European Aviation Safety Agency

Notice of Proposed Amendment 2017-16

Engine bird ingestion

RMT.0671

EXECUTIVE SUMMARY

The objective of this Notice of Proposed Amendment (NPA) is to improve the ability of aeroplane turbine engines to cope with the ingestion of birds that can reasonably be expected to be experienced during the service life of the engine.

This NPA proposes to amend the certification specifications for engines (CS-E) aeroplane turbine engine bird ingestion demonstration provisions in CS-E to include an additional requirement to continue to operate following the ingestion of a medium-sized bird into the engine core with a fan speed that is representative of the climb condition (or approach condition if no bird material is ingested into the engine core during the test).

The proposed changes are expected to improve safety and maintain alignment with FAA Part 33.

Action area:	Design and maintenance improvements		
Affected rules:	CS-E		
Affected stakeholders:	Turbine engine manufacturers		
Driver:	Safety	**Rulemaking group:**	No
Impact assessment:	Light	**Rulemaking Procedure:**	Standard

30.5.2017	2.10.2017	2018/Q2

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1. About this NPA

1.1. How this NPA was developed

The European Aviation Safety Agency (EASA) developed this Notice of Proposed Amendment (NPA) in line with Regulation (EC) No 216/2008[1] (hereinafter referred to as the 'Basic Regulation') and the Rulemaking Procedure[2]. This rulemaking activity is included in the EASA 5-year Rulemaking Programme[3] under rulemaking task (RMT).0671. The text of this NPA has been developed by EASA. It is hereby submitted to all interested parties[4] for consultation.

1.2. How to comment on this NPA

Please submit your comments using the automated **Comment-Response Tool (CRT)** available at **http://hub.easa.europa.eu/crt/**[5].

The deadline for submission of comments is **4 December 2017**.

1.3. The next steps

Following the closing of the public commenting period, EASA will review all comments.

Based on the comments received, EASA will develop a decision amending the certification specifications (CSs) and acceptable means of compliance (AMC) for Engines (CS-E).

The comments received and the EASA responses will be reflected in a comment-response document (CRD).

1 Regulation (EC) No 216/2008 of the European Parliament and of the Council of 20 February 2008 on common rules in the field of civil aviation and establishing a European Aviation Safety Agency, and repealing Council Directive 91/670/EEC, Regulation (EC) No 1592/2002 and Directive 2004/36/EC (OJ L 79, 19.3.2008, p. 1) (http://eur-lex.europa.eu/legal-content/EN/TXT/?qid=1467719701894&uri=CELEX:32008R0216).

2 EASA is bound to follow a structured rulemaking process as required by Article 52(1) of Regulation (EC) No 216/2008. Such a process has been adopted by the EASA Management Board (MB) and is referred to as the 'Rulemaking Procedure'. See MB Decision No 18-2015 of 15 December 2015 replacing Decision 01/2012 concerning the procedure to be applied by EASA for the issuing of opinions, certification specifications and guidance material (http://www.easa.europa.eu/the-agency/management-board/decisions/easa-mb-decision-18-2015-rulemaking-procedure).

3 http://easa.europa.eu/rulemaking/annual-programme-and-planning.php

4 In accordance with Article 52 of Regulation (EC) No 216/2008 and Articles 6(3) and 7 of the Rulemaking Procedure.

5 In case of technical problems, please contact the CRT webmaster (crt@easa.europa.eu).

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2. In summary — why and what

2.1. Why we need to change the rules — issue/rationale

The United States (US) National Transportation Safety Board (NTSB) issued several safety recommendations (SRs) to EASA following their investigation of the accident to US Airways Airbus A320, registered N106US, which ditched in the Hudson River on 15 January 2009[6]. Both engines were operating normally until they each ingested at least two large birds (weighing about 8 pounds each), one of which was ingested into each engine core, causing mechanical damage that prevented the engines from being able to provide sufficient thrust to sustain flight.

The number and size of the birds ingested by the engines exceeded the current CS-E bird ingestion standard for the applicable range of turbine engine inlet throat areas.

Due to the fact that birds were ingested into the cores of the engines during a phase of flight for which the current CS-E do not require any testing, the NTSB concluded that the current bird tests would be more realistic if the lowest expected fan speed for the minimum climb rate were used instead of the current fan speed for 100 %-rated take-off thrust, which would allow more bird material to enter into the engine core. This NTSB conclusion resulted in their recommendation to modify the small and medium-bird certification test standard to require that the lowest expected fan speed for the minimum climb rate be used for the core bird ingestion demonstration:

SR UNST-2010-088 issued to EASA by the NTSB:

> '*Modify the small and medium flocking bird certification test standard in Joint Aviation Regulations-Engines to require that the test be conducted using the lowest expected fan speed, instead of 100 % fan speed, for the minimum climb rate. (A-10-88)*'.

The NTSB also recommended the re-evaluation of the large-flocking-bird-ingestion-certification-test standards, including the core ingestion standards, to determine whether they should apply to the size class of the engine powering single-aisle medium-range aeroplanes, such as the Airbus A320 and Boeing 737 models.

SR UNST-2010-089 issued to EASA by the NTSB:

> '*During the bird-ingestion rulemaking database (BRDB) working group's reevaluation of the current engine bird-ingestion certification regulations, specifically reevaluate the Joint Aviation Regulations–Engines (JAR-E) large-flocking-bird-certification-test standards to determine whether they should:*
>
> *1) apply to engines with an inlet area of less than 3,875 square inches and*
>
> *2) include a requirement for engine core ingestion.*
>
> *If the BRDB working group's reevaluation determines that such requirements are needed, incorporate them into JAR-E and require that newly certificated engines be designed and tested to these requirements. (A-10-2-89).*'

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[6] Refer to National Transportation Safety Board (NTSB) Accident Report NTSB/AAR-10/03, adopted on 4 May 2010, entitled 'Loss of thrust in both engines after encountering a flock of birds and subsequent ditching on the Hudson River – US Airways Flight 1549 – Airbus A320-214, N106US – Weehawken, New Jersey – January 15, 2009'.

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In the US, the Federal Aviation Administration (FAA) responded to the NTSB recommendations by assigning a task to the Aviation Rulemaking Advisory Committee (ARAC) in order to address them. The Transport Airplane and Engine (TAE) Subcommittee accepted the tasking and agreed to provide recommendations to ARAC regarding the bird-ingestion-certification-test standards. The TAE formed an Engine Harmonization Working Group (EHWG) to carry out the task and provide recommendations to the TAE. EASA actively participated in the working group. The EHWG completed its investigation and recommended to the FAA that the core ingestion standard be made more rigorous by adopting an additional core ingestion certification demonstration for turbofan engines. The EHWG also made a series of related recommendations, including the current large-flocking-bird provisions.

In response, the FAA initiated rulemaking activities and a Notice of Proposed Rulemaking (NPRM) will be published that contains amendments to FAR Part 33.

It should be noted that there are no:

— exemptions pertinent to the scope of this RMT;

— relevant alternative means of compliance (AltMoC) considerations;

— direct references to International Civil Aviation Organization (ICAO) Standards and Recommended Practices (SARPs); or

— references to European Union (EU) regulatory material relevant to this RMT.

2.2. What we want to achieve — objectives

The overall objectives of the EASA system are defined in Article 2 of the Basic Regulation. This proposal will contribute to the achievement of the overall objectives by addressing the issues outlined in Chapter 2.1.

The specific objectives of this proposal are to:

— mitigate the safety effects of an engine bird ingestion event through the introduction of improved test parameters for aeroplane turbine engine bird ingestion testing based upon service experience; and

— maintain efficiency by minimising any differences between the EASA bird-ingestion-testing provisions and those of other certification authorities such as the FAA.

2.3. How we want to achieve it — overview of the proposals

This NPA proposes to amend the CS-E to require the applicant to demonstrate the ability of a turbine engine to cope with the ingestion of a medium flocking bird into the engine core at defined engine conditions.

2.4. What are the expected benefits and drawbacks of the proposals

The expected benefits and drawbacks of the proposal are summarised below. For the full impact assessment of alternative options, please refer to Chapter 4.

It is anticipated that there will be an improvement in safety due to the introduction of a new test requirement to demonstrate the ability of an engine to ingest a medium flocking bird into the engine core. The test will be conducted at conditions that are representative of the engine power or thrust

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during the climb phase of flight, which has been shown to be a potential gap in current engine bird ingestion testing. There will be an associated cost to engine manufacturers due to the cost of conducting the new bird ingestion test, but the impact has been assessed as being very low.

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3. Proposed amendments and rationale in detail

The text of the amendment is arranged to show deleted text, new or amended text as shown below:

— deleted text is ~~struck through~~;

— new or amended text is highlighted in grey;

— an ellipsis '[…]' indicates that the rest of the text is unchanged.

3.1. Draft Certification Specifications (Draft EASA decision)

CS-E 800 Bird Strike and Ingestion (See AMC E 800)

(a) *Objective*. To demonstrate that the ~~E~~engine will respond in a safe manner following specified encounters with birds, as part of the compliance with CS-E 540.

The demonstration will address the ingestion of large, medium and small birds, and also the effect of the impact of such birds upon the front of the ~~E~~engine.

(b) *Single large bird ingestion test*. An ~~E~~engine ingestion test must be carried out using a large bird as specified below. Alternative evidence may be acceptable as provided under CS-E 800 (~~f~~g)(1).

(1) *Test conditions.*

(i) The ~~E~~engine operating conditions must be stabilised prior to ingestion at not less than 100 % of the ~~T~~take-off ~~P~~power or thrust at the test day ambient conditions. In addition, the demonstration of compliance must account for ~~E~~engine operation at sea level take-off conditions on the hottest day that a minimum ~~E~~engine can achieve maximum rated ~~T~~take-off ~~P~~power or thrust.

(ii) The bird to be used must be of a minimum mass of:

(A) 1·85 kg for ~~E~~engine inlet throat areas of less than 1·35 m^2 unless a smaller bird is determined to be a more severe demonstration.

(B) 2·75 kg for ~~E~~engine inlet throat areas of less than 3·90 m^2 but equal to or greater than 1·35 m^2.

(C) 3·65 kg for ~~E~~engine inlet throat areas equal to or greater than 3·90 m^2.

(iii) The bird must be aimed at the most critical exposed location on the first stage rotor blades.

(iv) A bird speed of 200 knots for ~~E~~engines to be installed on aeroplanes or the maximum airspeed for normal flight operations for Engines to be installed on rotorcraft.

(v) Power lever movement is not permitted within 15 seconds following the ingestion.

(2) *Acceptance criteria*. Ingestion of this single large bird must not result in a ~~H~~hazardous ~~E~~engine ~~E~~effect.

(c) *Large flocking bird.* An ~~E~~engine test using a single bird must be carried out at the conditions specified below for Engines with an inlet throat area equal to or greater than 2.5 m^2. Alternative evidence may be acceptable as provided under CS-E 800 (~~f~~g)(1).

(1) *Test conditions.*

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(i) The ~~E~~engine operating conditions must be stabilised prior to ingestion at not less than the mechanical rotor speed of the first exposed stage(s) that, on an ISA standard day, would produce 90 % of the sea level static ~~R~~rated ~~T~~take-off ~~T~~thrust.

(ii) The bird speed must be 200 knots.

(iii) The bird mass must be at least as defined below

Engine Inlet throat Area (A) m^2	Mass of Bird Kg
A<2.50	Not applicable
2.50≤ A<3.50	1.85
3.50≤ A<3.90	2.10
3.90≤ A	2.50

(iv) The bird must be targeted on the first exposed rotating stage(s) at a blade airfoil height of not less than 50 %, measured at the leading edge.

(v) The following test schedule must be used:

Step 1 — Ingestion followed by 1 minute without power lever movement.

Step 2 — 13 minutes at not less than 50 % of ~~R~~rated ~~T~~take-off ~~T~~thrust.

Step 3 — 2 minutes at a thrust set between 30 % and 35 % of ~~R~~rated ~~T~~take-off ~~T~~thrust.

Step 4 — 1 minute at a thrust increased from that set in step 3 by between 5 % and 10 % of ~~R~~rated ~~T~~take-off ~~T~~thrust.

Step 5 — 2 minutes at a thrust decreased from that set in step 4 by between 5 % and 10 % of ~~R~~rated ~~T~~take-off ~~T~~thrust.

Step 6 — At least 1 minute at ground idle followed by ~~E~~engine shut down.

Each specified step duration is time at the defined step conditions. Power lever movement between each step will be 10 seconds or less, except that power lever movement for setting conditions of step 3 will be 30 seconds or less. Within step 2, power lever movements are allowed and are not limited.

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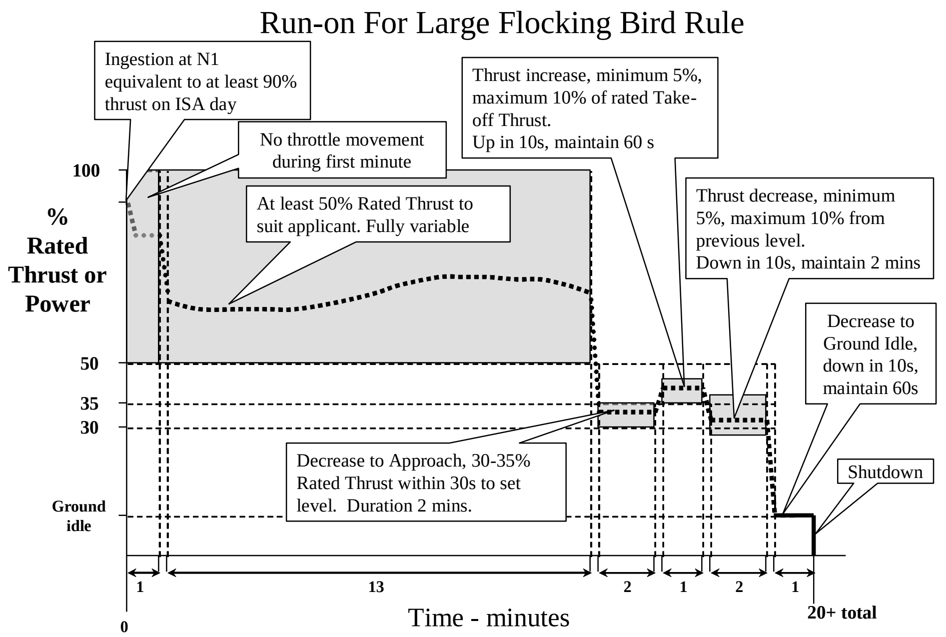

(2) *Acceptance criteria.*

The test of CS-E 800 (c)(1)(v) must not cause:

— The ~~E~~engine to be unable to complete the required test schedule,

— The ~~E~~engine to be shut down before end of step 6,

— A sustained reduction of thrust to less than 50 % ~~R~~rated ~~T~~take-off ~~T~~thrust during step 1,

— A ~~H~~hazardous ~~E~~engine ~~E~~effect.

(d) *Medium and small birds ingestion tests*. Engine ingestion tests and analysis with medium and small sized birds must be carried out as specified below. Alternative evidence may be acceptable as provided under CS-E 800 (~~f~~g)(1). The small birds test will not be required if the prescribed number of medium birds pass into the Engine rotor blades during the medium bird test.

(1) *Test conditions.*

(i) The ~~E~~engine operating conditions must be stabilised prior to ingestion at not less than 100 % of the ~~T~~take-off ~~P~~power or thrust at the test day ambient conditions. In addition, the demonstration of compliance must account for ~~E~~engine operation at sea level take-off conditions on the hottest day at which a minimum Engine can achieve maximum rated ~~T~~take-off ~~P~~power or thrust.

(ii) The critical ingestion parameters affecting power loss and damage must be determined by analysis or component tests or both. They must include, but are not limited to, the effects of bird speed, critical target location and first stage rotor speed. The critical bird ingestion speed must reflect the most critical condition within the range of airspeeds for normal flight operations up to 450 m (1 500 feet) above ground level, but not less than V1 minimum for ~~E~~engines to be installed on aeroplanes.

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(iii) Except for rotorcraft ~~E~~engines, the following test schedule must be used:

— Ingestion to simulate a flock encounter within one second

— 2 minutes without power lever movement

— 3 minutes at 75 % of the test conditions of CS-E 800 (d)(1)(i)

— 6 minutes at 60 % of the test conditions of CS-E 800 (d)(1)(i)

— 6 minutes at 40 % of the test conditions of CS-E 800 (d)(1)(i)

— 1 minute at ~~A~~approach ~~I~~idle

— 2 minutes at 75 % of the test conditions of CS-E 800 (d)(1)(i)

— Stabilise at idle and shut ~~E~~engine down.

These durations are times at the defined conditions, the power lever being moved between each condition in less than 10 seconds.

(iv) For rotorcraft E~~E~~engines, the following test schedule must be used:

— Ingestion to simulate a flock encounter within one second

— 3 minutes at 75 % of the test conditions of CS-E 800 (d)(1)(i)

— 90 seconds at minimum test bed idle

— 30 seconds at 75 % of the test conditions of CS-E 800 (d)(1)(i)

— Stabilise at idle and shut ~~E~~engine down.

These durations are times at the defined conditions, the power lever being moved between each condition in less than 10 seconds.

(A) *Medium birds*. Masses and quantities of birds will be determined from column 2 of Table A. When only one bird is specified, it must be aimed at the ~~E~~engine core primary flow path; the other critical locations on the ~~E~~engine face area must be addressed by appropriate tests or analysis or both.

When two or more birds are specified, the largest must be aimed at the ~~E~~engine core primary flow path and a second bird must be aimed at the most critical exposed location on the first stage rotor blades. Any remaining birds must be evenly distributed over the ~~E~~engine face area.

(B) *Small birds*. One 85 g bird for each 0·032 m^2 of the inlet throat area or fraction thereof with a maximum of 16 birds, distributed to take account of any critical exposed locations on the first stage rotor blades, but otherwise evenly distributed over the Engine face area.

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TABLE A of CS-E 800

Medium (flocking) birds

	Engine test (CS-E 800 (d)(1))	Additional integrity assessment (CS-E 800 (d)(3))
Engine inlet throat area (A) m^2	Number of birds x mass of birds Kg	Number x mass of birds kg
A < 0·05	none	none
0·05 ≤ A < 0·10	1 x 0·35	none
0·10 ≤ A < 0·20	1 x 0·45	none
0·20 ≤ A < 0·40	2 x 0·45	none
0·40 ≤ A < 0·60	2 x 0·70	none
0·60 ≤ A < 1·00	3 x 0·70	none
1·00 ≤ A < 1·35	4 x 0·70	none
1·35 ≤ A < 1·70	1 x 1·15 + 3 x 0·70	1 x 1·15
1·70 ≤ A < 2·10	1 x 1·15 + 4 x 0·70	1 x 1·15
2·10 ≤ A < 2·50	1 x 1·15 + 5 x 0·70	1 x 1·15
2·50 ≤ A < 2·90	1 x 1·15 + 6 x 0·70	1 x 1·15
2·90 ≤ A < 3·90	1 x 1·15 + 6 x 0·70	2 x 1·15
3·90 ≤ A < 4·50	3 x 1·15	1 x 1·15 + 6 x 0·70
4·50 ≤ A	4 x 1·15	1 x 1·15 + 6 x 0·70

(2) *Acceptance criteria*. The ingestion must not cause:

— More than a sustained 25 % power or thrust loss

— The ~~E~~engine to be shut down during the test.

(3) In addition, except for rotorcraft ~~E~~engines, it must be substantiated by appropriate tests or analysis or both that, when the full first stage rotor assembly is subjected to the quantity and mass of medium birds from Column 3 of Table A fired at the most critical locations on the first stage rotor, the effects will not be such as to make the ~~E~~engine incapable of complying with the acceptance criteria of CS-E 800 (d)(2).

(e) *Core engine flocking bird ingestion test*. Except for rotorcraft engines, an ingestion test shall be performed as follows:

(1) A core engine-flocking-bird-ingestion test shall be performed with one bird, using the heaviest bird specified in the second column of Table A above and ingested at a bird speed of 250 knots, unless it is shown by test or validated analysis that no bird material will be ingested into the core under the conditions of this sub-paragraph, in which case sub-paragraphs (e)(5), (6) and (7) should be applied. Prior to the ingestion, the engine shall be stabilised at the mechanical rotor speed of

the first exposed stage or stages that, on a standard day, would produce the lowest expected power or thrust required during a climb through 3 000 ft above ground level in revenue service.

(2) The bird must be targeted on the first exposed rotating stage or stages at the blade airfoil height measured at the leading edge that would result in the most bird material being ingested into the engine core.

(3) Ingestion into the engine core of a bird under the conditions prescribed in sub-paragraph (e)(1) and (e)(2) shall not cause any of the following:

(i) A sustained reduction of power or thrust to less than 50 % of the maximum rated take-off power or thrust during the run-on segment specified under paragraph (e)(4) below, that cannot be restored only by movement of the power lever.

(ii) A sustained reduction of power or thrust to less than flight idle power or thrust during the run-on segment specified under paragraph (e)(4) below.

(iii) Engine shutdown during the required run-on demonstration specified in paragraph (e)(4) below.

(iv) The conditions specified in paragraph CS-E 800 (b)(2).

(4) The following test schedule shall be used:

(i) Ingestion followed by 1 minute without power lever movement.

(ii) Followed by power lever movement to increase power or thrust to not less than 50 % of maximum rated take-off power or thrust, if the initial bird ingestion resulted in a reduction in power or thrust below that level.

(iii) Followed by 13 minutes at not less than 50 % of maximum rated take-off power or thrust.

(iv) Followed by 2 minutes between 30 and 35 % of maximum rated take-off power or thrust.

(v) Followed by 1 minute with power or thrust increased by between 5 and 10 % of maximum rated take-off power or thrust from that set in sub-paragraph (e)(4)(iv) of this paragraph.

(vi) Followed by 2 minutes with power or thrust reduced by between 5 and 10 % of maximum rated take-off power or thrust from that set in sub-paragraph (e)(4)(v) of this paragraph.

(vii) Followed by a minimum of 1 minute at ground idle, then engine shutdown. The durations specified are times at the defined conditions.

Power lever movement between each condition shall be 10 seconds or less in duration, except power lever movements allowed within sub-paragraph (e)(4)(iii), which are not limited, and those for setting power under sub-paragraph (e)(4)(iv) shall be 30 seconds or less in duration.

(5) If it is shown by test or analysis that no bird material will be ingested into the engine core under the conditions of sub-paragraph (e)(1), then the core engine ingestion test shall be performed with one bird using the heaviest bird specified in the second column of Table A and ingested at a bird speed of 200 knots. Prior to the ingestion, the engine must be stabilised at the mechanical rotor speed of the first exposed stage or stages that, on a standard day, would produce the power or thrust required during approach at 3 000 ft above ground level.

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(6) Ingestion into the engine core of a bird under the conditions prescribed in sub-paragraphs (e)(2) and (e)(5) must not cause any of the following:

(i) Engine shutdown during the required run-on demonstration specified in paragraph (e)(7) below.

(ii) The conditions specified in paragraph CS-E 800 (b)(2).

(7) The following test schedule must be used:

(i) Ingestion followed by 1 minute without power lever movement.

(ii) Followed by 2 minutes between 30 and 35 % of maximum rated take-off power or thrust.

(iii) Followed by 1 minute with power or thrust increased from that set in sub-paragraph (e)(7)(ii), by between 5 and 10 % of maximum rated take-off power or thrust.

(iv) Followed by 2 minutes with power or thrust reduced from that set in sub-paragraph (e)(7)(iv), by between 5 and 10 % of maximum rated take-off power or thrust.

(v) Followed by a minimum of 1 minute at ground idle, then engine shutdown. The durations specified are times at the defined conditions.

(8) Applicants must show that an unsafe condition will not result if any engine operating limit is exceeded during the run-on period.

(9) The core engine flocking bird ingestion test of this sub-paragraph (e) may be combined with the medium flocking bird test of sub-paragraph (d), if the climb fan rotor speed calculated in sub-paragraph (e)(1) is within 1 % of the first stage rotor speed required by sub-paragraph (d)(1).

(~~e~~f) *Impact.* The impact against the front of the ~~E~~engine of the largest medium bird required by CS-E 800 (d)(1)(v)(A) and of the large bird required by CS-E 800 (b)(1)(ii) must be evaluated for compliance with CS-E 540 under the ~~E~~engine conditions specified for the ingestion tests. The bird speed must be the critical bird ingestion speed for the critical locations within the range of airspeeds for normal flight operations up to 450 m (1 500 feet) above ground level, but not less than V_1 minimum for ~~E~~engines to be installed on aeroplanes or higher than the speeds for the ingestion tests.

The impact evaluation may be carried out separately from the ingestion evaluation; however any damage resulting from the impact on the front of the ~~E~~engine must be assessed in relation to consequential damage on the rotating blades.

(~~f~~g) *General*

(1) Engine tests must be performed as required under CS-E 800 (b), (c), (d) and (~~d~~e) unless it is agreed that alternative evidence such as ~~E~~engine test, rig test, analysis or an appropriate combination, may come from the Applicant's experience on ~~E~~engines of comparable size, design, construction, performance and handling characteristics, obtained during development, certification or operation.

(2) The ~~E~~engine test described in CS-E 800 (b)(1), with regard to the single large bird, may be waived if it can be shown by test or analysis that the specifications of CS-E 810 (a) are more severe.

(3) Compliance with CS-E 800 (c), in place of an ~~E~~engine test, may be shown by:

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(i) Incorporating the run-on specifications of CS-E 800 (c)(1)(v) into the ~~E~~engine test demonstration specified in CS-E 800 (b)(1); or

(ii) Using a component test at the conditions of CS-E 800 (b)(1) or (c)(1), subject to the following additional conditions:

(A) All components critical to achieving the run-on criteria of CS-E 800 (c) are included in the component test; and

(B) The components tested under (A) above are subsequently installed in a representative ~~E~~engine for a run-on demonstration in accordance with CS-E 800 (c)(1)(v), except that steps 1 and 2 of CS-E 800 (c)(1)(v) are replaced by a unique 14-minutes step at a thrust not less than 50 % of ~~R~~rated ~~T~~take-off ~~T~~thrust after the ~~E~~engine is started and stabilised, and

(C) Dynamic effects that would have been experienced during a full ~~E~~engine test can be shown to be negligible with respect to meeting the specifications of CS-E 800 (c).

(4) Limit exceedences may be permitted to occur during the tests of CS-E 800 (c), (d) and (~~d~~e). Any limit exceedence must be recorded and shown to be acceptable under CS-E 700.

(5) For an ~~E~~engine that incorporates an inlet protection device, compliance with this CS-E 800 must be established with the device functioning and the ~~E~~engine approval must be endorsed accordingly.

(6) If compliance with all of the specifications of CS-E 800 is not established, the ~~E~~engine approval will be endorsed accordingly by restricting the ~~E~~engine installations to those where birds cannot strike the ~~E~~engine or be ingested by the ~~E~~engine or adversely restrict the airflow into the ~~E~~engine.

(7) An ~~E~~engine to be installed in a multi-~~E~~engined rotorcraft does not need to comply with the medium or small bird specifications of CS-E 800 (d), but the ~~E~~engine approval will be endorsed accordingly.

(8) The ~~E~~engine inlet throat area, as used in CS-E 800 to determine the bird quantity and mass, must be established and identified as a limitation on the inlet throat area in the instructions for installation.

3.2. Draft acceptable means of compliance and guidance material (Draft EASA decision)

AMC E 800 Bird Strike and Ingestion

(1) Ingestion ~~T~~tests

(a) Single large ~~B~~bird

(i) The applicant is required to provide an analysis substantiating the definition of the ~~“~~‘most critical exposed location’~~”~~ (CS-E 800 (b)(1)(iii)). Determination of this location should include evidence where necessary on:

— The effect of the bird strike on rotating components (excluding any spinner).

— The compressor casing strength.

— The possibility of multiple blade ~~F~~failures

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— The strength of the ~~E~~engine structure and main shafts relative to the unbalance and excess torque likely to occur.

(ii) For complying with CS-E 800 (b)(1)(ii)(A), rig tests may be used to determine if a particular bird size will pass through the inlet.

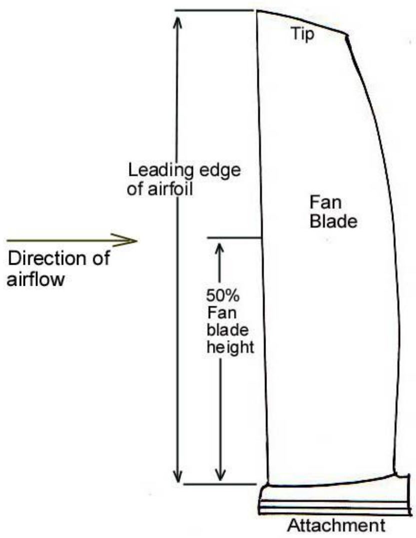
(iii) The complete loss of power or thrust is acceptable after ingestion of the single large bird.

(b) Large Flocking Bird

The following advisory material applies to the test of CS-E 800 (c).

(i) The minimum first stage rotor rotational speed (N1) at which the ~~E~~engine should be stabilised before ingestion should be determined from the ~~E~~engine performance data. ~~R~~rated ~~T~~take-~~O~~off ~~T~~thrust means the maximum take-off thrust produced at sea level static conditions on an ISA standard day.

(ii) The applicant should select a target on the first exposed rotating stage(s) of the ~~E~~engine (e.g. fan) at a blade span height of 50 %, or further outboard, as required by CS-E 800 (c)(1)(iv) (see figure below). The specified target location is at the discretion of the applicant.



The use of 'stage(s)' is intended to allow for alternative designs such as rear mounted fans where each exposed stage will be evaluated independently.

(iii) When setting the thrust between the steps of the 20-minutes run-on period, momentary thrust drops below the specified values may be acceptable as long as the duration does not exceed 3 seconds.

(iv) The engine is required to continue to run for 20 minutes and produce no less than 50 % of the ~~R~~rated ~~T~~take-off ~~T~~thrust for the initial 14 minutes. During the first minute, the thrust lever is not to be manipulated. During step 2, the thrust lever may be manipulated at the discretion of the applicant to seek a power setting where the engine can continue to operate, for example to minimise exceedences and/or vibration, provided that at least 50 % of ~~R~~rated ~~T~~take-off ~~T~~thrust is maintained. However, a momentary thrust drop below this value may be acceptable as long as the duration does not exceed 3 seconds.

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(v) Following the initial 14 minutes, the thrust is reduced and a maximum of 30 seconds is allowed for the applicant to manipulate the thrust lever to find the thrust specified. This is to allow for potential damage to the ~~E~~engine which might require careful throttle management.

(vi) The components referred to in CS-E 800 ~~(f)~~(g)(3)(ii)(A) include, for example, fan blades and their retention / spacer components, fan outlet guide vanes, spinners, fan disks and shafts, fan cases, frames, main bearings and bearing supports including frangible bearing assemblies or devices. The intent is that a sub-assembly test should adequately represent the mechanical aspects of a type design ~~E~~engine during the large flocking bird ingestion.

(vii) The dynamic effects (and related operability concerns) referred to in CS-E 800 ~~(f)~~(g)(3)(ii)(C) include, but are not limited to, surge and stall, flameout, limit exceedences, and any other considerations relative to the type design engine's ability to comply with the specifications of CS-E 800 (c).

(c) Medium and small flocking birds

(i) The ~~E~~engine test of CS-E 800 (d) will demonstrate that the ~~E~~engine will produce the required power or thrust, while keeping acceptable handling characteristics during a 20-minute run-on simulating return to the airport after bird ingestion at take-off. This will consequently demonstrate compliance with CS-E 540 (b).

(ii) The applicant will identify under CS-E 800 (d)(1)(ii) all the critical locations and those which have to be used during the small or medium bird engine ingestion tests and appropriately consider potential effects of assumed installations in aircraft. The spinner and other parts of the front of the engine may be evaluated separately under CS-E 800 ~~(e)~~(f).

(iii) In the tests performed under paragraph CS-E 800 (d), the ~~E~~engine is required to produce at least 75 % of test conditions power or thrust after ingestion of small and medium birds. Nevertheless, a momentary power/ thrust drop below this value is acceptable but its duration should not exceed 3 seconds after the ingestion.

(iv) Exceedences of ~~E~~engine operating limitations associated with Take-off conditions should not occur during the first 2 minutes following the ingestion of the birds in the 20-minute run-on test. If exceedence of limits occurs during these 2 minutes, except during the first 3 seconds of the test, this should be considered when complying with CS-E 700. After these initial 2 minutes without power lever movement, it is permitted to control exceedences, if any. Any intervention for controlling exceedences should be recorded and suitable instructions provided in the instructions for installation of the ~~E~~engine. After any such power lever adjustment, the ~~E~~engine should still produce the required power or thrust for the test. In CS-E 800 (d)(1)(iii) and (iv), a movement of the power lever means an action on the means which provides a power or thrust setting for the ~~E~~engine control. This can be a mechanical device in the test facility control room or an electronic signal sent to the Engine Control System.

(d) Core engine flocking bird ingestion test

(i) Determining climb rotor speeds; the calculation of the core ingestion test engine rotor speeds associated with the climb phase will depend on the aeroplane and the type of flight that is flown. For each engine model and installation, the engine manufacturer should:

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— Collaborate with the aeroplane manufacturer to determine the engine thrust at a 3000 ft altitude that is required to climb through that altitude, in International Standard Atmosphere (ISA) standard day conditions at 250 knots indicated airspeed (KIAS).
— Establish the associated minimum mechanical fan rotor speed for this condition using engine performance simulations.
— The fan speed chosen should be associated with the lowest rated thrust engine model offered for that aircraft installation. If multiple climb settings are available for a particular aircraft, then the lowest climb setting should be used to determine the core ingestion rotor speed targets.

(ii) Climb rotor speed considerations.

— There is typically little to no difference between take-off and climb rotor speeds for the smaller turbofan engines installed on business jets. For this reason, the climb conditions for the core ingestion demonstration will often be very close to the conditions prescribed for the medium flocking bird (MFB) test of CS-E 800(d), where the largest MFB is targeted at the core at the full rated take-off condition.

The most significant difference between the MFB test and the core ingestion demonstration is expected to be the fan critical bird speed versus the 250 KIAS core engine test bird speed. An applicant who wants to demonstrate the recommended 250 KIAS core bird within the existing MFB rated take-off test may do so, if the applicant can show an equivalent level of test severity. Therefore it is possible for the MFB core ingestion requirements to be satisfied by a single test at rated take-off thrust in which the largest MFB that is aimed at the core is fired into the engine at the 250 KIAS climb airspeed while the remaining bird velocities, targeting and run-on would follow the current MFB criteria. All birds in the test would still have to be fired within the 1 second requirement of CS-E 800 (d)(1)(iii). The objective is to show that the core ingestion is as rigorous at the current MFB fan speed condition as it would be at the aeroplane recommended climb fan speed condition.

(iii) Target selection and timing.

— The bird should be targeted at the engine in order to maximize the amount of bird material that enters the core for the given test condition. This will ensure that the core ingestion test properly challenges the core during an engine demonstration.
— The optimum target location varies with engine design. The span-wise location will depend on the geometric features of the front of the engine.
— The core bird target location should be determined so that it maximizes the amount of core ingested bird material for the core ingestion test by:
  - analysis based on component testing,
  - dynamic simulation verified by test, or
  - experience with similar designs.

(iv) Engine operation.

— A momentary, 3 second maximum, power or thrust decrease below the required value of each segment, or when setting power between segments, is acceptable.
— A power or thrust loss of greater than 3 seconds duration is considered to be a sustained power loss.

(v) Run-on sequence requirements.

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— The total test duration may exceed 20 minutes, due to the time used for accelerations and decelerations.

— Wherever a percentage of maximum rated take-off power or thrust is specified, the rotor speed to attain the specified power setting will vary with test day conditions.

— The power settings are a percentage of maximum rated take-off power or thrust, and not a percentage of the actual test day pre-ingestion power or thrust specified in CS-E 800 (e)(1) or (5).

(vi) Core ingestion prediction analyses.

— Some engine configurations may include features that reject all bird material from the core intake at the take-off and climb conditions. Such engines would be:

- exempt from the recommended climb ingestion criteria,
- subject only to the approach core ingestion test, and
- required to demonstrate 100 % bird rejection capability by analysis or similarity.

— Any analyses used to predict core ingestion will need to be validated using data that may be derived from:

- rig testing,
- engine testing, or
- field experience.

— If the standard CS-E 800 (d) MFB core demonstration results in any amount of bird material being found in the core, including a single feather or tissue fluorescence under ultraviolet light illumination, then:

- the prediction of zero core ingestion under the climb conditions of CS-E 800 (e)(1) will be considered invalid; and
- the climb condition core ingestion capability should be demonstrated.

— If during the MFB test required by CS-E 800 (d) a significant amount of bird material is shown to have been ingested into the engine core, then the core ingestion test required by CS-E 800 (e) may, if suitably justified, be shown to be less severe and therefore already demonstrated by the test of CSE 800 (d).

(2) Test facility related conditions

(a) The test facility should be appropriately calibrated to ensure that those controlling parameters defined by the analysis of the critical conditions which cannot be accurately controlled (e.g. bird speed, aiming locations) are within an acceptable tolerance. This tolerance band should be derived from an analysis of the sensitivity of the critical impact parameter to variation in the controlling parameters.

The “’critical impact parameter (CIP) ” is defined as a parameter used to characterise the state of stress, strain, deflection, twist, or other condition which will result in the maximum impact damage to the ~~E~~engine for the prescribed bird ingestion condition.

The critical impact parameter is generally a function of such things as bird mass, bird velocity, fan/rotor speed, impact location, and fan/rotor blade geometry. The state of maximum impact damage to the ~~E~~engine is relative to the ability to meet the criteria of CS-E 800. The CIP for most modern turbofan engines is fan blade leading edge stress, although other features or parameters may be more critical as a function of operating conditions or basic design. For turboprop and turbojet engines, a core feature will most likely be the critical consideration. Regardless of

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~~E~~engine design, the most limiting parameter should be identified and understood prior to any demonstration, as any unplanned variations in controlling test parameters will be evaluated for the effect on the CIP and CS-E 800 specifications.

For turbofan first stage fan blades, increasing the bird velocity or bird mass will increase the slice mass, and could shift the CIP from leading edge stress to blade root stress. For fan blades with part span shrouds, it may be blade deflection that produces shroud shingling and either thrust loss or a blade fracture that could be limiting. For unshrouded wide chord fan blades it may be the twist of the blade in the dovetail that allows it to impact the trailing blade resulting in trailing blade damage.

For certification tests, the CIP variation should not be greater than 10 % as a function of any deviation in test controlling parameters.

(b) The installation and especially the gun arrangement in some test facilities can induce air distortion in the ~~E~~engine inlet, reducing artificially the stability margins of the Engine. This should be identified prior to the test.

(c) Power or thrust should be measured by a means which can be shown to be accurate throughout the test to enable the power or thrust to be set without undue delay and maintained to within ± 3 percentage points of the specified levels. For the test of CS-E 800 (d), if, after the first 2 minutes, operation at the specified power or thrust levels would result in sustained high vibratory condition, the power or thrust may be varied within the ± 3 % band. Alternative load devices of some test facilities may be unable to control power level tolerance band to the desired level. This should be identified and approved prior to the test. Any exceedence of this ± 3 % band should be justified in relation to the objectives of CS-E 540 (b) or CS-E 800 (d).

(d) If turboprop or turboshaft engines are tested using an alternative load device which could induce different Engine response characteristics than when the ~~E~~engine is coupled with a propeller or installed in the aircraft, the interface with the test facility and aircraft or propeller systems should be monitored during the test and should be used for determining how the ~~E~~engine would respond in a representative installation and for ensuring that the ~~E~~engine would then comply with the specifications.

(e) Input and output data across the ~~E~~engine interfaces with the aircraft systems should be provided by the ~~E~~engine manufacturer in the instructions for installation regarding the expected interaction of the Engine with these systems during ingestion events. Of particular interest would be dynamic interactions such as auto surge recovery, propeller autofeather.

(3) Impact

(a) The front of the ~~E~~engine is defined as any part of the ~~E~~engine which can be struck by a bird. This includes components such as, but not limited to, nose cone/spinner on the fan or compressor rotor, an ~~E~~engine inlet guide vane assembly including centrebody, any protection device, or inlet-mounted components.

(b) Ingestion is defined as the passage of a bird into the rotating blades.

(c) The term ~~“~~’first stage rotor blades’~~”~~ when used in CS-E 800 includes the first stage of any fan or compressor rotor which is susceptible to a bird strike or bird ingestion. These first stage rotor blades are considered to be part of the front of the Engine. This definition encompasses ducted, unducted and aft fan designs. In this latter case, blades on two different rotors (in primary and secondary flows) would probably need to be considered.

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(4) General

(a) The ~~E~~engine configuration for the test should comply with CS-E 140. The normal functioning of automatic systems not requiring pilot intervention is acceptable provided that the dispatch criticality is addressed in the appropriate documentation. Systems which are not part of the ~~E~~engine, such as propeller autofeather system, should be disabled. Any OEI ratings do not have to be taken into account for compliance with CS-E 800 (d).

(b) The minimum ~~E~~engine referred to in CS-E 800 (b)(1)(i) or (d)(1)(i) is defined as a new ~~E~~engine that exhibits the type design's most limiting operating parameters with respect to the bird ingestion conditions prescribed by CS-E 800. These operating parameters include, but are not limited to, power or thrust, turbine temperature and rotor speed(s).

(c) CS-E 800 ~~(f)~~(g)(1) is intended to allow certification of design changes or derivative engines without conducting a full engine test. It is not intended, considering the present state of the art, to be used for certification of new engines. However, it offers the possibility of future advancement. Any parametric analysis used to substantiate derivative engines as allowed under CS-E 800 ~~(f)~~ (g) ~~(~~1) should fall within a 10 % variation in the critical impact parameter used to substantiate the original base engine. The critical impact parameter(s) is often associated with impact load at the point of bird and rotor blade contact. This is generally a function of bird speed, rotor speed, and blade twist angle. This 10 % variation on the critical impact parameter should not be assumed to be a direct tolerance on the applicants proposed changes to takeoff power or thrust ratings themselves.

(d) Any analytical means used in place of a test demonstration (where analysis is permitted) should be validated by evidence based on representative tests and should have demonstrated its capability to predict engine test results.

(e) When reference is made to 'exposed location' this should be understood to be any part of the engine which is not shielded.

(f) When the CS-E 810 test is proposed as an alternative to the single large bird test (see CS-E 800 ~~(f)~~(g)(2)), the demonstration should include consideration of unbalance as well as effects of the axial loading from the bird strike on bearings or other structures.

(g) Artificial birds may be used in the tests if they are internationally standardised and are acceptable to the ~~Agency~~ EASA.

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4. Impact assessment (IA)

4.1. What is the issue

The issue that needs to be addressed relates to the potential for a loss of thrust from an aeroplane turbine engine as a result of the ingestion of a bird into the core of the engine. The accident to US Airways Airbus A320, registered N106US, that ditched in the Hudson River on 15 January 2009 demonstrated that it is indeed possible for aeroplane turbine engines to suffer a loss of thrust following ingestion of a bird into the engine core in certain flight conditions. The current regime of bird ingestion tests that are required by CS-E does not include a dedicated test to determine the robustness of the engine to sustain the ingestion of a bird into the engine core at the flight conditions that were experienced by the US Airways Airbus A320 that ditched in the Hudson River. Therefore, the ability of an aeroplane turbine engine to continue to provide thrust following a bird ingestion into the engine core is not currently substantiated during type certification.

4.1.1. Safety risk assessment

<u>Input Data</u>

In response to the accident investigation and the related NTSB Recommendations, the FAA, EASA and the Aerospace Industries Association (AIA) initiated an engine bird ingestion threat and type certification rule study in 2009. The intent of the study was:

— to update the existing AIA bird ingestion database with new data through January 2009 (referred to as the AIA Working Group Phase III Database);

— to determine any changes to the bird threat observed in service; and

— to determine whether the existing certification requirements would meet their intended safety objective.

This study used updated bird ingestion data covering the period from January 2000 to January 2009, which includes over 11 000 bird ingestion records covering over 250 million flights. The report[7] concluded that although multi-engine ingestion rates were higher than predicted, the engine power or thrust loss rate is better than expected, thus the safety objectives are predicted to be met, but that core ingestion demonstration criteria could be strengthened.

The data provided by the engine manufacturers included information on each bird ingestion event contained in their own databases. The data required for the various analyses were the event date, engine model, aeroplane model, engine position, number of engines involved, power or thrust level available (after the event), bird species (if available), and the total hours and cycles for each engine model. The engine model was broken down into size classes (both by fan diameter and inlet area) and certification standard.

[7] Turbofan Bird Ingestion Regulation Engine Harmonization Working Group Report, 19 February 2015.

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Engine class	Inlet throat area, A m^2	Percentage of flights in data set	Percentage of events per engine class
A	3.90 < A	2 %	6 %
B	3.50 < A ≤ 3.90	5 %	10 %
C	2.50 < A ≤ 3.50	3 %	5 %
D	1.35 < A ≤ 2.50	41 %	62 %
E	0.40 < A ≤ 1.35	36 %	11 %
F	A ≤ 0.40	12 %	5 %
Unknown		1 %	

Table 1 Engine size classes based on inlet throat area and quantity in data set

Bird class	Bird mass, m (kg)	Percent of data set	Common examples
i	0 < m ≤ 0.23	36 %	Starling
ii	0.23 < m ≤ 0.45	3 %	Rock Dove
iii	0.45< m ≤ 0.68	3 %	Ring-billed gull
iv	0.68 < m ≤ 1.13	21 %	Herring Gull
I	1.13 < m ≤ 1.81	1 %	Glaucous-winged Gull
II	1.81 < m ≤2.72	4 %	Lesser Snow Goose
III	2.72 < m ≤ 3.63	1 %	Greater Snow Goose
IV	3.63 < m	0.3 %	Canada Goose
Unknown		31 %	

Table 2 Bird mass Class definitions and quantity in data set

The databases provided by the engine manufacturers contain all of the bird ingestion events known to them. The data were supplemented by reviewing the FAA/Department of Agriculture National Wildlife Strike Database and an EASA/National Aviation Authority (NAA) database and including any events that were previously not included in the manufacturer’s data.

The AIA Working Group Phase III Database (1/1/2000 – 31/1/2009) was used to determine whether there was sufficient evidence that would support the hypothesis that other flight phases can be as, or more, severe than the take-off phase regarding bird ingestion. Core and bypass ingestion data which

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had engine thrust loss (turbofans only) were analysed within flight phases for engine size and bird mass class.

Core ingestion

The database consists of 11 224 turbofan-engine-bird-ingestion events. Of these, 1 654 showed evidence of core ingestion and of these, 39 events resulted in an engine thrust loss. The focus of this particular analysis was on these 39 engine thrust loss events and specifically, the flight phases in which they occurred. The two flight phases which had the largest percentage of core ingestions resulting in engine thrust loss were climb and approach. Given a core ingestion, the data showed a 1.03 % probability of engine thrust loss during the climb phase, and a 0.73 % probability during the approach phase. Relative to the take-off phase (in the current CS-E 800 medium-flocking-bird-test procedure), the climb and approach phases have 5.7 and 4.0 times greater percentages of occurrence, respectively.

By-pass ingestion

The same analysis was completed for the bird ingestions that were considered to enter only the bypass and resulted in engine thrust loss. Of the 11 224 total bird ingestion events recorded, only 2 503 were identified as bypass-only ingestions. Of these bypass-only events, 24 resulted in an engine thrust loss. The two flight phases which had the largest percentage of bypass ingestions resulting in engine thrust loss were climb and take-off. The data showed a 0.36 % probability of engine thrust loss during the climb phase, and a 0.20 % probability during the take-off phase. The approach and landing phases, which were significant relative to the take-off phase for the core ingestion damage, were not significant for bypass ingestions.

Impact of flight phase and engine size on engine thrust loss due to bird ingestion

Further analysis was conducted to understand whether the flight phase and engine size affects the engine thrust loss. The data shows that for all engine size classes, with the exception of class A, which had no core ingestions that resulted in thrust loss, the highest percentage of thrust losses was during the climb phase. This was followed by either the approach or landing phases for all the engine size classes, except for class C which had its second highest percentage of events at take-off.

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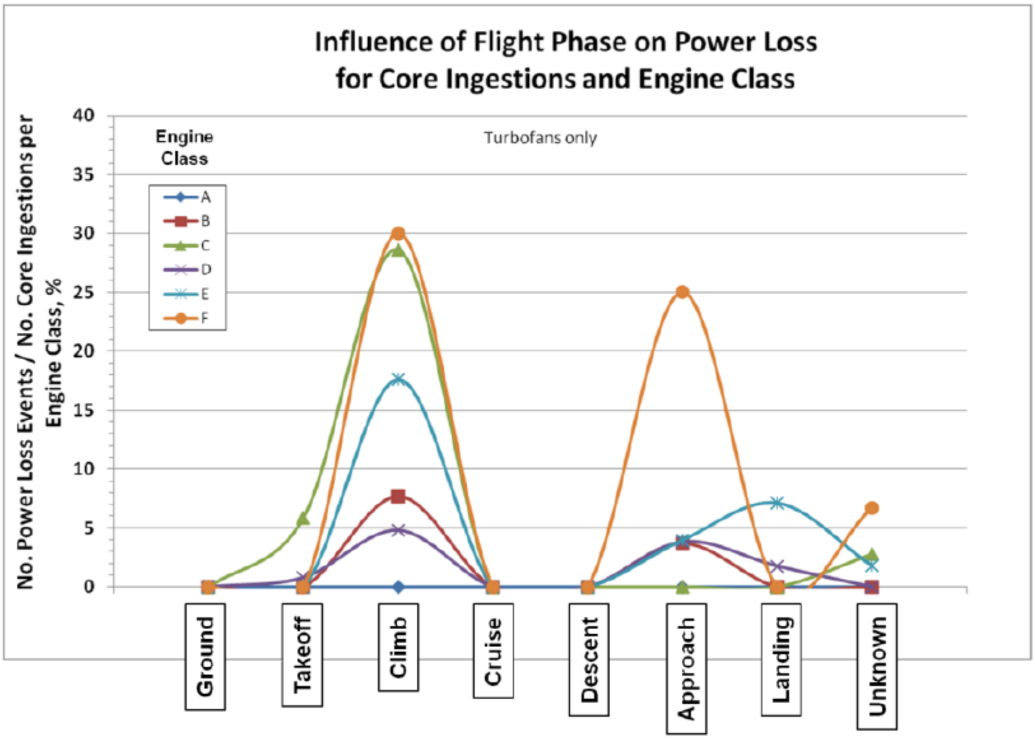

Figure 1 Core Ingestion Resulting in Thrust (Power) Loss vs. Flight Phase

An evaluation of the results of the bypass ingestions that result in engine thrust loss for each engine class and flight phase was conducted. The graphical representation of these results is shown in Figure 2. The data shows that for all engine size classes with the exception of class B, which had no bypass ingestions that resulted in thrust loss, the highest percentages of thrust loss were during the take-off or climb phases. Only the smaller engine size classes, E and F, showed engine thrust loss for the approach and descent phases, respectively.

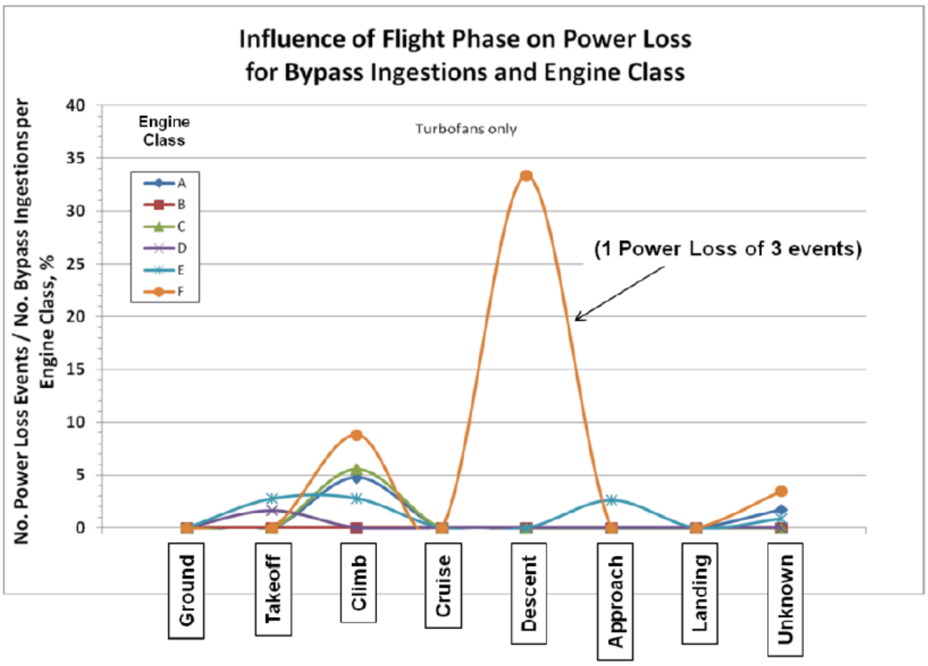

Figure 2 Bypass Ingestion Resulting in Thrust (Power) Loss vs. Flight Phase

<u>Impact of bird mass on engine thrust loss due to bird ingestion</u>

After determining the effect of the flight phase, the next analysis that was undertaken was to understand whether there was a relationship between the loss of thrust and the mass of the ingested bird. This was reviewed for the core ingestions as well as the bypass ingestions. The outcome of this review shows that on a percentage basis and generally speaking, the damage to engine components and the probability of thrust loss increase with the mass of the bird.

The data indicate that there is a large difference in thrust loss between core and bypass ingestions with increasing bird masses (classes III and IV defined in Table 2 above). The data indicates that a core ingestion event is approximately 5 % more likely to result in a thrust loss event than a bypass only event for the mass classes up to class II. For the heavier mass classes (class III and class IV), this difference increases dramatically. For class III, a core ingestion event is 19 % more likely to result in a thrust loss than a bypass ingestion and for class IV, a core ingestion is 30 % more likely to result in a thrust loss than a bypass ingestion.

Figure 3 combines the core and bypass results based on the range of each mass class.

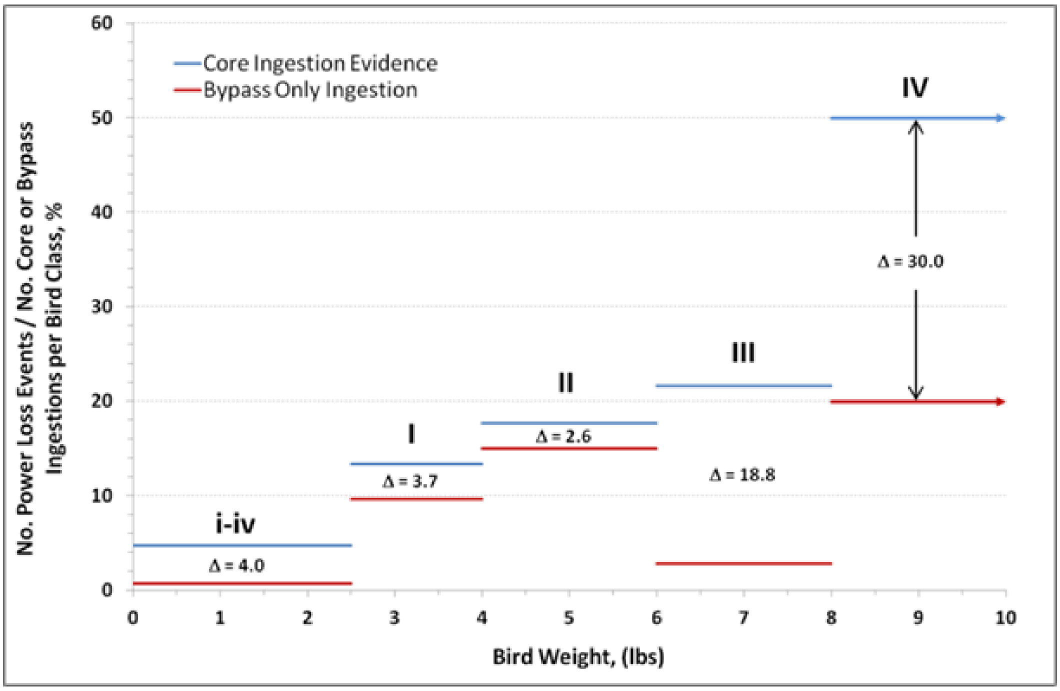

Figure 3 Influence of Bird Mass (Weight) Resulting in Thrust (Power) Loss

<u>Bird size effect on likelihood of core ingestion</u>

A comparison of medium-sized birds (1.5 lbs to 4.0 lbs) and large-sized birds (> 6.0 lbs) was done for core and bypass ingestions to determine whether there was an influence of bird size on the likelihood of core ingestion. For both the medium and large categories of bird size, roughly 54 % of ingestions involved some material going into the core. Further analysis of data implied that the likelihood of core ingestion is the same for both size categories of birds.

The inference that the likelihood of core ingestion is independent of bird size is consistent with the ingestion reporting criteria in which a finding of any bird material evidence in the core inlet is categorised as a core ingestion event.

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	Total	Core	Bypass
Medium Birds	996	542 (54.4 %)	454 (45.6 %)
Large Birds	78	42 (53.8 %)	36 (46.2 %)

Table 3 Bird Size Effect on Core Ingestion Proportion

Analysis summary

The data were found to be clear and consistent in showing that the likelihood of engine thrust loss due to bird ingestion correlates more strongly with high engine thrust (take-off and climb) versus low thrust (approach/landing). The high thrust data further show that a thrust loss due to bird ingestion is more likely to occur during the climb phase versus the take-off phase. In addition, ingestions in which at least some bird material was observed in the core were more likely to result in a thrust loss than bypass only ingestions, and that the probability of a core ingestion is independent of bird size (for medium and large flocking birds).

Based on the statistical analysis of this bird ingestion database , the EHWG observed that a core ingestion during the aircraft early climb phase presents the greatest likelihood of resulting in a bird ingestion related engine thrust loss, and would therefore provide the greatest opportunity for safety goal enhancement.

4.1.2. Who is affected

Designers and manufacturers of turbine engines installed on aeroplanes, aeroplane operators and aeroplane pilots are affected by this safety issue.

4.1.3. How could the issue/problem evolve

Figure 4 below provides a graphical representation of the number of bird encounters that have resulted in engine thrust issues for EASA air operator certificate (AOC) holders and those occurred in the territory of the EASA Member States (regardless of the nationality of the AOC holder) for the period 2009-2016. This data comes from the European Central Repository (ECR[8]). In addition, the rate of bird encounters per 100 000 movements is also depicted.

It can be seen from Figure 4 that the number of annual bird ingestions that result in engine issues is relatively stable and there does not appear to be an increasing trend in the number of occurrences. Likewise the rate of bird ingestions per movement does not indicate that that there is an overall increasing issue with bird ingestions that result in engine issues. Nevertheless it does represent a very important safety risk to tackle.

However, from this data, it is not possible to differentiate between core and fan bird ingestions and it is also not possible to establish the size of the bird ingested. It can be concluded that the prevalence of bird ingestions resulting in engine thrust loss is static and not likely to increase in the future unless the

[8] ECR is the occurrence database established by the Regulation (EU) No 376/2014, where all Members States and EASA integrate the occurrences reported to them by the aviation individuals and organisations.

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number of movements significantly increases. However, low-severity[9] events seem to have increased significantly in recent years.

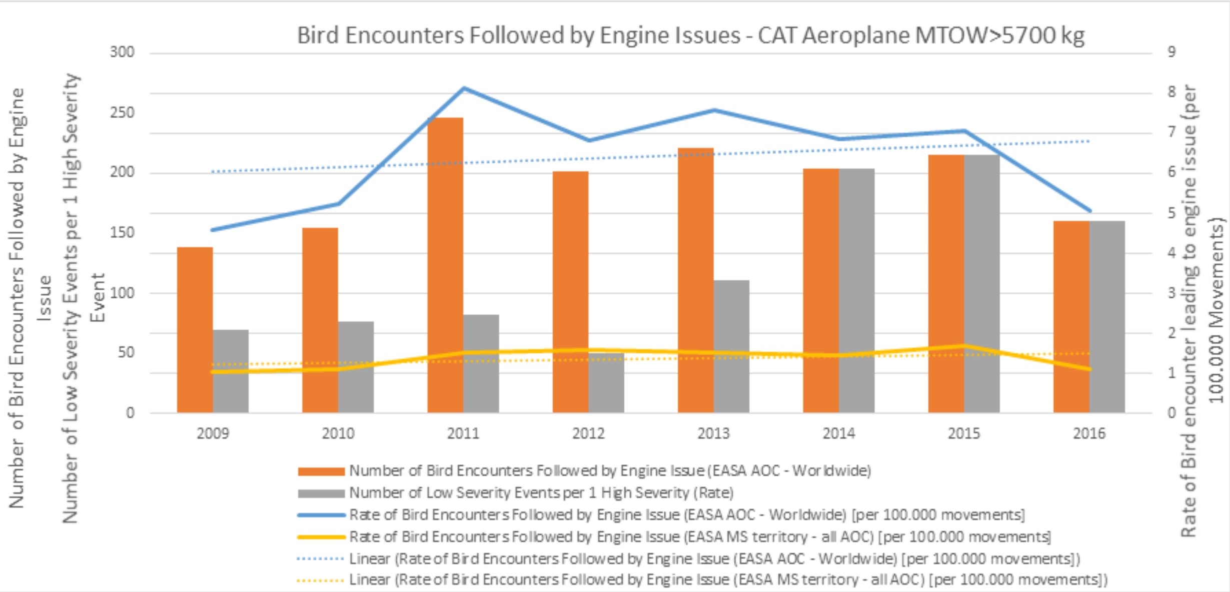

Figure 4 Bird encounters that have led to engine issues for CAT aeroplanes with a MTOW >5 700kg

4.2. How it could be achieved — options

Option 0 does not propose any changes to the current regulatory framework and relies on the current bird ingestion provisions in CS-E.

Option 1 proposes to amend the aeroplane turbine-engine-bird-ingestion-test provisions in CS-E to include the need for a demonstration of a medium flocking bird core ingestion at a fan speed respresentative of a climb condition.

Table 4: Selected policy options

Option No	***Short title***	**Description**
0	Do nothing	No policy change (no change to the rules; risks remain as outlined in the issue analysis).
1	Amend CS-E Medium Flocking Bird ingestion test provisions	Medium flocking bird ingestion demonstration provisions in CS-E could be amended to include an additional test specification for a turbine engine to be required to continue to operate following the ingestion of a medium-sized bird into the engine core with a fan speed that is representative of the climb condition.

[9] A low-severity event means an occurrence that is not an accident or a serious incident as per Regulation (EC) No 996/2010 on the safety investigation of accidents in civil aviation. A high-severity event is an accident or a serious incident as per the aforementioned regulation.

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4.3. What are the impacts

4.3.1. Safety impact

Medium and small bird ingestion

Ingestion of medium flocking birds during take-off and climb

The ARAC group assessed the statistical performance of the existing fleet with respect to freedom from catastrophic consequences. The fleet-wide statistics show the current fleet is on track to maintain the desired safety goal with the current regulations, and that on this statistical performance basis, no change to the core ingestion certification criteria would be justified.

However, it was determined that the original intent of the core ingestion demonstration in the current CS-E 800 is not being met due to the fact that the demonstration may not provide the greatest operating challenge to the engine core with respect to ingested bird mass and relative kinetic energy.

Normally the most vulnerable part of a turbofan engine to bird impact is the most forward stage. The primary concern is fan blade transverse fractures and/or airfoil deformation induced aerodynamic effects leading to a significant loss of thrust capability. To address these fan blade durability concerns, the current medium flocking bird (MFB) test parameters of bird speed, fan speed and impact location are optimised to present the greatest challenge to the fan blade. The current CS-E 800 does not stipulate any modifications to the fan critical test parameters for the core ingestion requirement other than that the largest single MFB is to be aimed at the core. Because the engine thrust setting and bird speed are, by default, considered the same for the core and the fan outspan test, the medium flocking birds are typically tested simultaneously or in rapid succession (CS-E 800 requires all birds to be ingested within one second) at similar bird speeds into the core and fan bypass during a single engine test event.

The difference in the MFB mass entering the core between the current critical fan blade conditions and a climb condition was assessed by the ARAC group. Various engine manufacturers provided analytical models and the results indicated that the most critical parameters that affect core ingestion of bird material are the flow path geometry, bird velocity, impact location, and fan rotor speed. The simulations concluded that the bird mass ingested into the core increases as the fan rotor speed is reduced and also as the bird speed is increased.

Further analysis revealed that the most appropriate flight speed to evaluate MFB core ingestion capability was the maximum aircraft speed that is normally used in service at the altitudes which birds are likely to be encountered. According to a USDA report[10], more than 91 % of the bird strikes to aircraft occurred below an altitude of 3 000 feet. Based on ICAO standard flight Noise Abatement Departure Profiles and service data from airframe manufacturers and the International Airline Pilots Association, expected flight speeds on commercial transport aeroplanes at altitudes from 0 to 3000 ft above ground level (AGL) range between 150 and 250 knots indicated airspeed (IAS).

It has also been determined that the ingestion parameters which are expected to result in the most significant damage to the core are based on several factors. Although the bird velocity is predicted to have the greatest influence on the amount of bird ingested into the core for a given design, the rotation speed of the first exposed rotor and the engine design are strong influences. It was shown by

[10] Dolbeer, Richard A., "Height Distribution of Birds Recorded by Collisions with Civil Aircraft" (2006), USDA National Wildlife Research Center – Staff Publications, Paper 500.

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various engine manufacturers' simulations that, in general for a given bird velocity, the amount of ingested bird material into the core is inversely proportional to the fan rotor speed.

Therefore, selecting a first stage rotor rotational speed that represents the most engine operations during a climb is expected to best support the maintainance of the core certification safety objective. This would require a collaborative effort between the aeroplane and engine manufacturers to establish a fan rotor speed for a climb core ingestion demonstration. In order to have a more effective test, an analytical assessment of the core target location to determine the location that maximises the bird mass ingested into the core would be required.

It is also important that the engine continues to provide thrust (run-on) following a bird ingestion. The ARAC group considered the run-on demonstration that would best confirm that the engine remained capable of executing an air turn back and safe landing at the airport after an MFB core ingestion event during a climb. The most appropriate demonstration was assessed to be that defined by the CS-E 800 provisions for large flocking birds. The basis for this conclusion was that the aircraft has completed the take-off phase and is climbing away from the airfield, conditions which are represented in the large-flocking-bird (LFB) provisions. These provisions establish that at least 50 % of the highest-rated thrust for the tested model remains available from the engine after the ingestion to ensure a thrust equivalent to a single engine inoperative take-off condition in the event of multi-engine core ingestion, followed by an engine run-on profile to ensure engine power can be safely managed during an air turn back and landing.

Ingestion of medium flocking birds during approach

From an aircraft safety point of view, the justification for addressing core ingestion criteria in the climb phase as opposed to approach is that on approach, the aircraft is aligned with the runway with the primary requirement to maintain the glide slope, and therefore the aircraft is in a better position to execute a safe landing when presented with a core ingestion engine thrust loss. During the climb phase, the aircraft is vectored away from the departure airport and needs to be able to at least maintain altitude while executing manoeuvres to clear obstacles and return to the airport. It is considered that the climb phase best represents the in-service combinations of airspeeds and thrust settings for core ingestion capability demonstration criteria in support of the safety objective for most engines.

The principal drivers of bird material ingested into the core are bird velocity (aircraft speed), fan rotational speed and the engine geometry leading up to the core intake. Recent experience has shown that some turbofan configurations may eject all of the bird mass into the fan bypass at high power conditions. This would result in the potential problem that engine configurations which reject all bird material from the core at the take-off and climb conditions would effectively not demonstrate any bird core capability at all if the CS-E 800 were restricted to climb and take-off conditions.

The outcome of the ARAC group's deliberations was the recommendation that those engine models which ingest no bird material into the core at the take-off and climb conditions should be tested in an approach condition. The most appropriate bird speed for the approach condition was determined to be 200 kt IAS (a typical approach airspeed at 3 000 ft AGL and 10 miles from the runway threshold) and the engine front rotor speeds to be the engine original equipment manufacturer defined revolutions per minute (RPM) consistent with a flight idle setting. Due to the fact that the aircraft would be on final approach in this condition, the engine should only be required to demonstrate throttle movement

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sufficient to maintain the glide slope as expressed in the final 6 minutes of the large flocking bird engine run-on requirement.

Ingestion of small flocking birds

An assessment of the core ingestion of small birds was also conducted by the ARAC group. It was hypothesised and considered that when comparing the bird mass for small flocking birds (e.g. European starlings - Sturnus vulgaris) to that of a Canada goose (Branta canadensis), engine encounters with large starling flocks could result in the equivalent mass of a single Canada goose. The data shows that these encounters with large numbers of small flocking birds have not resulted in permanent engine power losses, which is believed to be the result of the spacing between the birds (relative to the bird size) within a flock. Therefore, the threat from small flocking birds was determined to be adequately addressed by the current CS-E 800 provisions.

Large flocking bird ingestion

Large flocking bird ingestion for engines with inlet throat areas 1.35 to 2.5 m^2 (class D)

The A320 aircraft that was involved in the US Airways flight 1549 event (where both engines experienced a loss of thrust as a result of bird ingestion) used engines in this size class. Those engines were designed prior to the LFB provisions being included in CS-E 800, which are intended to demonstrate fan blade capability in terms of thrust loss and engine operability. The fan blades of the engines involved in US Airways flight 1549 were not severely damaged, and are believed to have been capable of producing substantial continued thrust. Therefore the event did not indicate a deficiency in the current CS-E bird ingestion provisions on fan blades at this engine size.

It is worth noting that this class of engine accrues the highest number of total flights within the transport category world fleet, and therefore is the most statistically significant category.

An analysis of the engine ingestion statistics has shown that class D sized engines are currently operating close to the safety objective of the current CS-E; therefore it is considered that there is no need to include this class of engine in the current large-flocking-bird-engine-test requirement at this time. In addition, it is expected that the overall class D fleet capability and safety margin will increase in the future as engines designed to the current CS-E 800 (which includes the provisions for large flocking bird testing) become more prevalent in the world fleet.

Furthermore, a simulation of fan blade impact was conducted by an engine manufacturer to compare the leading edge impact energy for the MFB versus the LFB criteria. The results show higher impact energy across the bypass fan rotor for the LFB up to 85 % span, at which point the MFB impact energy is higher. When this same analysis was repeated for the bird size and conditions for the LFB test, which would be nearly equivalent across the full span, it was found that a 1.58 kg bird run at the LFB condition would provide a similar level of challenge as the existing MFB criteria. The ARAC group thereby concluded that imposing the LFB requirement on the smaller class D engines would not result in a significant improvement in power loss rates.

Large flocking bird core ingestion testing

The ARAC group was also tasked with considering the appropriateness of introducing a large flocking bird core ingestion test.

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The relative effects of core ingestion of a medium flocking bird at the proposed climb condition and a large flocking bird at the derated take-off condition in the current CS-E 800 were assessed to determine whether there was a significant difference in the threat of core damage, which could lead to a power loss on a class D turbofan. It can be assumed that the LFB derated take-off condition would more than likely result in an increase in the mass ingested when compared to the MFB climb condition. This was shown to be the case by engine manufacturer simulations. The LFB condition resulted in a smaller mass fraction of the bird entering the core (0.39 for an LFB vs. 0.52 for an MFB), but an LFB results in a 20 % higher total mass entering the core than the MFB. However, it was also found that the difference in impact energy delivered to the core inlet was insignificant (± 2 %) between the LFB and MFB ingestion conditions. This is a result of the slower aircraft and fan rotor speed associated with the LFB ingestion criteria.

The ARAC group concluded that a large flocking bird core ingestion test is not necessary because this threat is a relatively small percentage of the overall risk of multi-engine power loss. Since power losses are predominantly driven by fan blade damage and fractures, the current engine certification test is considered to be the best demonstration of overall engine capability against this threat. Previous rulemaking efforts also determined that bypass ingestions make up the majority of the related risk, and that the safety objective of the CS-E 800 is met without the addition of a core ingestion element to the test.

<u>Conclusions of safety impact assessment</u>

The conclusions of the safety impact assessment are:

1. The current CS-E 800 provisions for core ingestion demonstration do not adequately represent the most critical flight phase with respect to core ingestion, due to the combination of high fan rotor speed and low aircraft speed.
2. It is considered to be necessary to maintain the current robust medium flocking bird demonstration at take-off power.
3. Additional CS-E 800 provisions should be included to require the specific demonstration of medium flocking bird ingestion into the engine core.
4. This demonstration should be conducted at the fan rotor speed associated with the lowest expected available climb thrust setting for the engine installation.
5. If it is shown that no bird material will be ingested into the engine core at climb thrust, then the demonstration should be performed at approach thrust.
6. The amendment of the CS-E 800 provisions for LFB demonstration for class D size engines would not provide any notable improvement in engine capability over and above the current and recommended ingestion provisions.

<u>Consideration and evaluation of safety recommendations</u>

During the safety impact assessment and consideration of different options, EASA took into account the relevant safety recommendations that were issued to EASA in order to establish and ensure that they have been appropriately addressed.

In accordance with safety recommendation UNST-2010-088, the lowest fan speed for a minimum climb condition for the medium flocking bird demonstration was evaluated. EASA considers that the SR was

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essentially incorporated into the proposed core ingestion demonstration by requiring the fan rotor speed associated with the lowest expected available climb thrust setting for the engine installation. However, no change is proposed to the maximum take-off requirement for other aspects of the medium flocking bird provisions since this is far more stringent for the fan blades.

In accordance with safety recommendation UNST-2010-089, the large flocking bird certification test provisions were reviewed to determine whether they should apply to engines in the class D size and include additional provisions for engine core ingestion. The potential benefit of adding a large flocking bird requirement to this engine size class was considered and it was found that, due to the shorter fan blade length in this size class, the large flocking bird test condition would not clearly provide any significant safety benefit for either the fan bypass threat or the core ingestion element. Simulations provided by an engine manufacturer revealed that the current additional integrity test requirement provides an equivalent structural challenge to the fan blade up to the 1.58 kg bird size. Manufacturer simulations also showed that the current medium flocking bird requirements provide similar energy at the core intake (within 2 %) despite the larger amount of bird material associated with the large flocking bird. Therefore no amendments to the large flocking bird provisions in CS-E 800 are proposed.

Summary of Safety Impact Assessment

Option 0 would not provide any improvement in safety.

Option 1 would provide an improvement in safety for the risk of a medium flocking bird being ingested into the engine core. Indeed several occurrences linked to this scenario could be prevented because the additional core ingestion test would uncover any design issues that need to be addressed and therefore the engine design should be able to sustain the ingestion of a medium flocking bird into the engine core.

4.3.2. Environmental impact

The options have no significant environmental impacts.

4.3.3. Social impact

The options have no significant social impacts.

4.3.4. Economic impact

Cost impacts are mostly assessed qualitatively in this chapter due to the very limited information received by EASA from requests addressed to manufacturers for estimated costs.

Option 0: creates no major impacts, however, the potential economic benefits from having engines with cores demonstrated to be more tolerant to bird ingestion would not be realised. This would result in the continuation of the current situation of operators having to overhaul their engines following damage caused by bird ingestion into the engine core.

Option 1: For new CS-E engine designs, the following costs are assessed:

— Non-recurring costs (NRC):
  - For manufacturers, the estimated costs will depend on whether the manufacturer is able to combine the new core ingestion test with the medium flocking bird ingestion test, or if a dedicated test is required.

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- If the new medium flocking bird core ingestion test is a dedicated test with no synergy from the medium flocking bird ingestion test, the estimated cost of the test is circa €2.5 million. This cost could be considered as very low compared to annual revenues of several engine manufacturers.
- If the synergy between the medium flocking bird ingestion test and the new medium flocking bird core ingestion test is maximised (the same engine may be used to run both tests) the estimated cost of the test is €0.5 million. This cost can be considered as very low/negligible.

— Recurring costs (RC):

- o The implementation of a new core ingestion test would not cause any additional recurring costs for manufacturers or operators.

There could be an economic benefit for operators from having an engine that is more tolerant to the ingestion of a medium flocking bird through the avoidance of the costs of having to overall the engine due to the resulting damage to the engine. It is estimated that the cost of overhauling an engine due to extensive damage created by the ingestion of medium or large bird, resulting in a significant loss of thrust, is in the order of €1.5 million to €2.0 million.

Summary: **Option 1** would create very low/negligible NRC to manufacturers when developing a new engine type. Furthermore there could be positive impacts for airline operators by not having economic losses due to damaged engines.

Question to stakeholders on economic impacts:

Stakeholders are invited to provide any relevant quantification and justification on the possible economic impacts of the options proposed, or alternatively to propose and justify another solution to the issue.

4.3.5. General Aviation and proportionality issues

The options have no significant impacts for small to medium enterprises or General Aviation.

4.4. Conclusion

4.4.1. Comparison of options

Impact	Option 0	Option 1
Safety impact	0	+
Economic impact	0	+/-
Total	0	+

The selection of the best option consists of a comparison between the potential safety benefit against the associated costs for impacted stakeholders.

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Option 0 is neutral. Selecting this option would not result in an improvement in safety or achieve any of the objectives.

Option 1 would provide a safety benefit and achieve the objectives, and when compared to the estimated costs, the balance is considered to be proportionate. There would be benefits for operators who could face lower costs in cases of engine loss/damage. This option also has the additional benefits of maintaining alignment with the FAA and Part 33 along with addressing the safety recommendations made to EASA.

Therefore, **Option 1** is the recommended option.

Question to stakeholders: stakeholders are also invited to provide any other quantitative information that they may find necessary to bring to the attention of EASA.

4.5. Monitoring and evaluation

One of the recommendations of the EHWG was the establishment of a dedicated AIA working group. It was proposed that the group should meet annually and add prior experience to the bird ingestion database. A number of suggested means of improving the quality of the database were also suggested, which this new working group could address. The working group could also provide recommendations on any deficiencies seen in the current rules, needs for rulemaking on new technology engines and recommendations for other means to mitigate the ingestion threat such as bird detection and avoidance.

EASA will closely monitor the development of this working group whilst also monitoring the number of bird ingestion events that result in engine thrust issues (see para 4.1.3).

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5. Proposed actions to support implementation

— Focused communication for advisory body meeting(s) (TeB, STeB)

(Advisory body members)

N/A

— Providing supporting clarifications in electronic communication tools EASA - NAAs (CIRCABC, SINAPSE or equivalent)

(Primarily targeted audience Competent Authority)

N/A

— EASA Circular

(Primarily targeted audience Competent Authority, Industry)

N/A

— Detailed explanation with clarification and indicated hints on the EASA web

(Industry, Competent Authority)

N/A

— Dedicated thematic workshop/session

(Industry, Competent Authority)

N/A

— Series of thematic events organised on the regional principle

(Industry, Competent Authority)

N/A

— Combination of the above selected means

(Industry, Competent Authority)

N/A

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6. References

6.1. Affected decisions

— Decision No. 2003/9/RM of the Executive Director of the Agency of 24 October 2003 on certification specifications, including airworthiness codes and acceptable means of compliance, for engines ('CS-E')

6.2. Other reference documents

— EHWG report, 'Turbofan Bird Ingestion Regulation', 19 February 2015

— Aircraft Accident Report NTSB/AAR-10/03 PB2010-910403, 'Loss of Thrust in Both Engines After Encountering a Flock of Birds and Subsequent Ditching on the Hudson River', US Airways Flight 1549, Airbus A320-214, N106US Weehawken, New Jersey, 15 January 2009

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