the functions of the Department, including whether the information will have practical utility; (b) the accuracy of the Department's estimate of the burden of the proposed information collection; (c) ways to enhance the quality, utility and clarity of the information to be collected; and (d) ways to minimize the burden of the collection of information on respondents.

All responses to this notice will be summarized and included in the request for OMB approval. All comments will also become a matter of public record on the docket.

Issued in Washington, DC, on January 30, 2015.

**Blane Workie,**

*Assistant General Counsel for Aviation Enforcement and Proceedings.*

[FR Doc. 2015–02405 Filed 2–5–15; 8:45 am]

BILLING CODE 4910–9X–P

## DEPARTMENT OF TRANSPORTATION

### Federal Aviation Administration

### Aviation Rulemaking Advisory Committee Meeting on Transport Airplane and Engine Issues

**AGENCY:** Federal Aviation Administration (FAA), DOT.

**ACTION:** Notice of public meeting.

**SUMMARY:** This notice announces a public meeting via teleconference of the FAA's Aviation Rulemaking Advisory Committee (ARAC) Transport Airplane and Engine (TAE) Subcommittee to discuss TAE issues.

**DATES:** The teleconference is scheduled for Tuesday, February 24, 2015, starting at 7:30 a.m. PST/10:30 a.m. EST. The public must make arrangements by February 20, 2015, to present oral statements at the meeting.

**ADDRESSES:** N/A.

**FOR FURTHER INFORMATION CONTACT:** Ralen Gao, Office of Rulemaking, ARM–209, FAA, 800 Independence Avenue SW., Washington, DC 20591, Telephone (202) 267–3168, FAX (202) 267–5075, or email at *ralen.gao@faa.gov.*

**SUPPLEMENTARY INFORMATION:** Pursuant to Section 10(a)(2) of the Federal Advisory Committee Act (Pub. L. 92–463; 5 U.S.C. app. 2), notice is given of an ARAC Subcommittee meeting via teleconference to be held February 24, 2015.

The agenda for the meeting is as follows:

- Engine Harmonization Working Group—Vote on Bird Ingestion Tasking Report
- Avionics System Harmonization Working Group—Phase 2 Low Speed Alerting Response to FAA request for clarification
- Proposed tasking on Transport Airplane Crashworthiness and Ditching Evaluation
- Materials Flammability Working Group—new tasking
- Transport Airplane Metallic and Composite Structures Working Group—new tasking
- Any other business

Participation is open to the public, but will be limited to the availability of teleconference lines.

To participate, please contact the person listed in **FOR FURTHER INFORMATION CONTACT** by email or phone for the teleconference call-in number and passcode. Please provide the following information: Full legal name, country of citizenship, and name of your industry association, or applicable affiliation. If you are participating as a public citizen, please indicate so. Anyone calling from outside the Arlington, VA, metropolitan area will be responsible for paying long-distance charges.

The public must make arrangements by February 20, 2015, to present oral or written statements at the meeting. Written statements may be presented to the Subcommittee by providing a copy to the person listed in the **FOR FURTHER INFORMATION CONTACT** section. Copies of the documents to be presented to the Subcommittee may be made available by contacting the person listed in the **FOR FURTHER INFORMATION CONTACT** section.

If you need assistance or require a reasonable accommodation for the meeting or meeting documents, please contact the person listed in the **FOR FURTHER INFORMATION CONTACT** section.

Issued in Washington, DC on February 3, 2015.

**Lirio Liu,**

*Designated Federal Officer, Aviation Rulemaking Advisory Committee.*

[FR Doc. 2015–02416 Filed 2–5–15; 8:45 am]

BILLING CODE 4910–13–P

## DEPARTMENT OF TRANSPORTATION

### Federal Transit Administration

### National Aging and Disability Transportation Center (NADTC) Under FTA's Technical Assistance Program

**AGENCY:** Federal Transit Administration (FTA), DOT.

**ACTION:** Notice; Request for Proposals (RFP).

**SUMMARY:** The Federal Transit Administration (FTA) is soliciting proposals under the Moving Ahead for Progress in the 21st Century Act's Section 5314 Technical Assistance and Standards Development Program from national non-profit organizations for a cooperative agreement to fund a National Aging and Disability Transportation Center (NADTC). FTA is releasing this notice of funding availability to promote the availability and accessibility of transportation options that serve the needs of people with disabilities, seniors and caregivers with a focus on effectively leveraging MAP–21 Section 5310 (5310) Enhanced Mobility of Seniors and Individuals with Disabilities Formula Grants and other transit investments. The NADTC builds upon twenty-five years of investment in accessible transportation training and technical assistance that improves mobility for seniors and individuals with disabilities throughout the country by removing barriers to transportation services and expanding community transportation mobility options.

**DATES:** Complete proposals must be submitted electronically by 11:59 p.m., Eastern Time on March 31, 2015. All proposals must be submitted electronically through the ''GRANTS.GOV'' APPLY function. Interested organizations that have not already done so should initiate the process of registering on the GRANTS.GOV site immediately to ensure completion of registration before the deadline for submission.

**ADDRESSES:** Proposals must be submitted electronically to *http://www.Grants.Gov.*

**FOR FURTHER INFORMATION CONTACT:** For general program information, as well as proposal-specific questions, please send an email to *Hendrik.opstelten@dot.gov* or call Rik Opstelten at (202)–366–8094. A TDD is available at 1–800–877–8339 (TDD/FIRS).

**SUPPLEMENTARY INFORMATION:**

### I. Overview

The Federal Transit Administration (FTA) is soliciting proposals to create a technical assistance center called the National Aging and Disability Transportation Center (NADTC). The need for accessible transportation that supports independent community living is growing in the United States. The U.S. Census Bureau American Community Survey in 2012 estimates that over 12 percent of the U.S. population (38 million) living in the community has a disability—up 2 percent from 2009. As people age, some will acquire a disability. For the fastest growing population in the U.S., older

**Aviation Rulemaking Advisory Committee (ARAC)**
**Transport Airplane and Engine (TAE) Subcommittee**

## Meeting Minutes

**Date:** February 24, 2015
**Time:** 10:30 a.m. (EST)
**Location:** N/A

### Call to Order /Administrative Reporting

Mr. John Piccola opened the meeting at 10:35 a.m.

| Item | November 2014 Meeting Action Items | Status |
|---|---|---|
| 1 | N/a | |
| 2 | | |

Following the reading of the Opening Statement, Mr. Craig Bolt shared the agenda (Handout 1).

### Engine Harmonization Working Group – Bird Ingestion Report Vote (see Handout 2)

Mr. Chris Demers and Mr. Les McVey presented this report.

The report received unanimous support from all working group members.

Mr. Keith Barnett stated he appreciated the executive summary very much.

Mr. Bolt had a question regarding Appendix B—that the report referenced other reports, but contains no information on where to find those report. He suggested that the working group insert a link to these referenced reports. Mr. Demers agreed.

There are no further questions for the report.

Mr. Bolt called for a vote to move this report to ARAC for review. All members of TAE votes to move this report to ARAC for review.

This report is accepted.

Mr. Bolt thanks the EHWG for a thoroughly-written and timely report from the working group.

### Avionics System Harmonization Working Group – Phase 2 Low Speed Alerting Response to FAA Request For Information (see Handout 3)

Mr. Clark Badie presented this report.

The working group presented potential guidance materials and standards for low speed alerting in early 2014. The last quarter of 2014, the FAA used the working group's submission to develop a report with two low-speed alerting design mitigation options, then requested feedback from the working group.

The feedback comments were mainly on the technical challenges the manufacturers may face in implementing a feasible solution, the associated costs, and also proposed a third design mitigation.

Mr. Doug Khim asks what is the next step for this project? Mr. Badie states that all final edits will be incorporated to the report. Mr. Bolt states that, after that, if TAE is OK with the report, it would move to ARAC for approval, and with ARAC approval, it would be submitted to the FAA.

Mr. Bolt called for a vote to move this report to ARAC for review.

All members of TAE votes to move this report to ARAC for review.

**Proposed Tasking on Transport Airplane Crashworthiness and Ditching Evaluation**

Mr. Ian Won presents this presentation.

This rulemaking intends to address new technology, while maintaining the current level of safety. This is not only to address use of composite materials in airplanes, but all new technology.

Mr. Khim presents Boeing's comments to the proposed tasking. (See Handout 4.) Boeing does not see a specific, high-priority need for this rulemaking. If the FAA intends to pursue this, Boeing supports this rulemaking, and wants to ensure that the new requirements are par with the level of safety already maintained by current certification procedures, and that we do not introduce additional requirements that would make the certification process more difficult without leading to significant safety increase. Boeing also believes 18-months tasking is not sufficient time, but a 24-months tasking would ensure a more thorough exploration of the topic, as well as work with EASA. Boeing suggests that rather than establish "new" safety level as the tasking current states, but more accurately to "maintain current level of safety. Also, what constitutes "unconventional design" would differ according to different manufacturers, and is therefore unclear.

Mr. Won states that while the FAA believes that is a good scope to maintain the current level of safety, the team did not write that detail because it does not want to limit ARAC to that scope. Further, while less so for larger airplanes like Boeing, smaller airplanes have a wide range of crashworthiness performance level that are well-document for the FAA. There are configuration differences that can affect airplane crashworthiness. While a blended-wing might be far-off in the future, these other configurations are not. The FAA does not intend to add requirements that would not help safety, but is looking to for requirements that cover large parts of the airplane and larger groups of people. Regarding the level of safety, the standard would maintain that level in consideration of the current and future design and construction methods.

Mr. Rolf Grenier states that Airbus does not currently see the need for, or safety benefit in this tasking.

Mr. Barnett asks a question regarding scope, that it would be difficult to complete this tasking even in 24-months, if it requires the consideration of all "conventional" or "unconventional" designs. What kind of designs would this apply to—if all current designs are "conventional", what is unconventional? Mr. Won states that the FAA will consider this and return with a more specific definition.

Mr. Piccola states that the safety benefit for the issues explored in this tasking will be determined during FAA rulemaking process later-on.

Mr. Won states that the FAA will change the length of tasking to 24 months.

Someone states taskings benefit from being more-specifically written. If it is defined too broadly, historically working groups have found it difficult to provide answers or come to agreements.

Mr. Grenier states that, if this tasking goes forward, it should be closely coordinated with EASA. Mr. Won agrees that the FAA will coordinate closely with EASA.

Mr. Khim states that this tasking looks like two taskings in one, and may require two subject-matter experts per organization to fully consider both crashworthiness and ditching issues. Mr. Won states that the two subject matters were kept together in one tasking because of the people working on it, timing for publication, and convenience. Mr. Grenier states that splitting the tasking and assign it to two working groups may be more streamlined and effective.

Mr. Piccola states that the FAA will consider the comments received today, re-send the tasking to TAE for consideration, then move it onwards to ARAC consideration at its March 2015 meeting.

**<u>New Tasking: Materials Flammability</u>**

Mr. Bolt states that Material Flammability working group will have a new tasking.

**<u>New Tasking: Transport Airplane Metallic and Composite Structures</u>**

Mr. Bolt states this tasking requires TAE to form a new working group. Interested organizations must submit their application by Feb 25, 2015.

**<u>Action Item Review/ Any Other Business</u>**

Mr. Barnett states that, at one point, TAE had a list of which working group were working on which tasking, and is this still being tracked. Mr. Bolt states that this is not currently tracked, but he will draw up a list.

| **Item** | **February 24, 2015 Meeting Action Items** | **Status** |
|---|---|---|
| 1. | | |

**<u>Future Transport Airplane and Engine Subcommittee Meetings</u>:**
The next subcommittee meeting will be held on June 3, 2015 at the Boeing Building in Arlington, VA.

**<u>Public Notification</u>**
The *Federal Register* published a notice of this meeting on February 6, 2015.

**<u>Approval</u>**
I certify the minutes are accurate.

Craig R. Bolt
Assistant Chair, ARAC

## MEETING ATTENDEES

| NAME | ORGANIZATION |
|---|---|
| John Piccola | FAA |
| Craig Bolt | |
| James Wilborn | FAA |
| Mary Schooley | FAA |
| John Gross | |
| Doug Khim | Boeing |
| Terry Trip | |
| Steve Chism | |
| Guizman | |
| Jill DiMarco | |
| Walter Dirogio | GAMA |
| Ralen Gao | FAA |
| Rolf Grenier | Airbus |
| Tom Peters | Embraer |
| Michel Provencher | TCCA |
| Dorina | FAA |
| Alan Strom | FAA |
| | |

**Transport Airplane and Engine ARAC Sub-Committee Meeting**

**Telcon meeting**

**February 24, 2015**
**All Times are Eastern Standard Time**

**Tuesday, Feb 24, 2015** – ***Call in number:***

| | |
|---|---|
| Dial In Access: (USA Only) | **888-924-3230** |
| Dial In Access: (Direct Dial) | **609-916-1975** |
| Dial In Access (Alternate USA Only) | **888-335-6670** |
| Dial In Access (Alternative Direct Dial) | **405-225-2375** |

Participant Passcode: **424932**

| | | |
|---|---|---|
| 10:30 | Call to Order, Reading of the Procedures Statement, Review of Agenda, | C. Bolt/ J. Piccola |
| 10:35 | Engine Harmonization WG – Bird Ingestion Report Vote | Chris Demers/Les McVey |
| 11:00 | Avionics System Harmonization Working Group – Phase 2 Low Speed Alerting Response to FAA request for information | C. Badie |
| 11:30 | Proposed tasking on Transport Airplane Crashworthiness and Ditching Evaluation | All |
| 12:00 | Any Other Business | |
| | New TAE Taskings: | |
| | Materials Flammability | |
| | Transport Airplane Metallic and Composite Structures | |

***-- ADJOURN --***

# Turbofan Bird Ingestion Regulation
# Engine Harmonization Working Group Report

**February 19, 2015**

## Executive Summary

The National Transportation Safety Board published several safety recommendations following their investigation into the US Airways A320 Flight 1549 forced landing into the Hudson River on January 15, 2009[1]. The ingestion of Canada geese into the core of both engines during climb caused significant thrust loss. Because the birds were ingested into the core during a phase of flight which is not represented in the current certification standard, the NTSB concluded that the current bird tests required by the Code of Federal Regulations (CFR) would provide a more realistic test if the lowest expected fan speed for minimum climb rate were used instead of the current fan speed for 100% rated take-off thrust, allowing more bird material to enter the core. This NTSB conclusion resulted in their recommendation to modify 14 CFR § 33.76(c) 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 ingestion demonstration.

In addition, the bird weight which was ingested into US Airways 1549 exceeded the bird weight specified for the engine inlet area range for this aircraft type in the current standard for flocking bird demonstrations. The NTSB recommended[1] that the FAA also reevaluate the 14 CFR § 33.76(d) large flocking bird ingestion certification test standards, including core ingestion, to determine if they should apply to the engine size class powering single aisle medium range aircraft such as the A320 and B737 models.

The FAA responded to the NTSB safety recommendations by establishing an Aviation Rulemaking Advisory Committee task to address them[2]. The Transport Airplane and Engine committee accepted the tasking and agreed to provide recommendations to the ARAC regarding the bird ingestion certification test standards. The TAE formed an Engine Harmonization Working Group to address the task and provide recommendations to the TAE. The EHWG has completed the review and recommends to the TAE and FAA that the core ingestion standard be made more rigorous by adopting an additional core ingestion certification demonstration for turbofan engines.

The recommendation is to demonstrate, by analysis, test, or both, a medium flocking bird core ingestion at the conditions of 250 KIAS bird speed, with the first exposed stage rotor speed set to represent the lowest expected climb thrust at standard day condition and 3,000ft altitude, and the bird targeted to maximize the bird material entering the core. After ingestion, the engine must successfully perform the 20-minute run-on demonstration from the large flocking bird requirements to show capability for a safe air turn back and landing at the airport. Furthermore, for engines which are shown not to ingest any bird material into the core at the climb condition, it must be shown that a medium flocking bird ingested during an approach phase at 200 KIAS and engine flight idle rotor speeds will be capable of performing the last 6-minutes of the large flocking bird run-on to demonstrate capability for maintaining glide slope during final approach and a safe landing.

The EHWG recommends no changes to the current Large Flocking Bird regulation. The LFB test as currently defined would not have changed the outcome of the US Airways 1549 event if extended to smaller engines, and the recommended MFB core ingestion test is expected to provide sufficient rigor to cover the ingestion of a larger bird at the LFB test conditions.

The FAA also recommended that the industry establish a process for regularly updating the bird ingestion database and performing statistical analyses to maintain an ongoing awareness of bird ingestion threat trends. The EHWG proposes to perform regular updates to the bird ingestion database under the auspices of the AIA.

TABLE OF CONTENTS

Nomenclature

| | |
|---|---|
| AIA | Aerospace Industries Association – Association representing the United States' major aerospace and defense manufacturers and provides a forum for government and industry representatives to exchange views and resolve problems on non-competitive matters related to the aerospace industry. |
| Airplane Event | A bird event which has one or more engine ingestions; a bird strike to the airplane without engine ingestion is not included |
| ARAC | Aviation Rulemaking Advisory Committee |
| Bird weight class | Based on species average weights – see Table 2.1.1 |
| Bypass ingestion | Bird material ingested into the fan outer span or is deflected into the bypass stream by fan blades and does not enter the primary flowpath. |
| CARS | Civil Aviation Regulatory and Safety Committee under AIA |
| Climb Phase | The climb phase is considered to begin from the end of take-off (from application of take-off power to 35' above the runway elevation) through the initial climb phase (first prescribed power reduction) to the first initial assigned cruise altitude. |
| Core Ingestion | Bird material enters the primary flowpath of the engine. Core ingestion occurrence is based on a finding of any trace of bird material (i.e. single feather, blood smear) on core entrance hardware or within the core itself, or cabin odor in flight |
| EHWG | Engine Harmonization Working Group |
| Engine size class | Based on inlet throat area, see Table 2.1 |
| Generic Bird | Ingestions with bird weight estimated based on engine effects (damage etc.) |
| Ingestion Rate | Airplane events (ingestions to one or more engines) per airplane cycle (departure) |
| Inlet Hilite | The ring formed by the forward-most points on the inlet lip. |
| LFB | Large Flocking Bird - Birds which weigh over 2.5 lbs. and tend to travel in large organized flocks (generally represented by waterfowl such as Geese, and Cormorants). |
| MEI | Multi-engine ingestion |
| MEPL | Multi-engine power loss |
| MFB | Medium Flocking Bird - Birds which weigh over 1 lb. to 2.5 lbs. and tend to travel in large organized flocks (typically gull species, and smaller waterfowl such as ducks). |
| Phase I | The initial ARAC rulemaking committee which developed the 14 CFR § 33.76 Amdt. 33-20 requirements using data gathered through 1995. |
| Phase II | The ARAC rulemaking committee which developed the 14 CFR § 33.76 Amdt. 33-23/24 (LFB) requirements using data gathered through 1999. |
| Phase III | The current CARS committee which reviewed the turbofan engine fleet experience with respect to 14 CFR § 33.76 Amdt. 33-23/24 LFB requirements and NTSB recommendations A-10-64 and A-10-65 using data gathered through January 2009. |
| Power Loss | Engine considered incapable of continued operation at ≥50% rated take-off thrust. |
| Real Bird | Ingestions with bird remains reliably identified to species |
| SEI | Single Engine Ingestion |
| Snarge | Bird matter – remains of birds, often only stains, which are found after bird strikes. This can be used to obtain species identification either through DNA analysis, or from embedded microscopic feather material. |
| Span Height | The radial distance from the base of the fan blade leading edge above the flowpath surface where it is exposed to the airstream out to the tip. |
| V2 | The airspeed at which the aircraft may safely become airborne with one engine inoperative |

# 1. INTRODUCTION

## 1.1. Purpose

To evaluate whether the requirements for small and medium bird core ingestion and the large flocking bird requirements for engines should be revised, and to define an industry led process for periodic update and review of engine bird ingestion data.

## 1.2. Background

In 2007 the FAA revised 14 CFR § 33.76 to include new requirements addressing the large flocking bird threat (bird mass greater than 2.5 lbs.) observed in service. Appendix E provides a brief history of the FAA bird ingestion regulations development. The FAA did this because the large flocking bird population (primarily Canada and Snow geese) had increased significantly in the previous 20 years, increasing the threat to aircraft. Therefore, changes were required to provide an adequate level of safety against this threat. US Airways 1549 ingested Canada geese (species average 8 lbs.) into each engine, which resulted in virtually complete loss of thrust in both engines.

In response to the accident investigation and related NTSB Recommendations, the FAA, EASA and the 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 of Jan. 2000 thru Jan. 2009, which includes over 11,000 bird ingestion records covering over 250 million flights. The report concluded that although multi-engine ingestion rates were higher than predicted, the engine power 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 FAA reviewed the 2009 study results and decided to assign ARAC a new task to address the specific tasks listed in Section 1.3.

## 1.3. Tasking

Review and assess the standards and advisory material for bird ingestion requirements as follows:

1. Evaluate the core ingestion element of small and medium bird requirements to determine if the intended safety objective of the current rule is adequate. Consider the threat from large flocking bird species in this assessment. Identify any deficiencies in the current rule, and provide the FAA with recommendations for changes as appropriate.
2. Evaluate large flocking bird requirements, to determine the need for new large flocking bird requirements, or advisory material, or both, for Class D engines (1.35–2.5$m^2$ inlet areas). Identify any deficiencies of the current rule, and provide the FAA with recommendations for changes as appropriate.
3. Review and consider the following National Transportation Safety Board (NTSB) safety recommendations when evaluating items 1 and 2 above.
   a. "A–10–64: Modify the 14 Code of Federal Regulations § 33.76(c) small and medium flocking bird certification test standard to require that the test be conducted using the lowest expected fan speed, instead of 100-percent fan speed, for the minimum climb rate."
   b. "A–10–65: During the bird ingestion rulemaking database (BRDB) working group's reevaluation of the current engine bird-ingestion certification regulations, specifically reevaluate the 14 Code of Federal Regulations § 33.76(d) 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

(2) Include a requirement for engine core ingestion."

If the BRDB[1] working group's reevaluation determines that such requirements are needed, incorporate them into 14 CFR § 33.76(d) and require that newly certificated engines be designed and tested to these requirements."

4. Define an industry led process for periodic update and review of engine bird ingestion data, such that industry and the authorities can maintain an awareness of the bird threat experienced in service.

Tasks 1 through 4 above should consider the Aerospace Industries Association engine bird ingestion database recently updated in coordination with FAA and the European Aviation Safety Agency. That database update was in response to the US Airways Flight 1549 Hudson River accident in January 2009 and related NTSB safety recommendations. The final ARAC report should include a summary of the overall work scope, conclusions and rationale for all recommendations related to the above tasks.

Required completion date of the above tasks is no later than March 31, 2015.

## 2. AIA WORKING GROUP PHASE III DATABASE

### 2.1. Input Data

The data provided by the engine companies included information on each bird ingestion event contained in their own databases. The data required for various analyses were event date, engine model, airplane model, engine position, number of engines involved, power level available (after the event), bird species (if available), and the total hours and cycles for each engine model. These data are managed by Boeing on behalf of the AIA and were employed in this study. These data are not included in this report.

The engine companies included information on whether there was evidence of core ingestion and the certification basis for the particular engine model. The data were sanitized to allow analysis of the combined data set by all of the engine companies without sharing proprietary information. The main data that needed to be sanitized were the engine and airplane models. The engine model was broken down into size classes (both by fan diameter and inlet area) and certification standard. For future work, data will be categorized by inlet area only as the regulations are based on inlet area.
The engine size classes based on inlet area are shown in Table 2.1.

**Table 2.1 Engine Size Classes Based on Inlet Throat Area and Quantity in Data Set**

| Engine Class | Inlet Throat Area, A ($in^2$) | Inlet Throat Area, A ($m^2$) | Percent of flights in Dataset | Percent of events in Dataset |
|---|---|---|---|---|
| A | $6045 < A$ | $3.90 < A$ | 2% | 6% |
| B | $5425 < A \leq 6045$ | $3.50 < A \leq 3.90$ | 5% | 10% |
| C | $3875 < A \leq 5425$ | $2.50 < A \leq 3.50$ | 3% | 5% |
| D | $2093 < A \leq 3875$ | $1.35 < A \leq 2.50$ | 41% | 62% |
| E | $620 < A \leq 2093$ | $0.40 < A \leq 1.35$ | 36% | 11% |
| F | $A \leq 620$ | $A \leq 0.40$ | 12% | 5% |
| Unknown | | | | 1% |

[1] This is the NTSB reference to the 2009 study noted in the section 1.2.

### 2.1.1 Data Quality

The databases provided by the engine companies 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/CAA database and including any events that were previously not included in the manufacturer's data.

The data collected are considered mostly complete for events that involved damage to the engines, as these are typically reported to the engine companies. Events with no damage are considered under-reported as many of them would either not be reported or may not have been noticed. Also, events with no damage that are reported typically do not have all of the information available compared to events with damage.

The bird weights listed were typically determined by using three sources. Currently, the main source considered is from CRC/Dunning (2007)[3]. Also used are Dunning (1992)[4] and Brough (1983)[5]. The bird weights listed mainly use the average adult weight for the species. If a bird event had a species noted but did not list a weight, Dunning (2007)[3] was the source used.

Many events did not have a bird species identified. This typically happens because remains were not collected (or not available). To enhance the data, the engine manufacturers attempted to identify a bird weight based on the damage to the engine (if available). The bird sizes were listed as generic large (>3 lbs.), medium (0.5 – 3 lbs.) or small (<8 oz.) so that this data could be included for purposes of analysis and the weights allocated to classes. These generic classifications were unique to Phase III.

Table 2.2.1. shows bird weight class definitions and quantities of each in the data set. Bird classes i through iv designate small and medium birds while bird classes I through IV represent large birds. Although including generic birds provides a more complete dataset, it can distort the data, since the 'small' were included in class i, 'medium' in class iv and 'large' in class II. This results in those classes (i, iv and II) becoming a larger proportion of the dataset than adjacent classes as shown in Table 2.1.1, and since power loss rates in generic bird events were lower than for real birds it would affect comparisons. Power loss rates with generic birds are believed to be lower because a more detailed investigation often occurs with higher damage levels or flight effects, thus if engine damage was easily and quickly repaired often there is no opportunity to retrieve remains.

Any future statistical work should proportion generic classifications across all of the groups in the same ratio as real ingestions to avoid this distortion effect.

**Table 2.1.1 Bird Weight Class Definitions and Quantity in Data Set**

| Bird Class | Bird Weight, w (lbs) | Bird Weight, w (kg) | Percent of Dataset | Common Examples |
|---|---|---|---|---|
| i | $0 < w \le 0.5$ | $0 < w \le 0.23$ | 36% | Starling |
| ii | $0.5 < w \le 1.0$ | $0.23 < w \le 0.45$ | 3% | Rock Dove |
| iii | $1.0 < w \le 1.5$ | $0.45< w \le 0.68$ | 3% | Ring-billed gull |
| iv | $1,5 < w \le 2.5$ | $0.68 < w \le 1.13$ | 21% | Herring Gull |
| I | $2.5 < w \le 4.0$ | $1.13 < w \le 1.81$ | 1% | Glaucous-winged Gull |
| II | $4.0 < w \le 6.0$ | $1.81 < w \le 2.72$ | 4% | Lesser Snow Goose |
| III | $6.0 < w \le 8.0$ | $2.72 < w \le 3.63$ | 1% | Greater Snow Goose |
| IV | $8.0 < w$ | $3.63 < w$ | 0.3% | Canada Goose |
| | Unknown | | 31% | |

## 2.2. Database Analyses

### 2.2.1. Impact of Flight Phase on Engine Power Loss Due to Bird Ingestion

The AIA Working Group Phase III Database (1/1/2000 – 1/31/2009) was used to determine if 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 had engine power loss (turbofans only) were analyzed within flight phases for engine size and bird weight class.

#### 2.2.1.1. Core Ingestion

Table 2.2.1.1.a. and 2.2.1.1.b. show the results from the database for bird ingestion events, regardless of bird weight class, for the various engine size classes and flight phases. As the table shows, 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 power loss. The focus of this particular analysis was on these 39 engine power 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 power loss were climb and approach. Given a core ingestion, the data showed a 1.03% probability of engine power loss during the climb phase, and a 0.73% probability during the approach phase. Relative to the take-off phase (current medium flocking bird test procedure), the climb and approach phases are 5.7 and 4.0 times greater in percentage of occurrence, respectively.

**Table 2.2.1.1.a Core Ingestion Data within Engine Size Class and Flight Phase**

| Flight Phase | No. of Turbofan Engine Bird Ingestion Events in Data Set | % of Turbofan Engine Data Set | No. of Core Ingestions | % of Total Core Ingestion Events | Core Ingestions Resulting in Power <50% | % of Total Core Ingestions Resulting in Power <50% |
|---|---|---|---|---|---|---|
| Ground | 295 | 3 | 5 | 0.30 | 0 | 0.00 |
| Takeoff | 1,686 | 15 | 320 | 19.35 | 3 | 7.69 |
| Climb | 1,279 | 11 | 219 | 13.24 | 17 | 43.59 |
| Cruise | 58 | 1 | 8 | 0.48 | 1 | 2.56 |
| Descent | 70 | 1 | 11 | 0.67 | 0 | 0.00 |
| Approach | 1,760 | 16 | 290 | 17.53 | 12 | 30.77 |
| Landing | 1,003 | 9 | 143 | 8.65 | 3 | 7.69 |
| Unknown | 5,073 | 45 | 658 | 39.78 | 3 | 7.69 |
| | 11,224 | 100 | 1654 | 100 | 39 | 100 |

**Table 2.2.1.1.b Core Ingestion Data within Engine Size Class and Flight Phase**

| Flight Phase | Core Ingestions Resulting in Power Loss for Engine Class A | Core Ingestions Resulting in Power Loss for Engine Class B | Core Ingestions Resulting in Power Loss for Engine Class C | Core Ingestions Resulting in Power Loss for Engine Class D | Core Ingestions Resulting in Power Loss for Engine Class E | Core Ingestions Resulting in Power Loss for Engine Class F | Core Ingestions Resulting in Power Loss for Engine Class Unknown | % in Flight Phase | % of Occurrence Given a Core Ingestion Event | Ratio Relative to Takeoff |
|---|---|---|---|---|---|---|---|---|---|---|
| Ground | | | | | | | | **0.00** | **0.00** | **0.00** |
| Takeoff | | | **1** | **2** | | | | **0.94** | **0.18** | **1.00** |
| Climb | | **1** | **2** | **8** | **3** | **3** | | **7.76** | **1.03** | **5.67** |
| Cruise | | **1** | | | | | | **12.50** | **0.06** | **0.33** |
| Descent | | | | | | | | **0.00** | **0.00** | **0.00** |
| Approach | | **1** | | **8** | **1** | **2** | | **4.14** | **0.73** | **4.00** |
| Landing | | | | **2** | **1** | | | **2.10** | **0.18** | **1.00** |
| Unknown | | | **1** | | **1** | **1** | | **0.46** | **0.18** | **1.00** |
| | **0** | **3** | **4** | **20** | **6** | **6** | **0** | | **2.36** | |

2.2.1.2. Bypass Ingestion

The same analysis was completed for the bird ingestions that were considered to enter only the bypass and resulted in engine power loss. Table 2.2.1.2.a. and 2.2.1.2.b show these results. Of the 11,224 total bird ingestion events recorded, only 2,503 were identified as bypass-only ingestions (the majority of ingestions fell under the “Unknown” classification and is the reason why the sum of the core and bypass ingestions does not equal the total number of bird ingestion events.), of these bypass-only events 24 resulted in an engine power loss. The two flight phases which had the largest percentage of bypass ingestions resulting in engine power loss were climb and take-off. The data showed a 0.36% probability of engine power 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.

**Table 2.2.1.2.a. Bypass Ingestion Data within Engine Size Class and Flight Phase**

| Flight Phase | No. of Turbofan Engine Bird Ingestion Events in Data Set | No. Of Bypass Ingestions | % of Total Bypass Ingestion Events | Bypass Ingestions Resulting in Power <50% | % of Total Bypass Ingestions Resulting in Power <50% |
|---|---|---|---|---|---|
| Ground | 295 | 20 | 0.80 | 0 | 0.00 |
| Takeoff | 1,686 | 317 | 12.66 | 5 | 20.83 |
| Climb | 1,279 | 424 | 16.94 | 9 | 37.50 |
| Cruise | 58 | 12 | 0.48 | 0 | 0.00 |
| Descent | 70 | 18 | 0.72 | 1 | 4.17 |
| Approach | 1,760 | 617 | 24.65 | 2 | 8.33 |
| Landing | 1,003 | 225 | 8.99 | 0 | 0.00 |
| Unknown | 5,073 | 870 | 34.76 | 7 | 29.17 |
| | 11,224 | 2503 | 100 | 24 | 100 |

**Table 2.2.1.2.b. Bypass Ingestion Data within Engine Size Class and Flight Phase**

| Flight Phase | Bypass Ingestions Resulting in Power Loss for Engine Class A | Bypass Ingestions Resulting in Power Loss for Engine Class B | Bypass Ingestions Resulting in Power Loss for Engine Class C | Bypass Ingestions Resulting in Power Loss for Engine Class D | Bypass Ingestions Resulting in Power Loss for Engine Class E | Bypass Ingestions Resulting in Power Loss for Engine Class F | Bypass Ingestions Resulting in Power Loss for Engine Class Unknown | % in Flight Phase | % of Occurrence Given a Core Ingestion Event | Ratio Relative to Takeoff |
|---|---|---|---|---|---|---|---|---|---|---|
| Ground | | | | | | | | 0.00 | 0.00 | 0.00 |
| Takeoff | | | | 4 | 1 | | | 1.58 | 0.20 | 1.00 |
| Climb | 1 | | 2 | | 3 | 3 | | 2.12 | 0.36 | 1.80 |
| Cruise | | | | | | | | 0.00 | 0.00 | 0.00 |
| Descent | | | | | | 1 | | 5.56 | 0.04 | 0.20 |
| Approach | | | | | 2 | | | 0.32 | 0.08 | 0.40 |
| Landing | | | | | | | | 0.00 | 0.00 | 0.00 |
| Unknown | 1 | | | | 1 | 5 | | 0.80 | 0.28 | 1.40 |
| | 2 | 0 | 2 | 4 | 7 | 9 | 0 | | 0.96 | |

2.2.2. Impact of Flight Phase and Engine Size on Engine Power Loss Due to Bird Ingestion

The next analysis was to understand if there could be a flight phase difference with engine size. Again, this was reviewed for the core ingestions as well as the bypass ingestions. Table 2.2.2.1.a. and 2.2.2.1.b. shows the results of the core ingestions that result in engine power loss for each engine size class and flight phase. The difference between Table 2.2.1.1.a and b. and 2.2.2.1.a. and b. is that the percent of core ingestions which result in engine power loss for each engine size class is now included. This calculation is based on the number of core ingestion events that result in power loss for each engine size class (shown in Table 2.2.1.1.a. and b.) and the total number of core engine events for each engine size class and flight phase shown in Table 2.2.2.1.a. The graphical representation of these results is shown in Figure 2.2.2.1 with the caveat that the 100%

point for cruise on class B engines was not shown. The data shows that all engine size classes, with the exception of class A which had no core ingestions that resulted in power loss, had the highest percentage 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.

**Table 2.2.2.1.a Core Ingestion Power Loss for Engine Size Class and Flight Phase**

| Flight Phase | No. of Core Ingestions | Core Ingestions in Engine Class A | Core Ingestions in Engine Class B | Core Ingestions in Engine Class C | Core Ingestions in Engine Class D | Core Ingestions in Engine Class E | Core Ingestions in Engine Class F | Core Ingestions in Engine Class Unknown |
|---|---|---|---|---|---|---|---|---|
| Ground | 5 | | 1 | 1 | 3 | | | |
| Takeoff | 320 | 6 | 19 | 17 | 254 | 12 | 12 | |
| Climb | 219 | 5 | 13 | 7 | 167 | 17 | 10 | |
| Cruise | 8 | 1 | 1 | 2 | 3 | 1 | | |
| Descent | 11 | 1 | | 1 | 6 | 2 | 1 | |
| Approach | 290 | 11 | 27 | 9 | 210 | 25 | 8 | |
| Landing | 143 | 6 | 7 | 2 | 114 | 14 | | |
| Unknown | 658 | 43 | 66 | 36 | 443 | 55 | 15 | |
| | 1654 | 73 | 134 | 75 | 1200 | 126 | 46 | 0 |

**Table 2.2.2.1.b Core Ingestion Power Loss for Engine Size Class and Flight Phase**

| Flight Phase | % of Core Power Loss Events to Core Ingestion in Engine Class A | % of Core Power Loss Events to Core Ingestion in Engine Class B | % of Core Power Loss Events to Core Ingestion in Engine Class C | % of Core Power Loss Events to Core Ingestion in Engine Class D | % of Core Power Loss Events to Core Ingestion in Engine Class E | % of Core Power Loss Events to Core Ingestion in Engine Class F | % of Core Power Loss Events to Core Ingestion in Engine Class Unknown |
|---|---|---|---|---|---|---|---|
| Ground | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| Takeoff | 0.00 | 0.00 | 5.88 | 0.79 | 0.00 | 0.00 | 0.00 |
| Climb | 0.00 | 7.69 | 28.57 | 4.79 | 17.65 | 30.00 | 0.00 |
| Cruise | 0.00 | 100.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| Descent | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| Approach | 0.00 | 3.70 | 0.00 | 3.81 | 4.00 | 25.00 | 0.00 |
| Landing | 0.00 | 0.00 | 0.00 | 1.75 | 7.14 | 0.00 | 0.00 |
| Unknown | 0.00 | 0.00 | 2.78 | 0.00 | 1.82 | 6.67 | 0.00 |
| | | | | | | | |

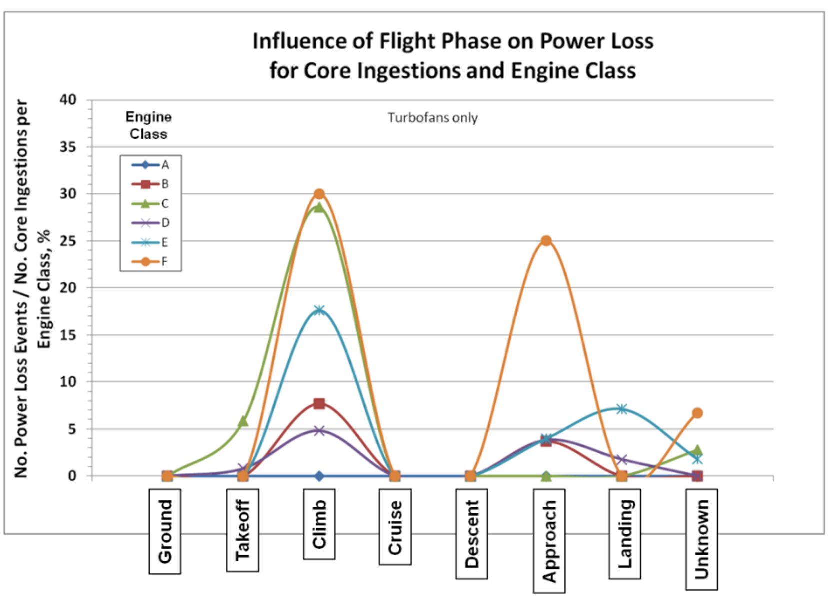


**Figure 2.2.2.1 Core Ingestion Resulting in Power Loss vs. Flight Phase**

Tables 2.2.2.2.a and 2.2.2.2.b show the results of the bypass ingestions that result in engine power loss for each engine class and flight phase. Again, the difference between Tables 2.2.1.2 and 2.2.2.2 are that the percent of bypass ingestions which result in power loss for each engine size class is now included. This calculation is based on the number of bypass ingestion events that result in power loss for each engine size class (shown in Table 2.2.1.2) and the total number of bypass engine events for each engine size class and phase class shown in the center section of Table 2.2.2.2.a. The graphical representation of these results is shown in Figure 2.2.2.2. The data shows that all engine size classes with the exception of class B which had no bypass ingestions that resulted in power loss, had the highest percentages of power loss during take-off or climb phases. Only the smaller engine size classes, E and F, showed engine power loss for the approach and descent phases, respectively.

**Table 2.2.2.2.a. Bypass Ingestion Power Loss for Engine Size Class and Flight Phase**

| Flight Phase | No. of Bypass Ingestions | Bypass Ingestions in Engine Class A | Bypass Ingestions in Engine Class B | Bypass Ingestions in Engine Class C | Bypass Ingestions in Engine Class D | Bypass Ingestions in Engine Class E | Bypass Ingestions in Engine Class F | Bypass Ingestions in Engine Class Unknown |
|---|---|---|---|---|---|---|---|---|
| Ground | 20 | 1 | 3 | | 13 | 1 | 2 | |
| Takeoff | 317 | 2 | 24 | 9 | 239 | 36 | 7 | |
| Climb | 424 | 21 | 80 | 36 | 146 | 107 | 34 | |
| Cruise | 12 | | 8 | 1 | 1 | 1 | 1 | |
| Descent | 18 | | | | 1 | 14 | 3 | |
| Approach | 617 | 18 | 121 | 30 | 339 | 76 | 33 | |
| Landing | 225 | | 14 | 5 | 178 | 18 | 10 | |
| Unknown | 870 | 58 | 152 | 55 | 346 | 115 | 144 | |
| | 2503 | 100 | 402 | 136 | 1263 | 368 | 234 | 0 |

**Table 2.2.2.2.b. Bypass Ingestion Power Loss for Engine Size Class and Flight Phase**

| Flight Phase | % of Bypass Power Loss Events to Bypass Ingestions in Engine Class A | % of Bypass Power Loss Events to Bypass Ingestions in Engine Class B | % of Bypass Power Loss Events to Bypass Ingestions in Engine Class C | % of Bypass Power Loss Events to Bypass Ingestions in Engine Class D | % of Bypass Power Loss Events to Bypass Ingestions in Engine Class E | % of Bypass Power Loss Events to Bypass Ingestions in Engine Class F | % of Bypass Power Loss Events to Bypass Ingestions in Engine Class Unknown |
|---|---|---|---|---|---|---|---|
| Ground | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| Takeoff | 0.00 | 0.00 | 0.00 | 1.67 | 2.78 | 0.00 | 0.00 |
| Climb | 4.76 | 0.00 | 5.56 | 0.00 | 2.80 | 8.82 | 0.00 |
| Cruise | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| Descent | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 33.33 | 0.00 |
| Approach | 0.00 | 0.00 | 0.00 | 0.00 | 2.63 | 0.00 | 0.00 |
| Landing | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| Unknown | 1.72 | 0.00 | 0.00 | 0.00 | 0.87 | 3.47 | 0.00 |
| | | | | | | | |

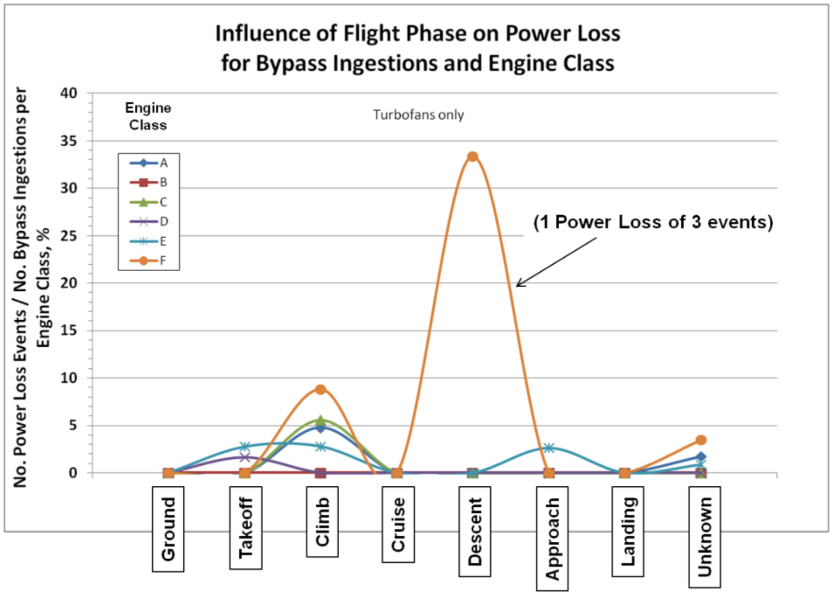


**Figure 2.2.2.2 Bypass Ingestion Resulting in Power Loss vs. Flight Phase**

2.2.3.Impact of Bird Weight on Engine Power Loss Due to Bird Ingestion

After determining the effect of the flight phase, the next analysis was to understand if there could be an effect on power loss due to bird weight. For accuracy, only the "real birds" were used from the data set and not the "generic birds" that were included when a bird species could not be positively identified. This was reviewed for the core ingestions as well as the bypass ingestions. Table 2.2.3.1 shows the results of the core ingestions that result in engine power loss for each engine size class and bird weight class. Table 2.2.3.2 shows the core engine ingestions that resulted in power loss. Table 2.2.3.2 shows that on a percentage basis and generally speaking, the weight (mass) of the bird increases the engine component damage and probability of power loss.

**Table 2.2.3.1 Core Ingestion Data for Engine Size Class and Bird Weight Class**
**Core Ingestion Data – Real Birds Only, Turbofan Engines Only**

| Bird Weight, w (lbs) | Bird Class | Total Number of Core Ingestions of Real Birds | Core Ingestions of Real Birds in Engine Class A | Core Ingestions of Real Birds in Engine Class B | Core Ingestions of Real Birds in Engine Class C | Core Ingestions of Real Birds in Engine Class D | Core Ingestions of Real Birds in Engine Class E | Core Ingestions of Real Birds in Engine Class F | Core Ingestions of Real Birds in Engine Class Unknown |
|---|---|---|---|---|---|---|---|---|---|
| 0 < w ≤ 0.5 | i | 105 | 2 | 8 | 4 | 78 | 7 | 6 | |
| 0.5 < w ≤ 1.0 | ii | 54 | 1 | 4 | 4 | 40 | 4 | 1 | |
| 1.0 < w ≤ 1.5 | iii | 61 | 1 | 5 | 2 | 48 | 2 | 3 | |
| 1.5 < w ≤ 2.5 | iv | 77 | 1 | 10 | 7 | 43 | 9 | 7 | |
| 2.5 < w ≤ 4.0 | I | 30 | 1 | 2 | | 24 | 3 | | |
| 4.0 < w ≤ 6.0 | II | 17 | 1 | | | 11 | 4 | 1 | |
| 6.0 < w ≤ 8.0 | III | 37 | | 1 | | 22 | 13 | 1 | |
| 8.0 < w | IV | 8 | | | 1 | 5 | 2 | | |
| | Unknown | 0 | | | | | | | |
| | Total | 389 | 7 | 30 | 18 | 271 | 44 | 19 | 0 |

**Table 2.2.3.2 Core Ingestion Data for Engine Size Class and Bird Weight Class**
**Core Ingestion Data Power Loss - Real Birds Only, Turbofan Engines Only**

| Bird Weight, w (lbs) | Bird Class | Core Ingestion of Real Birds Resulting in Power < 50% for Engine Class A | Core Ingestion of Real Birds Resulting in Power < 50% for Engine Class B | Core Ingestion of Real Birds Resulting in Power < 50% for Engine Class C | Core Ingestion of Real Birds Resulting in Power < 50% for Engine Class D | Core Ingestion of Real Birds Resultin g in Power < 50% for Engine Class E | Core Ingestion of Real Birds Resulting in Power < 50% for Engine Class F | Core Ingestion of Real Birds Resulting in Power < 50% for Engine Class Unknown | Total Number of Core Ingestions of Real Birds Resulting in Power <50% | % of Total Core Ingested Real Birds for Bird Class |
|---|---|---|---|---|---|---|---|---|---|---|
| $0 < w \le 0.5$ | i | | 1 | | 3 | | 2 | | 6 | 5.71 |
| $0.5 < w \le 1.0$ | ii | | 1 | | | | | | 1 | 1.85 |
| $1.0 < w \le 1.5$ | iii | | | | | 1 | | | 1 | 1.64 |
| $1.5 < w \le 2.5$ | iv | | | 2 | 3 | | 1 | | 6 | 7.79 |
| $2.5 < w \le 4.0$ | I | | | | 4 | | | | 4 | 13.33 |
| $4.0 < w \le 6.0$ | II | | | | 1 | 1 | 1 | | 3 | 17.65 |
| $6.0 < w \le 8.0$ | III | | | | 5 | 2 | 1 | | 8 | 21.62 |
| $8.0 < w$ | IV | | | | 4 | | | | 4 | 50.00 |
| | Unknown | | | | | | | | 0 | 0.00 |
| | Total | 0 | 2 | 2 | 20 | 4 | 5 | 0 | 33 | 8.48 |

In a similar manner, the bypass data is shown in Tables 2.2.3.3 and 2.2.3.4. Figure 2.2.3.1 overlays the core and bypass results based on the range of each weight class used for the abscissa. Bird weight classes i – iv were combined due to their relatively small deltas in individual weight range. The data indicate a large difference in power loss between core and bypass ingestions with increasing bird weights (classes III and IV). The data indicate that a core ingestion event is approximately 5% more likely to result in a power loss event than a bypass only event for the weight classes up to class II. For the heavier weight 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 power loss than a bypass ingestion and for class IV, a core ingestion is 30% more likely to result in a power loss than a bypass ingestion. However, because the data does not differentiate power loss due to core or bypass as the primary cause, some core power loss events are likely to be counted in the bypass category as well and therefore core power loss counts are believed to be overly represented in the data. This is further explained in Section 4.3.

**Table 2.2.3.3 Bypass Ingestion Data for Engine Size Class and Bird Weight Class**
**Bypass Ingestion Data - Real Birds Only, Turbofan Engines Only**

| Bird Weight, w (lbs) | Bird Class | Total Number of Bypass Ingestions of Real Birds | Bypass Ingestion of Real Birds in Engine Class A | Bypass Ingestion of Real Birds in Engine Class B | Bypass Ingestion of Real Birds in Engine Class C | Bypass Ingestion of Real Birds in Engine Class D | Bypass Ingestion of Real Birds in Engine Class E | Bypass Ingestion of Real Birds in Engine Class F | Bypass Ingestion of Real Birds in Engine Class Unknown |
|---|---|---|---|---|---|---|---|---|---|
| $0 < w \le 0.5$ | i | 305 | 4 | 56 | 7 | 152 | 57 | 29 | |
| $0.5 < w \le 1.0$ | ii | 108 | 5 | 19 | 9 | 64 | 11 | | |
| $1.0 < w \le 1.5$ | iii | 158 | | 18 | 3 | 122 | 15 | | |
| $1.5 < w \le 2.5$ | iv | 181 | 7 | 25 | 5 | 86 | 26 | 32 | |
| $2.5 < w \le 4.0$ | I | 31 | 3 | 6 | 5 | 14 | 3 | | |
| $4.0 < w \le 6.0$ | II | 40 | | 5 | 3 | 9 | 9 | 14 | |
| $6.0 < w \le 8.0$ | III | 36 | 1 | 4 | 7 | 17 | 7 | | |
| $8.0 < w$ | IV | 10 | | 2 | 1 | 3 | 4 | | |
| | Unknown | 0 | | | | | | | |
| | Total | 869 | 20 | 135 | 40 | 467 | 132 | 75 | 0 |

**Table 2.2.3.4 Bypass Ingestion Data for Engine Size Class and Bird Weight Class**
**Bypass Ingestion Data Power Loss - Real Birds Only, Turbofan Engines Only**

| Bird Weight, w (lbs) | Bird Class | Bypass Ingestion of Real Birds Resulting in Power < 50% for Engine Class A | Bypass Ingestion of Real Birds Resulting in Power < 50% for Engine Class B | Bypass Ingestion of Real Birds Resulting in Power < 50% for Engine Class C | Bypass Ingestion of Real Birds Resulting in Power < 50% for Engine Class D | Bypass Ingestion of Real Birds Resulting in Power < 50% for Engine Class E | Bypass Ingestion of Real Birds Resulting in Power < 50% for Engine Class F | Bypass Ingestion of Real Birds Resulting in Power < 50% for Engine Class Unknown | Total Number of Bypass Ingestions of Real Birds Resulting in Power <50% | % of Total Bypass Ingested Real Birds for Bird Class |
|---|---|---|---|---|---|---|---|---|---|---|
| 0 < w ≤ 0.5 | i | | | | | | 1 | | 1 | 0.33 |
| 0.5 < w ≤ 1.0 | ii | | | | | | | | 0 | 0.00 |
| 1.0 < w ≤ 1.5 | iii | | | | | | | | 0 | 0.00 |
| 1.5 < w ≤ 2.5 | iv | | | | | | 4 | | 4 | 2.21 |
| 2.5 < w ≤ 4.0 | I | 1 | | | 1 | 1 | | | 3 | 9.68 |
| 4.0 < w ≤ 6.0 | II | | | | | 3 | 3 | | 6 | 15.00 |
| 6.0 < w ≤ 8.0 | III | | | 1 | | | | | 1 | 2.78 |
| 8.0 < w | IV | | | | 1 | 1 | | | 2 | 20.00 |
| | Unknown | | | | | | | | 0 | 0.00 |
| | Total | 1 | 0 | 1 | 2 | 5 | 8 | 0 | 17 | 1.96 |

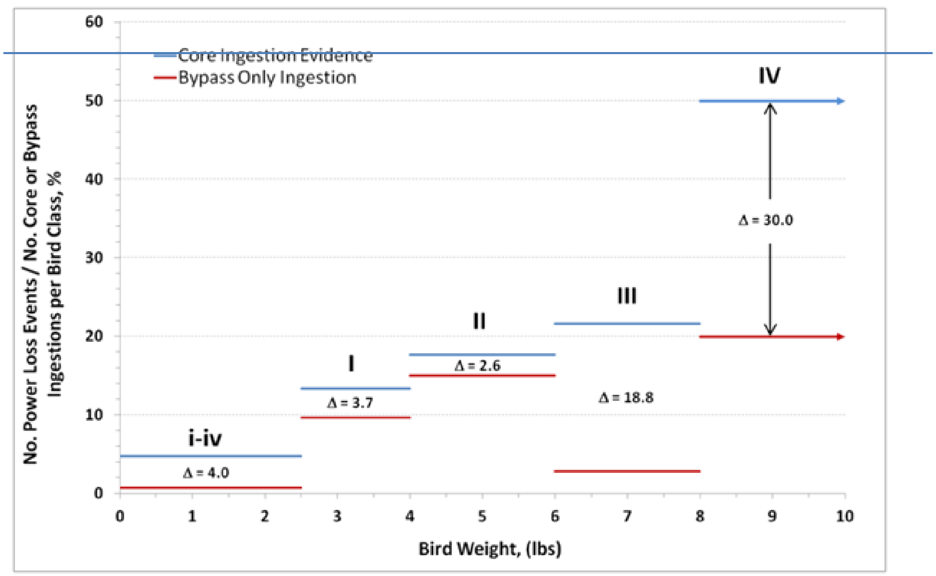


**Figure 2.2.3.1 Influence of Bird Weight Resulting in Power Loss**

### 2.2.4. Impact of Engine Power Setting on Power Loss Probability

An analysis was performed comparing higher power take-off (with climb) and lower power landing (with descent and approach) effect on power loss for turbofan core ingestion data. For the analyses in 2.2.4 and 2.2.5, the generic bird data were included and if the power loss was unknown that event was not included. Because of this, the total events included in the analyses are different than earlier sections. All engine size classes were combined to maximize the sample size and statistical inference. Future editions of the database may have enough events with more information allowing additional analyses by size. Bird weights from 1.0 to 4.0 lbs. were used in the comparison. Table 2.2.4.1 shows the results of the comparison. Along with the data, a chi-square test was run to determine the significance of the difference between the two phases. A p-value of 4.1% was calculated and at a significance level of less than 5% there is indication that there is a difference between the two phases and that power loss at higher power is more likely.

**Table 2.2.4.1 Engine Power Setting Analysis of Core Power Loss**

| | Total | Power loss | No Power loss |
|---|---|---|---|
| High Power | 253 | 12 (4.7%) | 241 (95.3%) |
| Low Power | 131 | 1 (0.8%) | 130 (99.2%) |

2.2.5.Bird Size Effect on Likelihood of Core Ingestion

A comparison of medium size birds (1.5 lbs. to 4.0 lbs.) and large size birds (> 6.0 lbs.) was done for core and bypass ingestions to determine if there was an influence of bird size on the likelihood of core ingestion. Table 2.2.5.1 shows the industry data used in the comparison. For both Medium and Large categories of bird size, roughly 54% of ingestions involved some material going into the core. The chi-square test p-value was calculated to be 92%, which implies 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 categorized as a core ingestion event. On a geometric basis, high bypass turbofan core intake areas are typically around 10% of the total inlet area. Since bird impact locations are random, it follows that core ingestions would be expected to occur much less often than bypass ingestions; however, some amount of bird material naturally enters the core as the bird debris spreads out after initial impact with the fan blade or inlet, which skews the numbers towards more core ingestion events than would be otherwise expected.

**Table 2.2.5.1 Bird Size Effect on Core Ingestion Proportion**

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

2.2.6. Analysis Summary

The data were found to be clear and consistent in showing that the likelihood of engine power loss due to bird ingestion correlates more strongly with high engine power (take-off and climb) versus low power (approach/landing). The high power data further show that a power 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 power loss than bypass only ingestions, and that the probability of a core ingestion is independent of bird size (medium and large flocking birds).

Based on these bird ingestion database statistical analysis results, 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 power loss, and would therefore provide the greatest opportunity for safety goal enhancement.

## 3. TASK FINDINGS

### 3.1. Safety Objective Assessment

The Safety Objective defined in the tasking is “freedom from multi-engine power loss events at a rate of 1E–8 per aircraft cycle”. This is consistent with the goal used during development of the original 14 CFR § 33.76 bird ingestion rule, and also with the 14 CFR § 33.78 Rain and Hail rule. It is also consistent with Continued Airworthiness requirements defined by AC39-8.

The Large Flocking Bird (Phase II) Working Group used slightly different guidelines; those were “freedom from Catastrophic Consequences below the rate of 1E-9 per flight hour” which is consistent with 14CFR 25.1309 requirements.

These objectives are very similar. The average flight leg across the commercial fleet is approximately 2 hours. The Hazard Ratio (percentage of multi-engine power loss events resulting in a catastrophic event) used in the Phase II working group was 18% (which was agreed to be conservative based on historic data). Thus a multi-engine power loss at 1E-8 per cycle would be equivalent to a Catastrophic Consequence rate of (1E-8 / 2 x 18%) or 0.9E-9 per flight hour.

The EHWG believes the current safety objective is adequate. The current data does not support any changes to the goal; any increase would require consequent increases in other areas to provide consistent safety standards.

### 3.2. Evaluate the Core Ingestion Element of Medium and Small Flocking Birds

In order to address the tasking to consider whether the current core ingestion test is meeting the safety goals outlined in the Phase II recommendation, the Working Group assessed the statistical performance of the existing fleet with respect to freedom from catastrophic consequences at a rate no greater than 1E-9 per aircraft flight hour. 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 warranted.

Although not specifically expressed in the CFR’s or Advisory Circulars, the Working Group’s conclusion regarding interpretation of the original intent of the core ingestion demonstration was that the current rule may not provide the greatest operating challenge to the engine core with respect to ingested bird mass and relative kinetic energy.

Historically, the most forward stage of a modern turbofan engine has presented the most vulnerable part of the engine to bird impact, with the concern for fan blade transverse fractures and/or airfoil deformation induced aerodynamic effects leading to significant loss of thrust capability. To address these fan blade durability concerns, the current Medium Flocking Bird (MFB) test parameters of bird speed, fan RPM and impact location are optimized to present the greatest challenge to the fan blade. The current regulations do not cite any modifications to the fan critical test parameters for the core ingestion requirement other than the largest single MFB is to be aimed at the core. Because the engine power setting and bird speed are, by default, considered the same for the core and fan outspan test, the medium flocking birds are typically tested simultaneously or in short succession (rule 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.

Another significant factor which has reduced the effectiveness of the core ingestion certification demonstration is the introduction of wide-chord fans; the consequent increase in transit time of bird material through the fan blade passage increases centrifuging and, at maximum take-off engine speeds much less bird material is ingested into the core during the test of a modern, wide chord fan as compared to earlier engines.

The difference in the MFB mass entering the core between the current critical fan blade conditions and a climb condition was assessed. Analytical model results from various OEM's indicated that the most critical parameters that affect core ingestion of bird material are flowpath geometry, bird velocity, impact location, and fan rotor speed. Figure 3.2.1 depicts the simulation results where the bird mass (noted as bird particles) ingested into the core increases as the fan rotor speed is reduced and also as the bird speed is increased. On a first order basis, the velocity of the bird represents the velocity of the aircraft at the time of ingestion, given that a typical MFB flight speed ( 20-45 KTS[6]) is significantly less than the aircraft speed (150-250 IAS) during low altitude flight, also the direction of the bird is random, as is its effect on relative bird velocity. Ingestions that occur at speeds lower than climb flight speeds (for a given engine power setting) result in less material entering the core and therefore are believed to present a lesser hazard to engine operation.

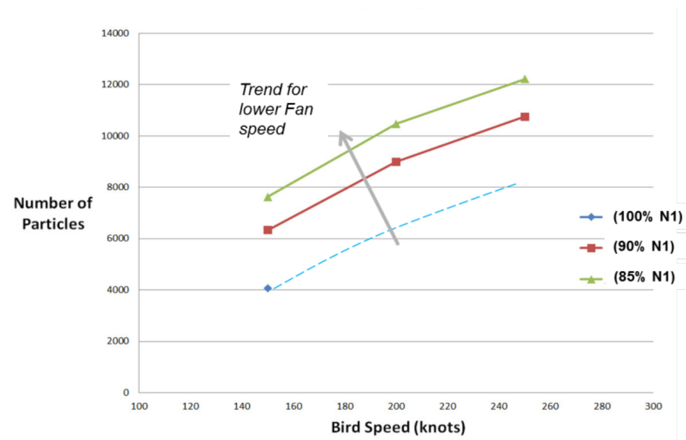


**Figure 3.2.1 Bird Mass Ingested Into Core as a Function of Fan and Bird Speed**

The Working Group determined that the most appropriate flight speed to evaluate MFB core 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[7], more than 91% of the bird strikes to aircraft occurred below 3,000' altitude. 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 aircraft at altitudes from 0-3000' AGL range between 150 and 250 knots indicated airspeed. Business jets operate with slightly different profiles which usually result in faster climb rates to cruise altitude, although the 250 knot maximum indicated airspeed is still observed.

Because the likelihood of bird material ingestion into the core is dependent on the relative bird velocity, it is established that a core specific bird velocity certification requirement be conservatively based on the highest anticipated aircraft speed below 3,000' altitude, which is 250 KIAS. For reference, the current FAA guidance in AC 33.76 that the rotating fan inlet fairing (aka "spinner") demonstrate impact capability for the largest medium bird using the most conservative bird speed expected during low level flight, which is typically demonstrated at 250 kts bird velocity.

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 (see Figure 3.2.1), the first exposed rotor RPM and engine design are strong influences. Various engine OEM simulation results have shown 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. The lowest fan rotor speeds during a typical flight occur during the approach phase; therefore, the maximum quantity of bird material ingested into the core would be expected to occur under the approach conditions of high aircraft velocity and flight idle engine power setting. However, the capacity to impart damage to the engine core is expected to increase with the higher engine rotor speeds achieved during the climb phase, given that the impact energy associated with mechanical damage increases with the square of bird relative velocity. This conclusion is supported by analysis of fleet bird strike data which has shown that, given a core ingestion, there is a greater likelihood of engine power loss during the climb phase (17% of all reported ingestions are responsible for 37% of the known power losses) relative to approach (25% of all ingestions with only 12% of the power losses) which supports the latter contention (see Section 2.2.2). Therefore, selecting a first stage rotor rotational speed that represents most engine operations during climb is expected to best support maintaining the core certification objective.

To establish a fan rotor speed for a climb core ingestion demonstration, a collaborative effort between the aircraft and engine OEM would be required. The aircraft OEM determines the thrust required to execute a desired climb profile through 3,000' AGL during standard day conditions for a given installation, and the engine OEM would calculate the first stage rotor RPM appropriate for that thrust requirement at that condition and 250 KIAS. It was recognized by the Working Group that climb thrust may not always be a singular entity, and that some installations have multiple climb settings available to operators and flight crews. The Working Group recommendation was to use the lowest available expected climb setting. This recommendation is based on the fact that a lower fan speed setting results in more bird material being ingested into the core while maintaining higher core speeds (relative to approach) associated with increased likelihood of damage.

The current 14 CFR § 33.76 rule and advisory material was found to be non-specific in defining the core ingestion radial targeting for the MFB core ingestion demonstration. It simply states that a MFB should be aimed at the core, and in most cases this is interpreted to mean targeting at the root of the fan leading edge. Engine OEM simulations demonstrated that targeting at the fan leading edge root does not always result in maximizing the bird mass ingested into the core. Therefore a more effective test requires an analytical assessment of the core target location to determine the location that maximizes the bird mass ingested into the core. Figure 3.2.2 shows the predicted mass fraction of a MFB that enters the core for three different engine designs as a function of the target location at the fan leading edge.

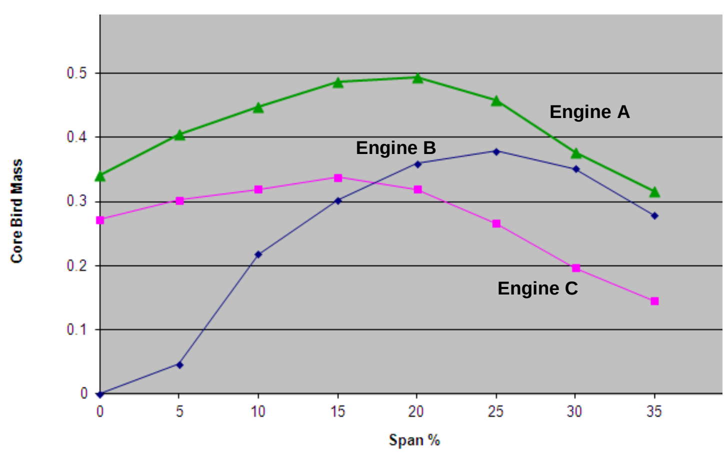


**Figure 3.2.2 Fraction of Bird Mass into the Core vs. Fan Impact Location**

The Working 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 a MFB core ingestion event during climb. The most appropriate demonstration was assessed to be that defined by the

Large Flocking Bird regulation. 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 LFB regulation. These requirements 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.

The Working Group considered the potential for an engine installation in which the lowest climb thrust was near the 50% of the highest rated thrust requirement described above. In this instance, if the engine loses thrust due to the ingestion, it may develop less than 50% of the highest rated thrust immediately afterwards, even though it may be capable of that at a higher throttle setting. The EHWG considered the option of requiring an immediate throttle push to above 50% thrust. While a trained airplane crew would probably do this in the real world when they realized more thrust was needed to continue climb, the EHWG believes that to cover this possibility, an initial thrust reduction following ingestion to below 50% of the highest rated thrust would be acceptable during the first minute without throttle movement provided the thrust capability is demonstrated during subsequent throttle movements for the following reasons:

- The 60 second delay is to ensure that the engine does not develop an undesirable condition while the crew assesses the situation. The engine is unlikely to be advantaged with no throttle movement since it may be operating with excessive vibrations or other unusual condition which may have a detrimental effect and could be relieved by moving the throttle.
- The engine still must show >50% capability and operability after the initial minute and this is at the highest engine rating applied, which is a conservative level.
- This time delay is consistent with the Large Flocking Bird requirement and avoids unnecessary complication of the requirements by defining specific allowances for time below 50% etc.
- The climb phase being demonstrated places the aircraft at an altitude and airspeed above V2 where more recovery time is available to the crew.

The tasking required an assessment of core ingestion of small birds. An engine OEM analysis comparing the bird mass for small flocking birds (e.g. European starlings - Sturnus vulgaris) to that of a Canada goose (Branta canadensis) indicated that 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 loss, which is believed to be the result of the spacing between birds (relative to bird size) within a flock. Therefore, the threat from small flocking birds was determined to be adequately addressed by the current regulation.

### 3.2.1. Consideration of the Approach Condition

The aircraft safety perspective which supports firstly 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 glide slope, and thus the aircraft is in a better position to execute a safe landing when presented with a core ingestion engine power 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 maneuvers to clear obstacles and return to the airport. Thus the climb phase best represents the in-service combinations of airspeed and power setting for core ingestion capability demonstration criteria in support of the safety objective for most engines.

The principle drivers of bird material ingested into the core are bird velocity (aircraft speed), fan rotational speed and engine geometry leading up to the core intake. Some turbofan OEM's have produced configurations which have been shown to eject all of the bird mass into the fan bypass at high power conditions. It was realized 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 regulation were restricted to climb and take-off conditions.

The Working Group attempted to establish quantitative criteria to determine whether an approach condition would be more appropriate than the climb condition, principally by means of a minimum percentage of bird material that is demonstrated to enter the core at climb. Due to the technical difficulty of determining the amount of bird material that enters the core during the climb ingestion condition, this approach was deemed to be impractical. The Working Group consensus therefore was to subject those engine models which ingest no bird material into the core at the take-off and climb conditions be tested at an approach condition. The most appropriate bird speed for the approach condition was determined to be 200 KIAS (typical approach airspeed at 3,000' AGL and 10 miles from the runway threshold) and the engine front rotor speeds to be the engine OEM defined RPM consistent with a flight idle setting. Because the aircraft would be on final approach at this condition, the engine should only be required to demonstrate throttle movement sufficient to maintain glide slope as expressed in the final 6 minutes of the Large Flocking Bird engine run-on requirement.

Verification of bird material entering the core would be typically determined by evidence of tissue observed using white light, by fluorescence under UV illumination, or the presence of feathers within the core intake aerodynamic splitter radius. Alternatively, an analysis shown to be calibrated to the regulators satisfaction was also considered to be a valid means of demonstrating that a given engine configuration does not ingest bird material into the core at the climb condition, and therefore would be subject only to an approach demonstration.

### 3.2.2. Business vs Commercial Flight Profiles

US Airways 1549 impacted birds at approximately 220 knots Indicated Air Speed (IAS), 2800 feet above ground level (AGL) and ~82% N1, well below the maximum take-off setting. Many large commercial transport aircraft use reduced thrust or derated take-off power settings. Reduced thrust or derated take-offs are used because they may provide substantial benefits in terms of engine reliability, maintenance, and operating costs, while operating at lower N1 speeds than the maximum take-off thrust rating. Climb power settings on large transport aircraft are also significantly lower than maximum take-off settings. Smaller corporate jet aircraft with small throat inlets are not typically certified to perform reduced thrust or derated take-offs (i.e. all take-offs are completed at max rated take-off thrust), and climb power settings on most smaller corporate aircraft are typically close to the maximum take-off thrust rating.

Based on ICAO standard flight departure profiles and service data from airframe manufacturers and the International Airline Pilots Association, expected flight speeds for large commercial transports at altitudes from 0-3000' AGL range between 150 and 250 knots indicated airspeed. Smaller corporate jet aircraft are typically operated to accelerate to the recommended cruise-climb speed schedule as quickly as possible after take-off. These recommended cruise climb speed schedules vary with aircraft type, but generally fall in the 175-250 KIAS range, similar to large commercial transports. It is therefore appropriate to use the same critical airspeed of 250 KIAS for all engines, regardless of engine size.

The selection of 3000' as the climb operating condition for core ingestion demonstration criteria was made by considering the tradeoff between increasing aircraft speed (i.e. increased bird material into the core) with altitude and also the likelihood of a bird encounter. The probability a bird encounter declines exponentially as the aircraft gains altitude; however, the aircraft speed typically increases as the aircraft gains altitude during departure climb. Generally, airspeed is restricted to 250 KIAS below 10,000' altitude, and most jet aircraft are easily capable of attaining this airspeed by 3,000’ (particularly business jets). Since more than 91% of the bird encounters occur below 3,000’ and the maximum airspeed expected in service at this altitude is 250 KIAS, it was determined that this would present the most conservative condition at which to set the climb criteria.

### 3.3. Evaluate the Large Flocking Bird Requirements

There are two separate requirements for LFB within the tasking. The discussion and conclusions on these two requirements are:

#### 3.3.1. LFB for engines with inlet throat areas 1.35 - 2.5m$^2$ (class D)

The A320 aircraft involved in the US Airways 1549 event used engines in this size class. Those engines were designed prior to the LFB rule which is intended to demonstrate fan blade capability in terms of thrust loss and engine operability. The fan blades of the engines involved in the “Hudson event” were not severely damaged, and are believed to have been capable of producing substantial continued thrust. Thus the event did not indicate a deficiency in current bird ingestion requirements on the fan blades at this engine size.

This class of engine accrues the highest number of total flights within the transport category world fleet, and thus is the most statistically significant category. It was noted that as engine bypass ratios increase to gain fuel efficiency, the aircraft currently powered by this class of engines, and accruing the majority of flights, will in the future tend to be powered by engines with inlets >2.5m$^2$ which will perform the LFB test during certification.

The Working Group has concluded that class D size engines are currently operating close to the safety objective of the current rule; therefore, there is no need to include this class engine in the current large flocking bird engine test requirement at this time.

Also, the Working Group expects that overall class D fleet capability and safety margin will increase markedly in the future as engines designed to the current rule become more prominent in the world fleet.

An OEM simulation of fan blade impact (see Appendix G) comparing the leading edge impact energy for the MFB versus the LFB criteria was conducted. 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 iterated to the bird size, run at the LFB condition, which would be nearly equivalent across the full span it was found that a 3.5 lbs. bird at run at the LFB condition would provide a similar level of challenge as the existing MFB criteria. The EHWG concluded that imposing the LFB requirement on the smaller class D engines would not result in a significant improvement in power loss rates.

However, the anticipated improvements in safety margin rely on the capability of new technology engines to match, or exceed that demonstrated by the latest engines today. This is discussed in section 4.1.

#### 3.3.2. Core ingestion element for LFB

The Working Group has concluded that a large flocking bird core ingestion test is not required because this threat is a relatively small percentage of the overall risk of multi-engine power loss. Since power losses are predominately driven by fan blade damage and fracture, the current engine certification test is considered the best demonstration of overall engine capability against this threat. The previous rulemaking effort also determined that bypass ingestions make up the majority of related risk, and that the safety objective of the rule is met without an additional core ingestion element to the test.

The relative effects of core ingestion of a Medium Flocking Bird at the proposed climb condition and Large Flocking Bird at the derate take-off condition in the current regulation were assessed to determine if there was a significant difference in the threat of core damage which could lead to a power loss on a class D turbofan. It was intuitively recognized that the LFB derated take-off condition would likely result in an increase in the mass ingested over a MFB climb condition, and engine manufacturer simulations showed this to be the case. The LFB condition resulted in a smaller mass fraction of the bird entering the core (0.39 LFB vs. 0.52 MFB), but a LFB results in a 20% higher total mass into 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.

### 3.4. Consideration of NTSB Safety Recommendations

The EHWG was tasked to review and consider the two NTSB safety recommendations cited in the US Airways 1549 report during the rule advisory deliberations. NTSB recommendation number A-10-64 was to consider using the lowest fan speed for a minimum climb condition for the MFB demonstration. The NTSB recommendation was essentially incorporated into the recommended 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 should be made to the maximum take-off requirement for other aspects of the MFB regulation since this is far more stringent for the fan blades.

NTSB safety recommendation A–10–65 requested that the EHWG reevaluate the LFB certification test standards to determine whether they should apply to engines in the class D size and include a requirement for engine core ingestion. The potential benefit of adding a LFB requirement to this engine size class was carefully evaluated and it was found that, due to the shorter fan blade length in this size class, the LFB test condition would not clearly provide any significant safety benefit for either the fan bypass threat or the core ingestion element. Engine OEM simulations revealed that the current additional integrity test requirement provides an equivalent structural challenge to the fan blade up to the 3.5 lbs. bird size. OEM simulations also show that, the current MFB requirements provide similar energy at the core intake (within 2%) despite the larger amount of bird material associated with the LFB.

## 3.5. Define an industry led process for periodic update and review

The Engine Harmonization Working Group recommends that the AIA be approached to set up a Working Group under its CARS (Civil Aviation Regulatory and Safety) committee. Initially, the group should meet annually and add prior experience to the database. Since the database has not been updated since 2009, and significant work is involved in this process, an incremental addition of 2-3yrs of data is recommended for the first two years. The needs for continued work should be assessed after 5 years.

The new CARS WG should review the conclusions of the prior AIA WG which identified many areas for improving the database quality and improve its usefulness. For example, when possible:

- database entries should include, the primary strike locations and secondary finds (i.e. inlet primary, core and bypass secondary)
- reports should indicate whether altitude is AGL or Pressure Altitude

- generic birds should continue to be split into small/medium/large weight categories and these should then be distributed between the sub-categories in the same proportions as the ‘real’ bird identifications.

The new WG should provide recommendations on any deficiencies seen in 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.

## 4. ISSUES

### 4.1. Future Engine Products and Bird Ingestion Certification Requirements

As noted above in section 3.2.1, the anticipated improvements in safety margin do rely on the capability of new technology engines to match, or exceed that demonstrated by the latest engines today. New technology engines such as “Open Rotor” engines will have significantly different architectures. A general rulemaking effort by EASA has preliminarily considered the certification requirements of this type of engine, however many aspects are difficult to address without a dedicated body of specialists since the assumptions of current certification rules may not apply. Some of the issues are:

- Very low fan blade solidity

  The rigor of the current MFB critical parameter requirement relies on the fact that firing a bird into the fan at the appropriate speed and radial location will achieve a “full slice” onto at least one fan blade. The low solidity of Open Rotor fans could allow a bird to pass between the fan blades with minimal, or zero contact. A critical “full slice’ would be almost impossible to achieve without millisecond timing of the bird/blade impact criteria. With current test facilities this is impossible to achieve. An engine test may be impossible, and under current FAA regulations a component test would not be considered sufficient.

- Contra-rotating fan rotors
  If a bird impacts the 1st stage of a Contra-rotating fan, it will be propelled at very high velocity aft and outwards, if the remains impact the 2nd fan stage then the stresses imparted to that stage may be far higher than those onto the 1st stage. While a multi-engine, multi-critical impact to both stages is most likely extremely remote, consideration must be given to this possibility. A Monte-Carlo type assessment is probably appropriate (as was done for LFB test definition) to determine the test requirements which can assure meeting the safety goals.
- Core ingestion bird weight for equivalent safety in same aircraft class
  The EASA proposal currently defines the core ingestion bird weight based on inlet throat area. While this may be appropriate, the goal of the EASA rulemaking was to provide “equivalent safety” between Open Rotor engines and current turbofans. Since the bypass ratio of Open rotor engines is much higher than equivalent thrust-class turbofans, this would result in a much lower bird weight demonstration into the core for engines with similar thrust class. Also, some configurations have no fan to ‘protect’ the core, and those that do have less centrifuging due to the low fan solidity. These factors can result in at least a perception of lower safety standards.
- The Large Single Bird test relies on the fact that a containment case exists around the fan stage, and does not require a critical speed ingestion. It may be appropriate for Open Rotor engines to require a critical LSB bird speed to provide a valid comparison between the ‘blade out’ test and the LSB test.
- Monte-Carlo analyses may be essential across all aspects of certification demonstrations to prove equivalent safety.

Based on these observations, the Working Group recommends future rulemaking activity identify means to introduce requirements which assures capability of future engine designs. Since EASA has already initiated general rulemaking activity for Open Rotor engines and installations, the Working Group recommends this activity be conducted under continued EASA tasking.

4.2. Availability of Bird Species Identification Sources

For bird ingestions which occur on United States soil or to U.S. registered aircraft, bird species identification is available through the U.S government funded Smithsonian Institution's Feather Identification Laboratory. For ingestions which occur outside of the U.S. to non-U.S. registered aircraft, sources for obtaining species identification is more difficult. Even for known international sources, concern for avian borne diseases and import/export restrictions often hinders the shipment of bird material between countries. Providing a readily available means for global species identification would provide for high quality assessments of bird ingestion threats and fleet performance relative the established safety goals. To this end, the EHWG recommends that the AIA or another appropriate group work to establish and maintain protocol and a list of laboratories which could readily provide bird species identification.

4.3 Differentiating Between Core Induced Power Loss vs. Material in the Core

The bird ingestion data included core ingestion information (either "core" or "not core") for 37% of all the reported ingestion events. A core ingestion was noted when any evidence of a bird was found within the core regardless of other locations where bird strike evidence was found. In many of the bird ingestion entries it was difficult to differentiate between data entries in which the core was the primary strike location (a "direct hit"), was an artifact from a strike at another location, or was a core ingestion independent of another bird strike.

Considering only the ingestion events for which core information was provided, ~40% indicated the presence of bird material in the core either suspected due to a reported odor in the cabin or actual findings during the post-strike engine inspection. This is a significantly higher percentage than would be expected based on random bird strike locations for a high bypass turbofan engine, which suggests that, at most, 10% of the total engine bird strikes would be directed at the core flow path.

It is believed that the presence of bird remains within the engine core is not a reliable indicator of significant core ingestion because bird strikes on aircraft structure other than the core intake area, such as the inlet lip, spinner cap, and radome, regularly result in some amount of avian material entering the core. Single bird impacts which have occurred in the outer spans of the fan blades or against the front of the core intake fairing also are known to result in material entering the core.

These secondary means of core bird material ingestion imply more direct core ingestion involvement in bird strike related operational discrepancies than has actually occurred. When attempting to assess the proportion of significant bird strike engine effects assigned to core, consideration needs to be given of the concept of bird material ingestion into the core during events in which the core is not the primary strike location. Accurate core ingestion data are of particular concern when attributing an engine power loss event to a strike location on the engine and airframe, with a distinction made between the ingestion of significant amount of bird debris, such as the main body of the bird, directly into the core and ingestions of small amounts of material secondary to a primary strike at another location.
Thus increased rates of power loss when there is evidence of core ingestion do not imply that core-induced power losses occur at higher rates than bypass only.

4.4 Changed Product Rule

The recommended core ingestion demonstration is a severe requirement; many engines currently in service with demonstrated safe operational histories against birds may not be able to perform this test successfully. It is recommended that design changes on those engines which do not significantly affect core robustness or core ingestion mass during the current MFB certification test should not require the new demonstration point under the Changed Products Rule. Changes which would make the core more susceptible to damage (e.g. changes which would result in significantly less centrifuging and therefore more material entering the core, or changes which would reduce the downstream compressor stages' tolerance to foreign material) should be evaluated to determine the appropriateness of the additional demonstration.

## 5. CONSENSUS

The analysis, conclusions and recommendations developed by Working Group were arrived at with full consensus among all of the members of the EHWG. There were no dissenting opinions on the EHWG's final position.

The conclusion that the current core ingestion demonstration criteria did 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 was quickly and unanimously agreed upon. The EHWG also agreed to maintain the current robust MFB demonstration at take-off power; therefore the EHWG decided that an additional requirement for a core specific demonstration would be needed. The most appropriate airspeed and altitude criteria were likewise quickly settled based on the available data and industry analysis. It was also agreed that an analytical means to show core ingestion capability needs to be preserved. A means to best demonstrate engine capability required a thorough assessment of a multitude of approaches. Incorporation of a more rigorous core ingestion demonstration into the MFB, LFB and LSB test procedures was examined closely to provide a possible means of compliance without risking additional engine assets, but all of these proposals, with the possible exception of engines where the take-off and climb power ratings are nearly identical, were ultimately considered as too compromising for the intended core ingestion challenge. Thus, an additional requirement to verify core capability for the most critical flight phase via analysis or test was developed by the EHWG and agreed upon.

There was also consensus that requiring the LFB demonstration for class D size engines would not provide any notable improvement in engine capability over and above the current and recommended ingestion requirements

## 6. RECOMMENDATIONS

### 6.1. Core Ingestion Demonstration

Based on review of the most recent bird ingestion database statistical analysis and results from manufacturer bird ingestion simulations, the EHWG concluded that the current core ingestion criteria defined by the CFR's does not adequately challenge the core section of engines with modern wide-chord fan blades relative to the most likely threat to the core expected in service. Therefore, the Working Group recommends that the current bird ingestion regulations be modified by including an additional core ingestion demonstration, by test, analysis, or both, of the largest Medium Flocking Bird (as defined in 14 CFR § 33.76 Table 2) at a climb condition which reflects the highest typically allowed aircraft speed (defined as 250 KIAS) and the lowest climb fan rotor speed expected to occur during the climb phase at 3,000' AGL. The combination of high aircraft speed and low rotor speed will increase the amount of bird material which can enter the core. In addition, the bird should be targeted to maximize the amount of bird ingested into the core at that condition.

It is also recommended that the ingestion should be followed by one minute with no power lever movement after ingestion followed by the full 20-minute engine run-on profile as defined in the current LFB requirements of 14 CFR § 33.76 (d)(5)(i) through (vi) to ensure that a safe return to the departure airport can be accomplished with the available post-ingestion thrust. An allowance for less than 50% of rated take-off thrust of the day but greater than idle during the first minute after the ingestion should be provided for reasons noted in Section 3.2.

For engine configurations which are shown by analysis or test to eject 100% of the bird from the core under the proposed climb conditions, it must be demonstrated by test, analysis, or both that the engine can ingest the largest medium flocking bird at the approach condition (defined as 200 KIAS and approach idle rotor speed) and be capable of safely continuing a stable approach and safe landing. Capability for continuation of a stable approach after core ingestion could be accomplished by performing the final 6 minutes of the engine run-on profile defined in the current LFB requirements of 14 CFR § 33.76 (d)(5)(iii) through (vii) to ensure that a safe landing at the arrival airport can be accomplished with the available post-ingestion thrust. Again, the bird should be targeted to maximize the amount of bird ingested into the core at that condition.

For the purpose of determining whether all bird material is ejected into the bypass following a core strike, if any material, including a feather(s) or tissue is observed (via white light or UV fluorescence) inside the core to bypass splitting highlight, core ingestion will be considered to have occurred. Thus, if an engine is found by analysis to fully eject all core bird material into the bypass but other bird ingestion testing (i.e. 14 CFR § 33.76 (c) MFB test) shows otherwise, the recommended additional core demonstration at the climb condition shall be performed.

For either the climb or approach demonstrations or analysis above, the engine should be shown to not present an unsafe condition to the aircraft as defined in the current 14 CFR § 33.76 requirements if any operating limit is exceeded during the engine run-on.

6.2. Large Flocking Bird into engines in the 1.35-2.5$m^2$ engine size class.

As noted in 3.3.1, the US Airways 1549 event did not indicate a deficiency in current bird ingestion requirements on the fan blades in the 1.35-2.5$m^2$ engine size.

The current fleet of engines in the 1.35-2.5$m^2$ category is still predicted to meet the 1E-9 per aircraft hour and 1E-8 per aircraft cycle safety objectives. Improvements in bird strike capability due to earlier rule changes are still being reflected in the fleet experience, thus future fleets should show further safety gains.

The phase II LFB committee concluded that the current MFB critical test conditions effectively drive capability for larger birds in this size class; based on the latest data and engineering judgment, this Working Group has drawn the same conclusion.

Based on these observations, a Large Flocking Bird test requirement for engines less than 2.5$m^2$ is not recommended since the current 2.5 lbs. Medium Flocking Bird test is providing sufficient margin for larger birds.

6.3. Large Flocking Bird Core Demonstration

As discussed in 3.3.2, the recommended core ingestion test with MFB at 250 KIAS provides a more direct and quantifiable assessment of core ingestion capability than the LFB test condition, thus no change is recommended to the Large Flocking Bird test requirements to include a core ingestion element.

6.4. Database Updates and Future Committee Work

As detailed in 3.5, industry should request AIA to set up a Working Group under its CARS (Civil Aviation Regulatory & Safety) committee.

6.5. New Technology engines

Based on the discussion in 4.1, the Working Group recommends that EASA extend their rulemaking activity for open rotor engines to further consider the bird ingestion requirements for that type of propulsor.

## 6.6. Advisory Material

### 6.6.1. Core Bird Targeting

To ensure that the MFB core ingestion test properly challenges the core during an engine demonstration, the bird should be targeted at the engine to maximize the amount of bird material that enters the core for the given test condition. As discussed in Section 3.2, the optimum target location varies with engine design and the span wise location will have some dependency on the geometric features of the front of the engine. The core bird target location that maximizes the amount of core ingested bird material for a MFB core test should be determined by any means acceptable to the regulator, including component test or dynamic simulation verified by test or experience.

### 6.6.2. Determining Climb Rotor Speeds

The calculation of the core ingestion test engine rotor speeds associated with the climb phase is airplane and mission dependent. For each engine model / aircraft installation, the engine OEM's should collaborate with the airplane OEM's to determine the engine thrust at a 3000' altitude during ISA Standard Day conditions that is required to execute the climb phase through the 3,000' level. The engine OEM's should then establish the associated minimum mechanical fan rotor speeds for this climb thrust at the stated climb condition using engine performance simulations for 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.

### 6.6.3. Climb Rotor Speed Considerations

There is typically little to no difference between take-off and climb rotor speeds for the smaller turbofan engines (class E and F) installed on business jets. For this reason, the climb conditions recommended for the core ingestion demonstration are very close to the conditions prescribed for the existing MFB test where the largest MFB is targeted at the core at the full rated take-off condition. The most significant difference between the existing criteria and the proposed core ingestion demonstration is expected to be the fan critical bird speed versus the 250 KIAS core recommendation.

Consideration should be given to an applicant who wants to demonstrate the recommended 250 KIAS core bird within the existing MFB rated take-off test provided that the applicant can show an equivalent level of test severity.

In other words, the MFB core ingestion requirements could be satisfied by a single test at rated take-off thrust in which the largest MFB which is aimed at the core is ingested at the 250 KIAS climb airspeed while the remaining bird velocities, targeting and run-on would follow the current MFB criteria.

Advisory material should be provided for the above approach. It should discuss the bounds of applicability (i.e. equivalence of bird mass and energy into the core, engine rotor speeds, etc.). The goal is to show that the core ingestion is as rigorous at the current MFB fan speed condition as it would be at the recommended climb fan speed condition.

Allowance of this approach could eliminate a redundant test.

### 6.6.4. Core Ingestion Prediction Analyses

Some engine configurations could include features which reject all bird material from the core intake at the take-off and climb conditions. Such engine designs would be exempt from the recommended climb ingestion criteria and subject only to the approach core ingestion test. The engines would be required to demonstrate 100% bird rejection capability by analysis or similarity. Any analyses used for predicting core ingestion will need to be validated using data, which may include rig testing, engine testing or field experience. However, should the standard 33.76(c) MFB core demonstration result 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 will be considered invalid and the recommended climb condition core ingestion capability must be demonstrated.

## 7. REFERENCES


1. NTSB/AAR-10/03PB2010-910403; NTSB Accident Report - Loss of Thrust in Both Engines After Encountering a Flock of Birds and Subsequent Ditching on the Hudson River
2. FAA FR Doc. 2013–05228; Notice of new task assignment for the Aviation Rulemaking Advisory Committee
3. Dunning, John; CRC Handbook of Avian Body Masses, Second Edition; 2007.
4. Dunning, John; CRC Handbook of Avian Body Masses; 1992.
5. Brough, Trevor; *Average Weights of Birds*; Ministry of Agriculture, Fisheries and Food, Aviation Bird Unit, Worplesdon Laboratory, Guildford, Surrey 1983.
6. Bruderer B, Boldt A (2001) Flight characteristics of birds: I. Radar measurements of speeds. Ibis 143: 178–204.
7. Dolbeer, Richard A., "Height Distribution of Birds Recorded by Collisions with Civil Aircraft" (2006), USDA National Wildlife Research Center – Staff Publications, Paper 500.
8. DOT/FAA/AR-TN03/60; "Study of Bird Ingestions into Aircraft Turbine Engines (December 1968 – December 1999)", September 2003. Available through the National Technical Information Service (NTIS), Springfield, Virginia 22161.

Appendix A. List of Working Group Members

| | | |
|---|---|---|
| Chris Demers | Pratt &Whitney | Co-Chairman |
| Les McVey | GE Aviation | Co-Chairman |
| Alan Strom | FAA Standards | |
| Angus Abrams | EASA | |
| DC Yuh | Transport Canada | |
| Amy Anderson | FAA Airports | |
| John Barton | Snecma | |
| Mark Beauregard | Pratt & Whitney Canada | |
| Walter Drew | Airbus | |
| Tom Dwier | Cessna | |
| Ken Knopp | FAA Tech Center | |
| Bryan Lesko | ALPA | |
| Julian Reed | Rolls-Royce | |
| Russ Repp | Honeywell | |
| Terry Tritz | Boeing | |

## Appendix B. Amendment to Phase II Final Report[7]

The final report from Phase II (DOT/FAA/AR-TN03/60) contained an error on page 10; the two charts were switched and should have been shown like this:

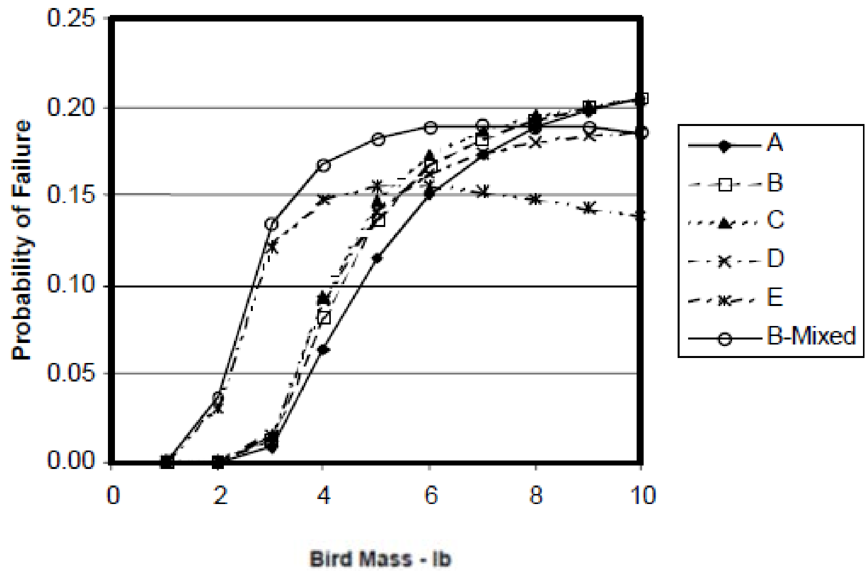


**FIGURE 4. SINGLE ENGINE POWER LOSS PROBABILITY, GIVEN AN INGESTION**

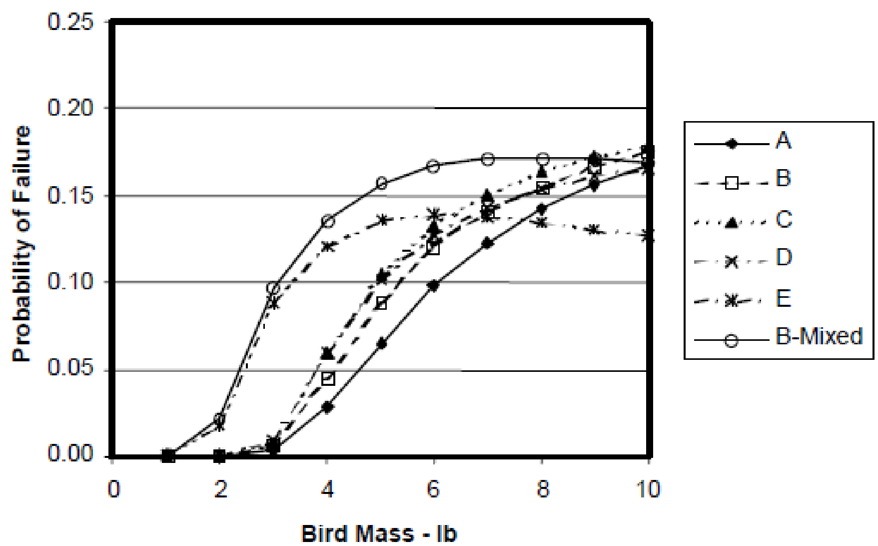


**FIGURE 5. DUAL ENGINE POWER LOSS PROBABILITY, GIVEN A DUAL INGESTION**

As they were shown originally, it appeared that a dual engine power loss was more probable than a single engine power loss. A power loss is dependent on four primary conditions, aircraft speed, engine rotational speed, bird mass and impact location on the engine face. For a dual engine ingestion event, only the impact location will vary between the two engines, the other parameters will be the same or similar, so the probability of dual power loss given a dual ingestion is less than the probability of single engine power loss, but is more than the single engine power loss probability squared which has been suggested. For this reason, a Monte Carlo method was used to derive the figures above, and as shown here they are correct.

## Appendix C. Supporting Data from AIA Phase III Database

### C1 Frequency of Core and Bypass Ingestions on Engine Power Loss

The Working Group also reviewed the AIA Phase III Database to determine if there was difference in the rate of occurrence (or frequency) between core ingestions and bypass ingestions that resulted in an engine power loss. If, for example, core ingestions resulted in significantly more power loss, then there would be merit to question if the FAA/EASA regulations are more directed towards fan integrity rather than core integrity. One caveat is that core ingestion was defined in the Phase III database as any evidence of bird in the core (snarge, feathers, etc.) so it is possible that an engine could have power loss due to fan damage but if any bird evidence was found in the core it was classified as a core ingestion. "Core ingestion evidence" will be used to denote this in the figures below. The database was sorted by date, filtered by ingestion type, and a new calculation was added which created a running tally of the percent of occurrence where the ingestion resulted in power loss using the data up to that particular date. The filtering was repeated until the core ingestion, bypass ingestion, unknown ingestion, and all ingestions were completed. The resulting run chart is shown in Figure C-1. With the caveat explained above, the data showed that power loss in which bird material was found in the core resulted in ~2.4 times the rate as bypass only ingestions. However, as noted in Section 4.3 of this report, the finding of bird material in the core is not a definitive indicator that a bird was ingested directly into the core intake.

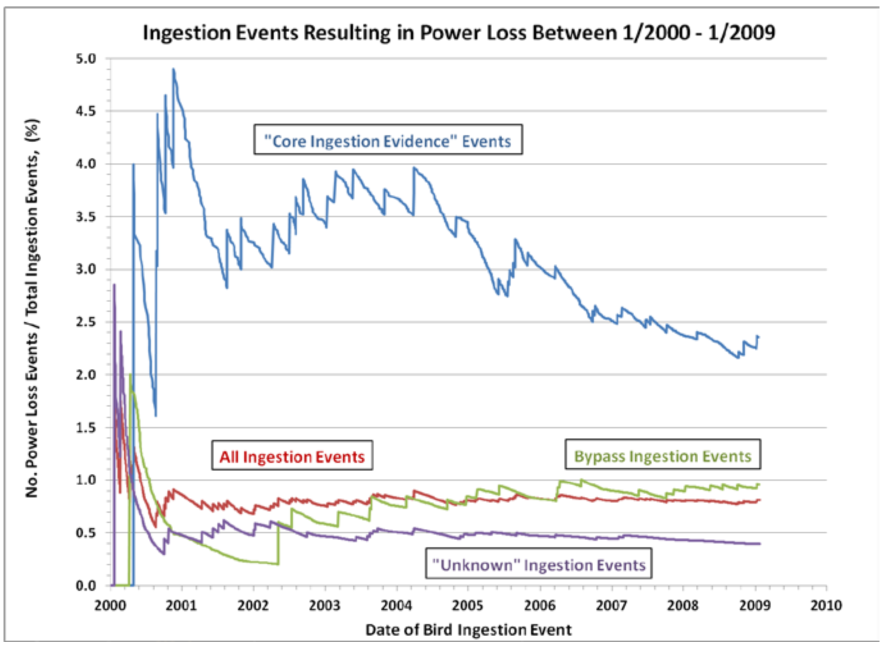


**Figure C1-1. Core Ingestions Evidence Have the Highest Percentage of Power Loss**

### C2 Impact of FAA/EASA Part 33 Bird Ingestion Amendments on Engine Power Loss

The database was also examined to determine how the FAA/EASA Part 33 bird ingestion amendments affected the engine power loss after an ingestion event. In a similar technique as described in the previous Section, the data was sorted and filtered by the various categories but this time the Amendment in which the engine was certified was also filtered. The Part 33 Amendments were grouped as follows: 14 CFR § 33.13, 14 CFR § 33.19, AC 33-1, -1A, -1B; 14 CFR § 33.77 Amdt. 33-6; 14 CFR § 33.77 Amdt. 33-10; 14 CFR § 33.76 Amdt. 33-20; and 14 CFR § 33.76 Amdt. 33-23 and 24. A brief description of these Amendments is included in Appendix E. The purpose of this study was to understand if these Amendments are affecting the aircraft fleet per their intent. Figure C2-1 shows how the core ingestions (some evidence in core) that resulted in power loss were affected by the various Amendments. Although the data sample only covers nine years of fleet service, it does indicate that the more recent Amendments have a much improved result (lower percentage resulting in power loss) than the earliest Amendments and Advisory Circulars. Figure C2-2 shows a similar plot for the bypass only ingestions (no evidence in core). Although the scale had to be changed, the conclusion was the same.

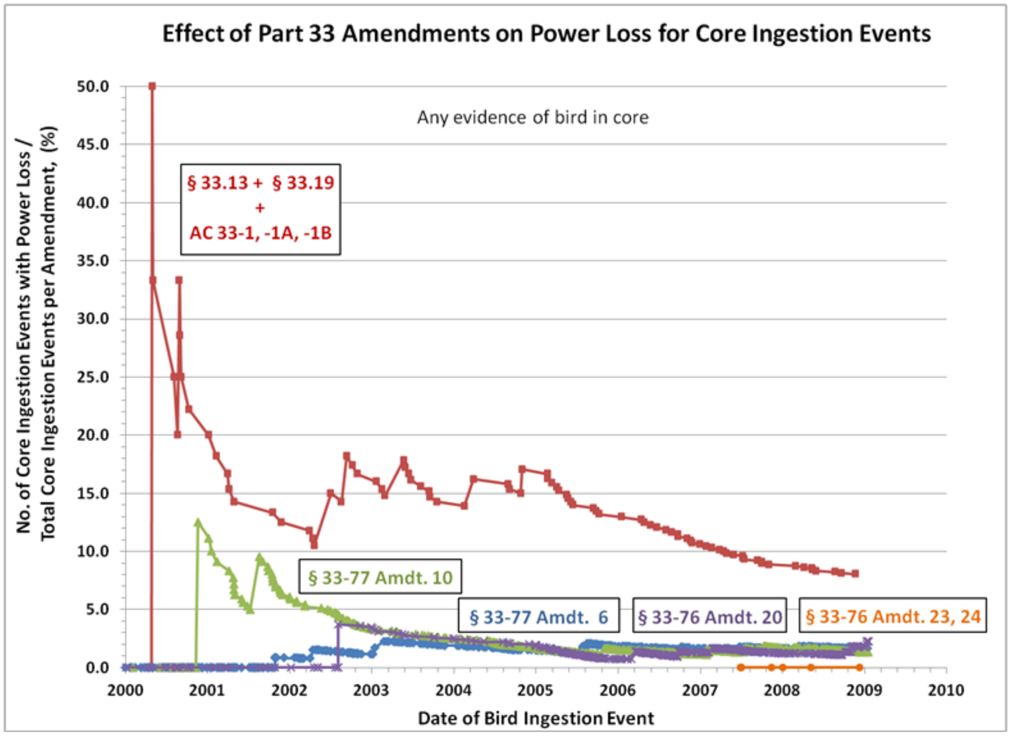


**Figure C2-1. Effect of 14 CFR § 33 Amendments on Power Loss for Core Ingestion Evidence Events.**

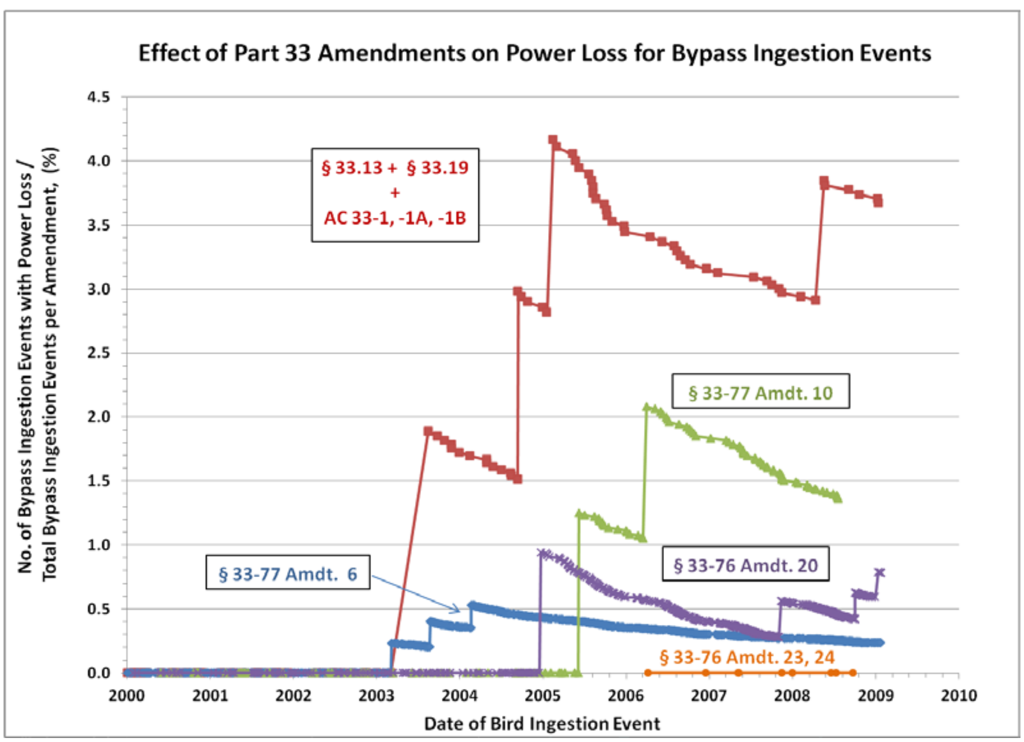


**Figure C2-2. Effect of 14 CFR § 33 Amendments on Power Loss for Bypass ONLY Ingestion Events.**

The plots above do not provide a comparison of how the introduction date of the Amendment affected the fleet since the current aircraft fleet has engines certified under all of these Amendments. In order to understand the timing aspect, the last points for each Amendment from Figures C2-1 and C2-2 were combined and plotted with the date of Amendment introduction in Figure C2-3. Both the total number of ingestion events with power loss and the total ingestion events per Amendment are tabulated to provide further understanding on the relevance of the percentage value. Within the Amendments, the largest reduction occurred with the introduction of 14 CFR § 33.77 Amdt. 33-6 in 1974. The data sample for the most recent 14 CFR § 33.76 Amdt. 33-23 and 24 is too small to make any meaningful comparisons. Focusing on Amendments 6, 10, and 20; on average the number of power loss events is greater for core ingestion evidence. This is in agreement with the conclusion from Figure C1-1 which is the 14 CFR § 33 regulations were more focused on establishing test conditions to ensure robustness of the fan blade critical outboard region (bypass ingestion) than establishing different test conditions to ensure a robust core (core ingestion).

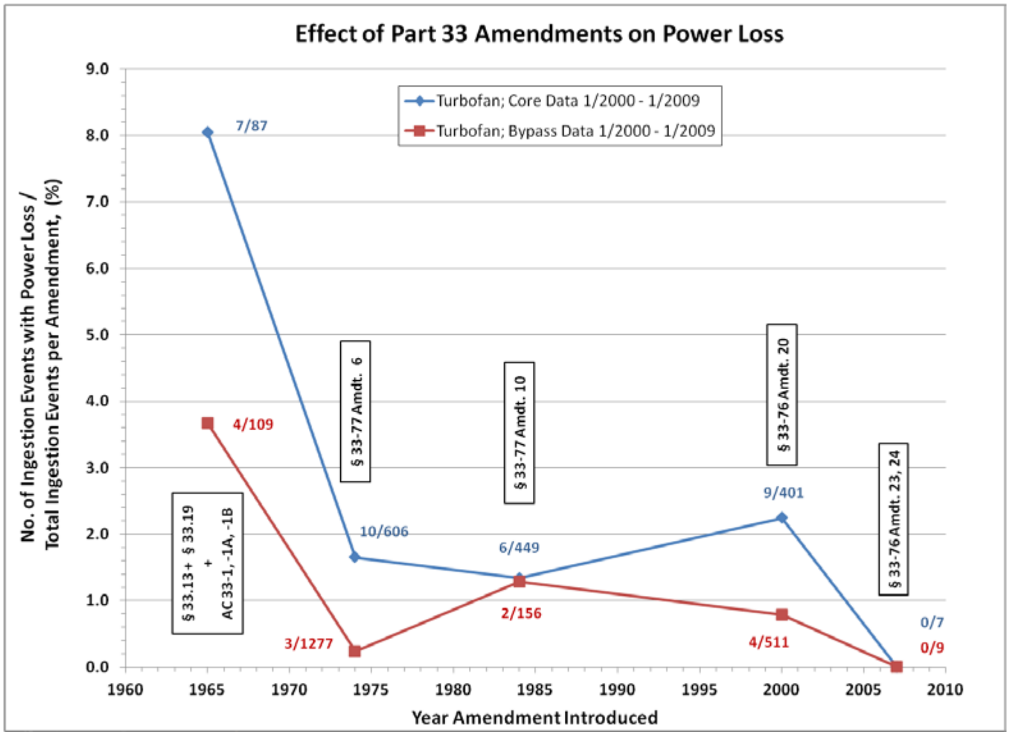


**Figure C2-3. Effect of 14 CFR § 33 Bird Regulation Amendments on Power Loss**

## Appendix D. Bird Ingestion Results from Prior FAA Sponsored Studies

Three previous FAA sponsored reports were reviewed for comparison: "*Bird Ingestion Into Large Turbofan Engines*", February 1995; "*Engine Bird Ingestion Experience of the Boeing 737 Aircraft – Expanded Data Base*", July 1992; and "*Study of Bird Ingestions into Small Inlet Area Aircraft Turbine Engines*", December 1990. Although fan and compressor technology has advanced since these studies were completed and therefore bird ingestion results may not follow the same trends, the purpose was to provide additional information to the ARAC Working Group Committee from a historical aspect. A brief summary for each of the reports is presented in the following Sections.

### D1 "*Bird Ingestion into Large Turbofan Engines*"

Data for this study was collected over a twenty-six month period between January 1989 and August 1991. Table 2.2 from the report denotes the engine manufacturer, engine model and aircraft that were used in this study. Based on the engine size classifications from the Engine Harmonization Working Group (EHWG) Committees and included in the Phase III Database, these engines would represent classes B, C and D.

Figures 5.2a, 5.2b and 5.3 from the report show the number of bird ingestions that resulted in engine damage by phase of flight. The figures show that there were a similar number of bird ingestion events between departure (Take-off Roll, Take-off, Take-off Climb, and Climb) and arrival (Descent Approach, Approach, Landing Approach, Landing, and Landing Roll). Take-off Roll and Landing Roll had the largest amount of ingestion events, respectively, which is different than the Phase III database indicated. The study differentiated on the level of damage that occurred based on types of failures and/or quantity. Results showed that "significant" damage occurred more often during departure than arrival; and, no level of damage after bird ingestion occurred more often during arrival than departure. In summary, bird ingestions for engine classes B, C and D during departure phases of flight have higher level of engine damage.

The report also had data specifically related to core ingestions. Figure 6.1 and Table 6.1 from the report show that most bird ingestion events that resulted in core ingestion occurred during departure; and that the severity of core damage, as defined in the report, occurs more often during departure. In the report, a core ingestion tree diagram was presented (Figure 6.3). The figure maps the result of each of the 183 core ingestion events observed over the data collection time period. Twenty-six of the total core ingestions resulted in surge but no physical core damage and all of these were during departure. Fifty-six of the total core ingestions resulted in physical core damage and had equal number of events during departure and arrival; however, no surge issues were recorded during arrival, while five of the departure events resulted in non-recoverable surge. The largest amount of the total core ingestions resulted in no core damage or surge. Of these, the number of departure and arrival events was very similar.

### D2 "*Engine Bird Ingestion Experience of the Boeing 737 Aircraft – Expanded Data Base*"

Data for this study included engine models JT8D and CFM56 and was collected over a thirty-six month period between October 1986 and September 1989. These engines would represent class D. Table 6.5 from the report shows the analysis results for two sets of flight phases; Take-off and Climb (T/C), and Approach and Landing (A/L). Over the three year period when data was collected, there were 1107 bird ingestion engine events where the phase of flight was known. Of these, 674 events occurred during the combined T/C phases, while 406 events occurred during the combined A/L phases. In terms of the frequency of ingestion events, the data indicated that the combined T/C phases occur more often than the frequency of the combined A/L phases.

The table also shows number of known phase of flight occurrences where a bird ingestion event resulted in damage to the engine. Unfortunately, the damage was not differentiated between core and bypass. For the combined T/C phases, there were 300 recorded events. Likewise, for the combined A/L phases there were 96 recorded events.

The last column shows the known phase of flight occurrences where a bird ingestion event resulted in engine failure. Of the ingestion events that caused engine damage, 9% of them resulted in engine failure. For the combined T/C phases there were 35 recorded events and for the combined A/L phases there were 2 recorded events. The results show that the probability of engine damage for engine class D is greater when the ingestion occurs during the Take-off and Climb phases of flight.

D3 "*Study of Bird Ingestions into Small Inlet Area Aircraft Turbine Engines*"

Data for this study included engine models ALF502 and TFE731 and was collected over a twenty-four month period between May 1987 and April 1989. The engine model JT15D and was also collected but over a twelve month period. These engines would represent classes E and F. Table 5.6 from the report shows the analysis results for two sets of flight phases; Take-off and Climb, and Approach and Landing. Over the two year period where data was collected, there were 156 bird ingestion engine events where the phase of flight was known. Of these, 75 events occurred during the combined Take-off and Climb phases, while 70 events occurred during the combined Approach and Landing phases. In terms of the frequency of ingestion events, the data indicated that the two combined phases were similar.

The table also shows the number of known phase of flight occurrences where a bird ingestion event resulted in damage to the engine. Unfortunately, the damage was not differentiated between core and bypass. For the combined T/C phases, there were 56 recorded events and for the combined A/L phases there were 33 recorded events.

The last column shows the known phase of flight occurrences where a bird ingestion event resulted in engine failure. Of the ingestion events that caused engine damage, 10% of them resulted in engine failure. For the combined T/C phases there were 5 recorded events and for the combined A/L phases, there were 4 recorded events. The results show that for engine classes E and F there was not a significant difference in flight phases for engine damage as the result of bird ingestions events.

## Appendix E. Summary of FAA Regulations

14 CFR § 33 prior to Amdt. 33-6 applied bird ingestion standards via 14 CFR §§ 33.13 (Design Features) and 33.19 (Durability) with the actual test conditions specified in AC 33-1(1965), 33-1A (1968) and 33-1B (1970). The requirements in AC 33-1B later became the basis for paragraph 14 CFR § 33.77 in Amdt. 33-6.

14 CFR § 33 Amdt. 33-6 (effective date 10/31/1974) introduced new paragraph 14 CFR § 33.77 (Foreign Object Ingestion). Foreign objects were defined as birds, water, hail, rotor blade fragments, sand and gravel, and tire tread.

a. The bird requirements covered small flocking birds (3 oz.), medium flocking birds (1.5 lb.) and large single bird (4 lb.).
b. The small and medium flocking bird requirements include run-on with no greater than 25% thrust loss.
c. The large single bird criteria are safe shutdown (no run-on required).

14 CFR § 33 Amdt. 33-10 (effective date 3/26/1984) revised paragraph 14 CFR § 33.77 in a number of areas, two related to bird ingestion, as follows:

a. Added a specific 5-minute run-on period for small and medium flocking birds (no specific run-on time period was included in the original rule).
b. Added a definition for inlet area (previously not defined).

14 CFR § 33 Amdt. 33-20 (effective date 12/13/2000) deleted the existing bird ingestion requirements from 14 CFR § 33.77, and introduced new paragraph 14 CFR § 33.76 (Bird Ingestion). The new paragraph was a significant expansion of bird requirements over the previous regulation. Significant changes for larger engines included:

a. The medium bird mass changed from 1.5 lb. for all engines to a combination of 1.5 lb. plus 2.5 lb. birds as a function of engine size.
b. The medium bird run-on time period changed from 5 minutes (no throttle movement) to a 20 minute run-on with throttle movements simulating an air turn-back and landing.
c. The large single bird mass changed from 4 lb. for all engines to 4 lb., 6 lb. or 8 lb. as a function of engine size.
d. This section was revised (effective date 1/1/2004) to correct typographical errors in the original 14 CFR § 33.76 Amdt. 33-20 publication.

14 CFR § 33 Amdt. 33-23 (effective date 11/16/2007) revised 14 CFR § 33.76 to add a new class of bird requirement called Large Flocking Birds for larger size engines, as follows:

a. One large flocking bird is ingested with a mass equal to 4.1 lb., 4.5 lb. or 5.5 lb. based on engine size.
b. The run-on requirement is a 20 minute period of operation with throttle movements simulating an air turn-back and landing, and no greater than a 50% rated take-off thrust loss.
c. Updated the safety analysis reference (§ 33.75 revision) for large single bird.
d. All other requirements from original § 33.76 are unchanged.
e. This section was further revised by Amdt. 33-24 (effective date 11/17/2007) to update regulatory references.

Appendix F. ICAO Noise Abatement Departure Profiles

The International Civil Aviation Organization has established Noise Abatement Departure Profiles to minimize the noise impact of departing aircraft on local communities. There are two NADP's, one for departure from airports in close proximity to communities and another for farther communities.

NADP 1
This profile reduces noise in close proximity to the departure end of an airport runway
This has higher power setting and lower airspeeds initially after take-off. Requires operators to:

(a) Initial climb to at least 800ft Above Airport Elevation (AAE):
 - (i) power set for take-off,
 - (ii) flaps/slats in take-off configuration, and
 - (iii) climb speed V2 + 10 to 20 kt.

(b) At or above 800 ft. AAE:
 - (i) initiate power reduction;
 - (ii) maintain a climb speed V2 + 10 to 20 kt,
 - (iii) maintain flaps/slats in take-off configuration.

(c) At or below 3000 ft AAE:
 - (i) maintain positive rate of climb;
 - (ii) accelerate to en route climb speed; and
 - (iii) Retract flaps/slats on schedule.

(d) At 3000 ft AAE, transition to normal en route climb speed.

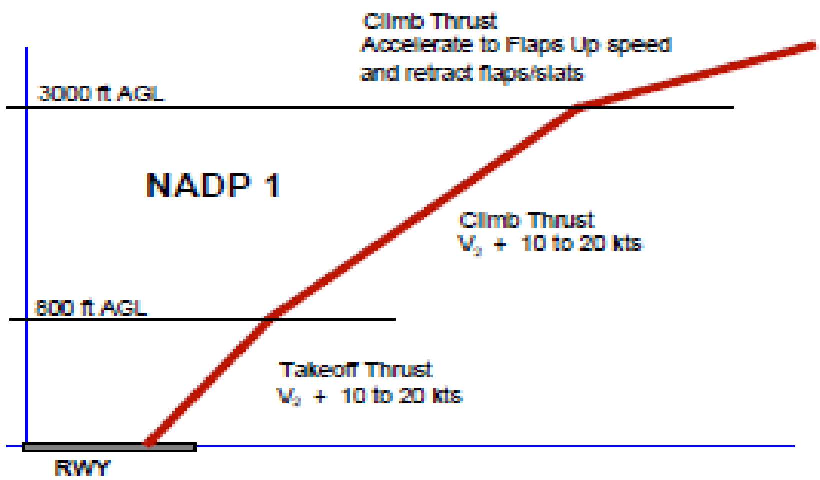


**Figure 1: NADP Near Departure Profile**

NADP 2
NADP 2 profiles reduce noise over an area more distant from the runway end and involve a lesser power setting to mitigate the noise

a) initial climb to at least 800 ft AAE:
 - (i) power as set for take-off,
 - (ii) flaps/slats in take-off configuration, and
 - (iii) climb speed V2 + 10 to 20 kt.

(b) At or above 800 ft. AAE, maintain a positive rate of climb and accelerate towards Vzf (flap retraction speed) and either

(i) reduce power with the initiation of the first flap retraction; or

(ii) reduce power after flaps/slats retraction.

(c) Continue the climb to 3000 ft AFE at a climb speed of Vzf + 10 to 20 kt.

(d) At 3000 ft AAE, transition to normal en route climb speed.

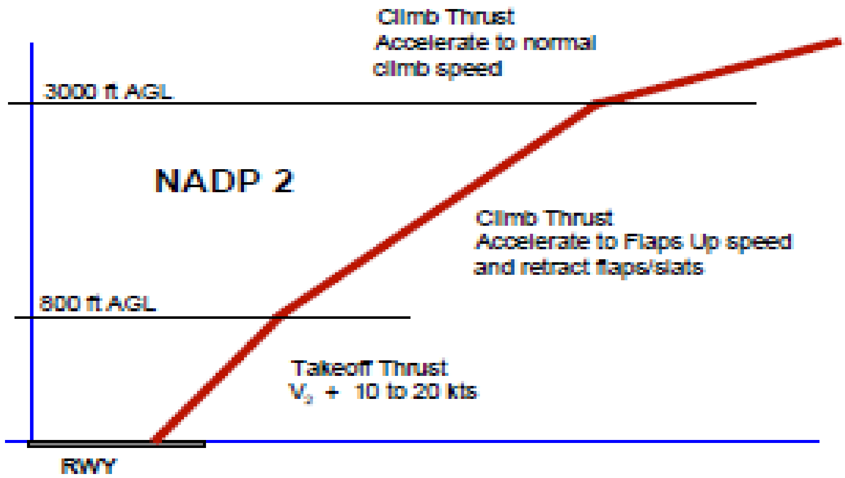


**Figure 2: NADP Distant Departure Profile**

Below are flight profiles for the A320 (class D inlet engines) in a study from the Minneapolis Airport.

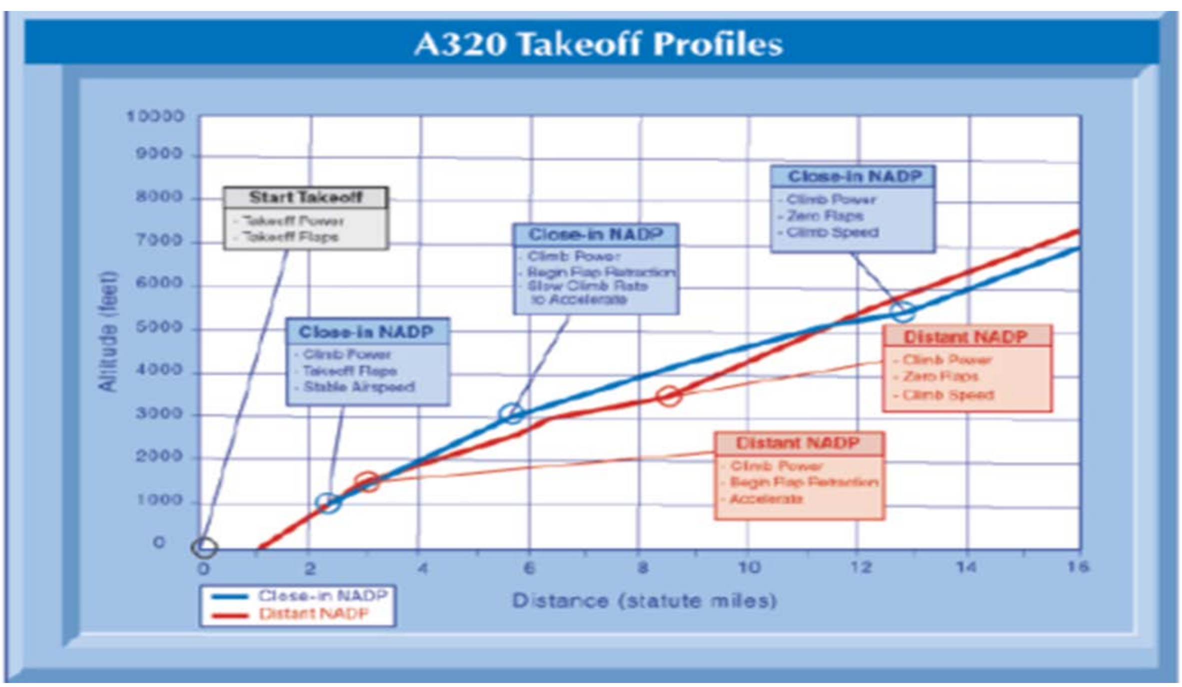


**Figure 3 Noise Departure Profiles for KMSP Airport**

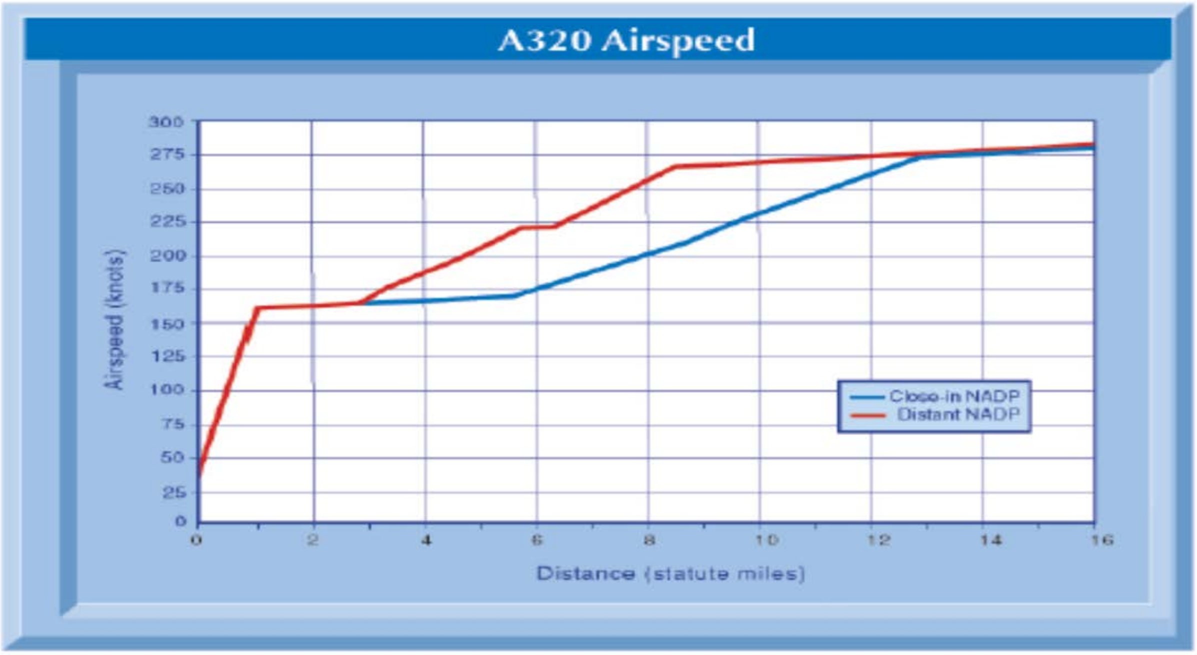


**Figure 4 : Noise Departure Profiles for KMSP Airport**

The critical part is the airplane accelerates between 4 and 8 nautical miles from the airport from 200-250 knots with an altitude transition from 1500 – 3200 feet AGL.

Appendix G. Large Flocking Bird at Engine Size Class D– Impact Energy Viewpoint

NTSB recommendation A-10-65 proposed that the current LFB rule be extended downward in inlet area to apply to class D engines in addition to classes A, B and C. A simple analysis of fan blade impact energies at the class D engine size has been completed in order to demonstrate the view that a separate LFB test at this engine size is not of value and therefore not necessary.

In order to understand the difference between the various current relevant bird rules at the class D size a theoretical model was constructed to provide fan blade impact energies. Typical parameters such as fan blade tip diameter, variation of inlet angle and setting angle across the span and hub tip ratio were assumed. In addition, typical rotational speeds for the engine radius identified were assumed and the appropriate forward speeds were taken from the rule definitions.

Figure 1 contains the basic results from the analysis presented in the form of impact energy vs percentage span for the class D MFB and Large Single Bird (LSB) rule conditions in addition to the class C engine LFB conditions.

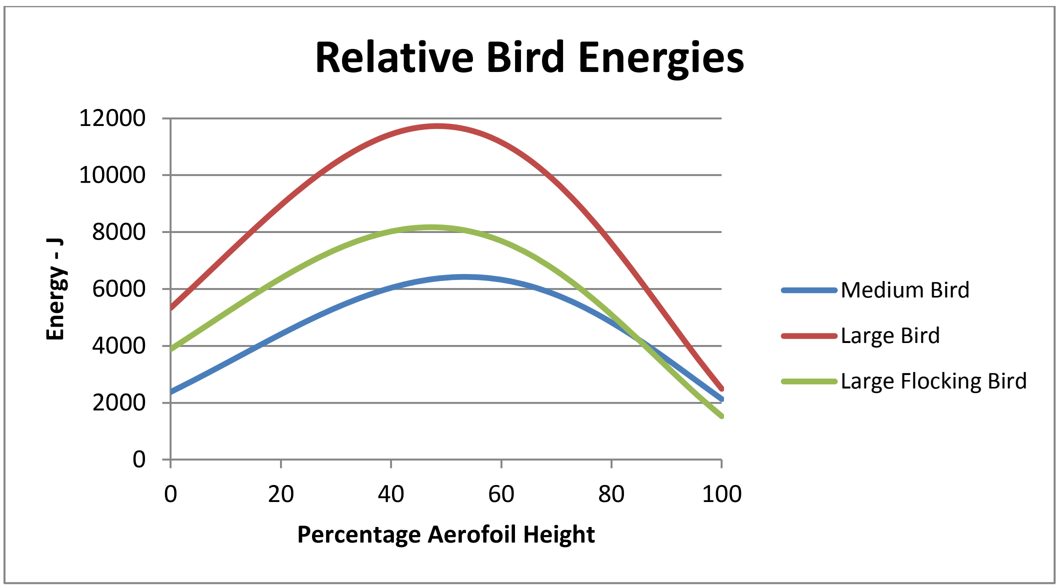


**Figure 1. – Relative Energy Levels of Existing Rule Conditions**

The first conclusion to make from this data is that if the LFB class C rule as is were mandated at class D engine size then it would not be more severe than the existing class D medium bird rule at all positions on the fan blade; there is a clear cross-over at ~85% span where the existing MFB would become more severe. This hints at redundancy for any LFB rule.

The second conclusion to make from the data is that from the minimum LFB height of 50% to the cross-over defined above, the typical actual distance for a class D engine would be of the order of 8”. Given all the other (non-bird strike) design requirements for fan blades, it is considered very unlikely that having designed a blade satisfactorily to withstand an energy at ~85%, a zone of significant ‘weakness’ could exist below this to 50% height.

The third conclusion is that the energy from the current LSB rule is considerably bigger than either the current MFB rule or the class C LFB rule. Again, it is considered very unlikely that in the design of a fan blade for a safe shut down at the LSB condition (without causing a more severe event than the fan blade-off defined in 33.94 or CSE 810) there would be no subtle increase of capability of a fan blade for strikes with smaller birds. This observation is borne out by service events e.g. US Airways 1549 event where extra capability in addition to that tested clearly does exist.

Given that at 50% height the MFB impact energy is not as great as the class D LFB impact energy, the model as generated was then used to perform an iterative exercise to establish what bird mass a MFB energy level would be equivalent to at the LFB conditions. This data is presented in Figure 2.

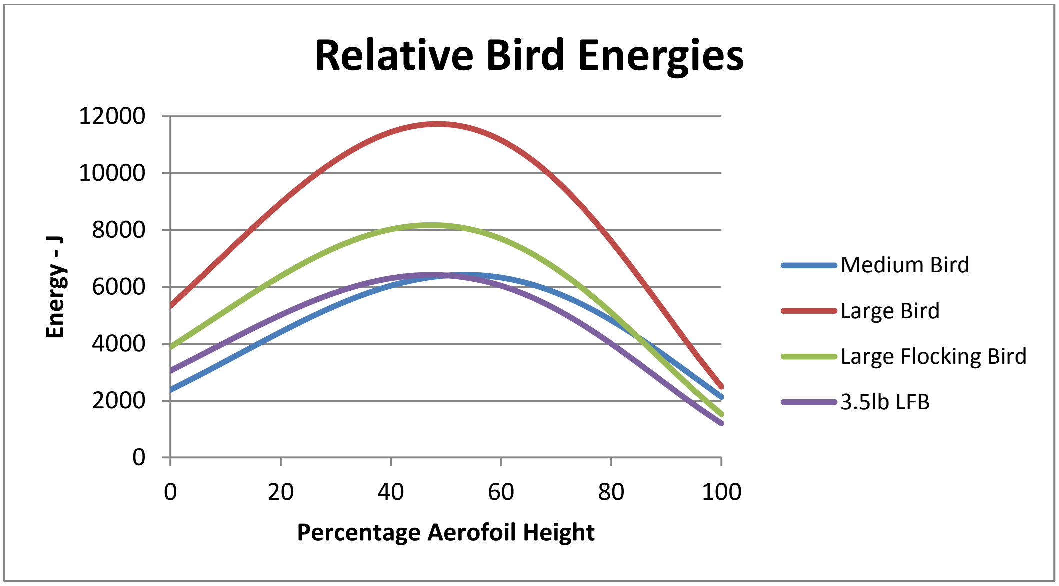


**Figure 2. – Relative Energy Levels of Existing Rule Conditions and 3.5lb LFB**

From this exercise it is concluded that the existing MFB class D requirement is already equivalent to a LFB of 3.5lb which is a very significant proportion of the class C engine level of 4.1lb.

In addition it should be noted that the MFB peak energy level occurs at a slightly higher radius (i.e. closer to the more vulnerable fan blade tip) than the LFB and as such the comparison in Figure 2 is conservative.

Overall it is concluded that the addition of a LFB requirement at class D size could not be shown clearly to add any significant additional capability to fan blade designs in this category and as such its introduction cannot be supported as a safety improvement.

Mr. Craig R. Bolt
Assistant Chair, Aviation Rulemaking Advisory Committee (ARAC)
Pratt & Whitney
400 Main Street, Mail Stop 165-30
East Hartford, CT 06108

23 February, 2015

Dear Mr. Bolt,

The Avionics Systems Harmonization Working Group (ASHWG) has reviewed the report provided by Mr. Wilborn and Mr. Jacobsen from the FAA, titled “Part 121/129 Low Airspeed Alerting Analysis, Review of Design Mitigations.”

Many thanks to Mr. Wilborn and Mr. Jacobsen for providing the ASHWG with the opportunity to review and comment.

The report included two low speed alerting design mitigation options:

- Option 1: Add low airspeed aural caution – Implement an aural alert to trigger at an airspeed above the stall warning speed by an appropriate margin
- Option 2: Ensure compliance with latest §25.1329(h) requirements on low speed awareness (must protect against, or alert to, low airspeed)

<u>ASHWG Feedback on the Options</u>:
It is not completely clear what the difference is between the two design mitigation options. Both would seem to require at least an aural low speed alert. What would the rest of the Option 1 requirements be if they are not the same as the CFR 14 25.1329(h) requirements?

The analysis should consider a third design mitigation, to demonstrate that existing aircraft are compliant with the latest 25.1329(h) using the latest Acceptable Means of Compliance.

There was no additional ASHWG feedback on the methodology described in the report. However, there is some feedback on the technical challenges the manufactures may face in implementing a feasible (let alone compliant) solution:

- An interface to the various Stall Warning Computers may be needed for a particular aircraft type, in order to obtain a “Maneuvering Speed” value which is basically an Angle of Attack before that for Stick Shaker. That will likely turn many of the “Software Only” change fields in the report to “Software+Hardware” change and increase complexity. For example, on one particular aircraft a Maneuvering Angle of Attack (AOA) equivalent to Maneuvering Speed was needed, and that had to come from a Stall Margin/Yaw Damper computer to provide that signal.

> *NOTE: The ASHWG members will provide any updates for specific aircraft that should change from a "Software Only" to a "Software + Hardware" update. This will be provided no later than 13 March, 2015*.

- As an alternative, Maneuvering AOA could be probably calculated from raw AOA but would need to be corrected for Flap position and for some aircraft types, thrust. That would still likely require aircraft wiring changes.

Regarding the cost data in the report:

1. Cost – The costs appear to be off by nearly an order of magnitude.
    a. Need to consider
        i. OEM design/cert non-recurring. This may include development costs to determine a suitable 'maneuvering speed' or 'maneuvering AOA' if that data does not exist. This may require simulator or aircraft testing.
        ii. Supplier design/cert non-recurring, and
        iii. Updating training simulators for 3 different simulator suppliers.
    b. Each of the three is easily $200-500K, with the supplier cost easily approaching $1M many times.
    c. The cost of certification for the OEM and supplier is significant.
    d. Recommend that a minimum cost of $600k be used in the analysis for the SW only changes, $1M for SW+HW (minor) and $2.5M for SW+HW(major).
2. Some applications may incur additional costs:
    a. May have more than one LRU
        i. One for the visual effect (PFD), and
        ii. One for the aural effect (EGPWS or warning/alerting system) of the alert.
        iii. OEM design costs also must consider airframe wiring when multiple LRUs are involved.

iv. Recommend that for a complex change (more than one LRU) the total cost be doubled for the analysis.

The cost / benefit analysis may consider a different set of benefits for freighter fleets, as well as account for any regional or global differences in the cost per fatal accident. The level of safety should be equivalent, however, regardless of the flight operations. For example, the expected cost per fatality in the EU is estimated around € 2 M rather than $ 9.1 M - this will have an effect on the cost-benefit ratio.

In addition to the report, a follow up file titled “LAA Fleet Projection for Cost Benefit” was provided to the ASHWG, providing additional detail for the fleet projection used in the cost-benefit calculations for the low airspeed alert analysis.

Regarding the fleet data/sizing, the FAA report should clarify the scope and intent of the Part 121/129 rules and how might they read. For example, what are the target fleets for retroactive implementation of the low speed alert? Certain fleets were considered to be excluded for various reasons when the ASHWG survey was developed. A Part 121 rule applies to all models unless stated otherwise.

Additional feedback regarding the fleet data/sizing

1) The graph plotted on the far right of the table shows the gray area as “Flt Env Prot”. Many airplanes included in there do not have Flight Envelope Protection that would meet any requirement, so the gray area should also state that it includes airplanes that already have a low airspeed alert.

2) The B747-800 in the FBW section should be moved to Non-FBW and listed as B747-8.

3) The B777-300 shows only 2 airplanes. There are closer to 500. The search should include the 777-300ER.

4) The 767-400 has the Boeing standard low airspeed alert as a basic feature. Change from SW Only to None.

5) The 747-400 has the Boeing standard low airspeed alert as an option and most have it. Change from SW Only to None.

6) The 757-200, 767-200, and 767-300 should be changed from SW Only to HW & SW. Most will require a HW change to a SW loadable EICAS computer.

Best regards,

Clark Badie,

Avionics Systems Harmonization Working Group