Federal Aviation Administration

Memorandum

Date:	October 22, 2015
To:	Manager, Boeing Aviation Safety Oversight Office, ANM-100B
From:	Manager, Transport Airplane Directorate, ANM-100
Prepared by:	Shaun Ripple, ANM-100B
Subject:	INFORMATION: Equivalent Level of Safety (ELOS) Finding for En Route Climb Speed on Boeing Model 737-7/-8/-9 airplanes, FAA Project Numbers PS12-0037, PS12-0038, and PS12-0039
ELOS Memo #	PS12-0038-F-3
Regulatory Ref:	14 CFR 25.123(a) and (b), Amendment 25-121

This memorandum informs the certificate management aircraft certification office of an evaluation made by the Transport Airplane Directorate (TAD) on the establishment of an equivalent level of safety (ELOS) finding for the Model 737-7/-8/-9 (MAX) aircraft.

Background

En route climb speeds are used for calculating climb gradient capability in the event of an engine failure during the en route phase of flight. Amendment 25-121 to Title 14, Code of Federal Regulations (14 CFR) 25.123 invokes minimum speed requirements based on takeoff reference speeds. This change introduces two issues that prevent a direct showing of literal compliance for the 737 MAX:

1) At some weights, the 737 MAX final takeoff speed (V_{FTO}) is expected to be faster than the speed selected for en route climb. This is in conflict with the literal wording of the regulation.

2) The regulation requires that the en route climb speed be compared to the stall reference speed (V_{SR}) with ice and V_{FTO}, both of which are only defined for altitudes within a few thousand feet of maximum airport altitudes, while the en route climb speeds must be determined at higher altitudes.

For these two reasons, an equivalent level of safety finding is necessary to establish a clear path for demonstration of compliance.

Applicable Regulation(s)

14 CFR 25.123(a) and (b), Amendment 25-121

Regulation(s) requiring an ELOS fining

14 CFR 25.123(a) and (b), Amendment 25-121

Description of compensating design features or alternative Methods of Compliance (MoC) which allow the granting of the ELOS (including design changes, limitations or equipment needed for equivalency)

After examining the minimum speed requirement, it is concluded that there is no safety concern associated with trading airspeed for altitude in transition from the final takeoff to the en route climb segment, provided the en route climb speed provides sufficient maneuver capability and margin to stall. This scenario is similar to that of an engine failure during the en route phase, where transition from the normal operating speed to the engine-inoperative en route climb speed is typical. In addition, this requirement is not directly applicable to 737MAX operations since, as with other Boeing models, the 737MAX Airplane Flight Manual (AFM) analyses for the final takeoff and en route climb phases of flight are separate calculations. Therefore, there is no continuous transition from final takeoff to the en route climb segment in the takeoff obstacle clearance analysis. This is consistent with the guidance provided in paragraph 9 of FAA Advisory Circular 120-91. The only applicable hazards the speed-related aspects of the regulation address are required margin to stall and required maneuver capability.

By meeting the following criteria, which are a modification to the criteria in regulation § 25.123 at Amendment 25-121, the 737 MAX will meet the level of safety intended by the regulation. The modifications are indicated in bold underlined font. For brevity and clarity, within this issue paper, the symbol "ALT_{naxEO}" is defined to mean the pressure altitude at which the gradient of the one-engine-inoperative actual flight path is zero for the en route configuration.

(a) For the en route configuration, the flight paths prescribed in paragraph (b) and (c) of this section must be determined at each weight, altitude, and ambient temperature, within the operating limits established for the airplane. The variation of weight along the flight path, accounting for the progressive consumption of fuel and oil by the operating engines, may be included in the computation. The flight paths must be determined at a speed not less than**:**

(0)(i) 1.18VSR, for pressure altitudes up to the lower of 20,000 feet or ALT_{maxEO} for each operational weight; and

(0)(ii) the speed that provides 40 degree bank maneuver capability to stick shaker, for pressure altitudes up to the lower of 20,000 feet or ALT_{maxEO} for each operational weight; and

(0)(iii) the speed that provides 40 degree bank maneuver capability to initial buffet for pressure altitudes up to ALT_{maxEO} for each operational weight,

with--

(1) The most unfavorable center of gravity;
(2) The critical engines inoperative;
(3) The remaining engines at the available maximum continuous power or thrust; and
(4) The means for controlling the engine-cooling air supply in the position that provides adequate cooling in the hot-day condition.

(b) The one-engine-inoperative net flight path data must represent the actual climb performance diminished by a gradient of climb of 1.1 percent for two-engine airplanes, 1.4 percent for three-engine airplanes, and 1.6 percent for four-engine airplanes--
(1) In non-icing conditions; and
(2) In icing conditions with the en route ice accretion defined in appendix C, if:
(i) A speed of 1.18 V_{SR} with the en route ice accretion exceeds the en route speed selected for non-icing conditions by more than the greater of 3 knots CAS or 3 percent of V_{SR} **(this criterion is applicable only for altitudes up to the lower of 20,000 feet pressure altitude or ALT_{maxEO} for each operational weight)**; or
(ii) The degradation of the gradient of climb is greater than one-half of the applicable actual-to-net flight path reduction defined in paragraph (b) of this section **(this criterion is applicable at all operational altitudes)**.
(iii) If either of the icing impact criteria specified in paragraphs (b)(2)(i) and (b)(2)(ii) are exceeded, the speed used to determine the flight paths in icing conditions must meet the new criteria (a)(0)(i) and (a)(0)(ii) with en route ice.

Explanation of how design features or alternative Methods of Compliance (MoC) provide an equivalent level of safety to the level of safety intended by the regulation

Provisions of the compensating factors ensure that the en route climb speed provides the margin to stall speed in non-icing and icing conditions, and the maneuver capability to stick shaker or initial buffet, required to achieve the level of safety consistent with the intent of § 25.123(a) and (b) at Amendment 25-121. New criteria (a)(0)(i), (a)(0)(ii) and (a)(0)(iii) ensure that the en route climb speed will provide at least the minimum stall speed margin and maneuver capability required for V_{FTO} in non-icing conditions, for altitudes up to and exceeding those for which V_{FTO} is defined, thus meeting the intent of the minimum speed requirement of § 25.123(a) for non-icing conditions. ALT_{maxEO} is used as an upper altitude limit for these criteria because that is the maximum altitude the airplane will fly in a steady-state engine-out condition for a sustained period of time. Criteria (a)(0)(i) and (a)(0)(ii) are limited to a maximum altitude of 20,000 feet because stall speeds and the related stall warning requirements are not defined at arbitrarily high altitudes. Stall speeds are not required to be defined more than 1,500 feet above the airport altitude (takeoff) or 1,500 feet above the runway threshold (landing). The 20,000 feet value is a conservatively high altitude to ensure stall speeds are defined several thousand feet above the highest airports in the world.

If the en route climb speed for icing conditions must be directly addressed due to ice effects exceeding one of the thresholds specified in paragraphs (b)(2)(i) and (b)(2)(ii), the effects of en route ice must be included when showing compliance to criteria (a)(0)(i) and (a)(0)(ii) (i.e. stall speed margin and maneuver capability to stick shaker at altitudes up to the lower of 20,000 feet pressure altitude or ALT_{maxEO}) . The effects of en route ice are not applicable to criteria (a)(0)(iii) (i.e. maneuver capability to initial buffet) because, as stipulated in § 25.21(g) of Amendment 25-121, § 25.251(e) is specifically exempt from consideration in icing conditions.

The FAA accepts the compensating factors in the form of the proposed criteria for en route climb speeds provide an equivalent level of safety with that intended by § 25.123(a) and (b).

FAA approval and documentation of the ELOS finding

The FAA has approved the aforementioned ELOS finding in project Issue Paper F-3, titled "En Route Climb Speed." This memorandum provides standardized documentation of the ELOS finding that is non-proprietary and can be made available to the public. The TAD has assigned a unique ELOS memorandum number (see front page) to facilitate archiving and retrieval of this ELOS. This ELOS memorandum number should be listed in the type certificate data sheet under the Certification Basis section. An example of an appropriate statement is provided below.

Equivalent Level of Safety Finding has been made for the following regulation(s):

14 CFR 25.123(a) and (b), Amendment 25-121, En route flight paths

(documented in TAD ELOS Memo PS12-0038-F-3)

Original signed by

Rob Duffer — 10/22/15

Transport Airplane Directorate, Aircraft Certification Service — Date

ELOS Originated by BASOO	BASOO Manager	ANM-100B