate and timely indication of inadequate take-off performance.'

FRAN-2005-001 (accident (fatal) to Boeing 727-223, reg. 3X-GDO, on 25 December 2003 in Cotonou Airport, Benin, causal factor: overloaded aeroplane with forward CG (values unknown to the flight crew)): 'The BEA recommends that the Civil Aviation Authorities, in particular the FAA in the United States and the EASA in Europe, modify the certification requirements so as to ensure the presence, on new generation airplanes to be used for commercial flights, of on-board systems to determine weight and balance, as well as recording of the parameters supplied by these systems.

The BEA recommends that the Civil Aviation Authorities put in place the necessary regulatory measures to require, where technically possible, retrofitting on airplanes used for commercial flights of such systems and the recording of the parameters supplied.'

FRAN-2008-328 (BEA France Study on the Use of Erroneous Parameters at Takeoff, report dated May 2008): 'Improve the certification norms so that computers trigger crew warnings or activate protection systems when inconsistent data are inputted, obviously erroneous or far from usual values.'

NETH-2007-004 (accident to Boeing McDonnell Douglas MD-88, reg. TC-ONP, on 17 June 2003 in Groningen-Eelde Airport, the Netherlands, causal factor: inadequate pitch trim setting): 'It is recommended to the Civil Aviation Authority, the Netherlands (IVW) to develop certification requirements for aircraft from the civil aviation category, to provide weight and CG measurements to the crew of new aircraft and to investigate the possibility to provide these data with existing aircraft.'

NETH-2018-001 (investigation of two serious incidents (September 2014 in Groningen-Eelde Airport, the Netherlands (causal factor: incorrect TOW used for take-off performance calculation), September 2015 in Lisbon airport, Portugal (causal factor: take-off performance calculated for an incorrect runway/take-off position combination due to an EFB input error) with the Boeing 737-800): 'To prioritise the development of specifications and the establishment of requirements for Onboard Weight and Balance Systems (OWBS)'

NETH-2018-002 (investigation of two serious incidents (September 2014 in Groningen-Eelde Airport, the Netherlands (causal factor: incorrect TOW used for take-off performance calculation), September 2015 in Lisbon airport, Portugal (causal factor: take-off performance calculated for an incorrect runway/take-off position combination due to an EFB input error) with the Boeing 737-800): 'To, in cooperation with other regulatory authorities, standardisation bodies, the aviation industry and airline operators, start the development of specifications and the establishment of requirements for Take-off Performance Monitoring Systems without further delay.'

NETH-2020-001 (serious incident to Boeing 777, reg. VT-JEW, on 21 April 2017 in Amsterdam, the Netherlands): 'To European Union Aviation Safety Agency: To take the initiative in the development of specifications and, subsequently, develop requirements for an independent on board system that detects gross input errors in the process of take off performance calculations and/or alerts the flight crew during take off of abnormal low accelerations for the actual aeroplane configuration as well as insufficient runway length available in case of intersection take offs. Take this initiative in close consult with the aviation industry, including manufacturers of commercial jetliners amongst which in any case The Boeing Company'.

UNKG-2009-080 (serious incident to Airbus A330-243, reg. G-OJMC, on 28 Oct 2008 in Montego Bay-Sangster International Airport, Jamaica, causal factor: incorrect TOW used for take-off performance calculation): 'It is recommended that the European Aviation Safety Agency develop a specification for an aircraft take-off performance monitoring system which provides a timely alert to flight crews when achieved takeoff performance is inadequate for given aircraft configurations and airfield conditions.'

UNKG-2009-081 (serious incident to Airbus A330-243, reg. G-OJMC, on 28 October 2008 in Montego Bay-Sangster International Airport, Jamaica, causal factor: incorrect TOW used for take-off performance calculation): 'It is recommended that the European Aviation Safety Agency establish a requirement for transport category aircraft to be equipped with a take-off performance monitoring system which provides a timely alert to flight crews when achieved take-off performance is inadequate for given aircraft configurations and airfield conditions.'

EASA identification of the safety issue

In the EASA 2022 Annual Safety Review (ASR), the 'Entry of aircraft performance data' is identified as one of the Priority 1 safety issues among the safety risks for large aeroplanes. It is one of the main common safety issues contributing to runway excursions and aircraft upset key risk areas.

In the European Plan for Aviation Safety (EPAS) 2023-2025, Volume III, the 'Entry of aircraft performance data' (SI-0015) is recorded in the list of Commercial Air Transport – Aeroplanes (CAT A) safety issues per category and priority, and it is categorised as 'mitigate – define', which means for definition and programming of safety actions.

Related certification specifications

In CS-25 (certification specifications for large aeroplanes), CS 25.703 requires that a take-off configuration warning system be installed. This requirement was introduced in Europe with JAR-25 Amendment 5 effective on 1 January 1979. In the USA, this requirement was added to FAR Part 25 by Amendment 25-42 effective on 1 March 1978.

CS 25.703 requires that the take-off warning system provides an aural warning to the flight crew during the initial portion of the take-off roll, whenever the aeroplane is not in a configuration which would allow a safe take-off. The intent of this rule is to require that the take-off configuration warning system covers (a) only those configurations of the required systems which would be unsafe, and (b) the effects of system failures resulting in wrong surface or system functions if there is no separate and adequate warning already provided. Conditions for which warnings are required include wing flaps or leading edge devices not within the approved range of take-off positions, and wing spoilers (except lateral control spoilers meeting the requirements of CS 25.671), speed brakes, parking brakes, or longitudinal trim devices in a position that would not allow a safe take-off. Consideration should also be given to adding rudder trim and aileron (roll) trim if these devices can be placed in a position that would not allow a safe take-off.

2. Industry design solutions developed to mitigate the safety issue

Some design solutions that can mitigate the above safety issue have been developed, and some of them are already certified.

(a) Take-off performance monitoring system (TOPMS)

A TOPMS is a system that monitors the performance (including acceleration) of the aeroplane during the take-off run and compares it to planned or reference take-off profiles. Such a system can generate an alert to the flight crew prior to reaching the V_1 speed (i.e. the take-off decision speed) if the performance is considered inadequate. The acceleration is a key parameter monitored by such system.

(b) Take-off position checking system

Some systems check the actual position (with GPS data) of the aeroplane at the time of take-off initiation and generate an alert under certain conditions when the aeroplane is outside the intended runway and/or at a runway location such that the available distance is lower than the computed lift-off distance. Some systems also increase the flight crew awareness of their actual position during taxi up to the take-off position to mitigate the risk of error.

(c) Take-off parameters and configuration checking system

Some systems exist that, in addition to ensuring compliance with CS 25.703 ('Take-off configuration warning system'), perform different checks throughout different phases from the cockpit preparation to the take-off initiation and provide an alert to the flight crew when an error is identified:

— During cockpit preparation, it is possible to detect gross errors made on weight and take-off speed values entered in the aeroplane FMS (e.g. out-of-range value, incoherent speeds, insufficient margins with minimum control or stall speeds). It is also possible to detect an inconsistency between a computed lift-off distance and the available runway length (using the FMS input for performance parameters and runway selection);

— After engine start, it is possible to re-check the consistency of the lift-off distance taking into account additional information that becomes available, such as the actual fuel quantity on board;

— During the taxi phase, it is possible to check the actual positions of take-off critical surfaces, such as flaps and horizontal stabiliser (pitch trim), and compare them with the FMS take-off performance data. Regarding the pitch trim, the actual stabiliser trim position may also be compared to a computed value based on a CG value when available (e.g. calculated by taking into account the aeroplane weight and the fuel repartition). It is also possible to repeat the check of the take-off speeds and lift-off distance as done in the previous steps to increase robustness;

— At the time of take-off initiation (thrust is applied), it is possible to check the lift-off distance; this time using the actual aeroplane position and alert if the available runway distance is too short.

(d) On board weight and balance system (OBWBS)

An OBWBS is a system that measures the actual gross weight of the aeroplane and calculates the CG of the aeroplane. The OBWBS typically requires the installation of sensors in the landing gears. The signals from these sensors (e.g. strut pressures or elongation) are used to determine the weight (or mass) and the CG of the aeroplane.

The information computed by the OBWBS is then available to the pilots for checking the values used for the performance calculations and the ones entered in the FMS (a procedure is required).

Although not yet existing, a connection of an OBWBS to the aeroplane's avionics system could also be used to directly identify a difference between the FMS values and the values determined by the OBWBS and to generate an alert to the flight crew when a significant difference is identified.

3. Initial outline of the regulatory material to be developed

Taking into account design solutions that have been developed by industry to date, the objective is the introduction of design requirements aiming at detecting or preventing the errors described in Section 1 above by providing means to timely inform or alert the flight crew. Design requirements will be considered to address new large aeroplane designs. An analysis and impact assessment will be conducted to assess the feasibility and the benefit of design requirements applicable to existing (already type certificated) large aeroplane designs. The opportunity and benefit to develop an industry standard(s) should also be considered to support the compliance with the new design requirements.

This RMT will therefore propose new design requirements addressing:

— new large aeroplane designs, with an amendment of CS-25 (certification specifications and acceptable means of compliance); and

— subject to an impact assessment confirming the technical feasibility and that the safety benefits outweigh the cost impacts, existing large aeroplane designs, with an amendment of Part-26 (additional airworthiness specifications for a given type of operations) and the associated CS-26 (certification specifications and guidance material).

4. Other information

EASA assessed 85 occurrences (13 incidents, 67 serious incidents, 5 accidents) that were reported and investigated by safety investigation authorities between 2007 and 2022. A safety benefit analysis has been conducted to determine the relative effectiveness of available design solutions based upon the number of occurrences (incidents and accidents). The analysis concluded that 80 of these occurrences could have been prevented by design solutions.