3rd Technical Report

On Propulsion System and Auxiliary Power Unit (APU) Related Aircraft Safety Hazards

A joint effort of The Federal Aviation Administration and The Aerospace Industries Association

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Questions concerning distribution of this report should be addressed to:

Federal Aviation Administration
Manager, Engine and Propeller Directorate.

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I. FOREWORD

The material presented in this “Third CAAM Report” has been developed by experts from industry and the FAA under the auspices of the Aerospace Industries Association (AIA) Propulsion Committee (PC). At the request of the FAA, the AIA PC sanctioned the reconvening of the Continued Airworthiness Assessment Methodologies (CAAM) Committee to update the database of safety-significant propulsion system and APU historical malfunctions.

This report contains the following material:

1. Standardized definitions of safety-significant propulsion system and auxiliary power unit (APU) malfunctions, and rationale for definition changes from the first and second CAAM reports;
2. Standardized definitions of propulsion system and APU-related aircraft hazard levels based on the consequences to the aircraft, passengers and crew, and rationale for definition changes from the first and second reports;
3. Data on safety-significant event quantities, hazard ratios, rates and generic summaries for severe and serious events during the period 2001 through 2012; and
4. Pareto prioritization of safety-significant propulsion system and APU malfunctions.

The material presented is not separable and should be considered in its entirety. The safety-significant events were gathered and analyzed based on the malfunction and aircraft hazard level definitions. These definitions are fundamental keys to understanding the data presented and they are unique to this activity. The material presented in the first and second CAAM reports have proved extremely valuable in addressing propulsion-related safety concerns; this third report attempts to address questions and open issues generated by almost 25 years' use of the first and second reports.

It should be noted that differences in the participating organizations and in event classification norms between the CAAM1, CAAM2, and CAAM3 groups may have introduced variation in reported event rates.

It is likely that further opportunities for clarification or improvement of consistency will be identified during the use of the data presented in this report. The users are encouraged to provide comments or suggestions to this effect, which may be used during further updates of the CAAM database.

II. BACKGROUND

In 1993, the Aerospace Industries Association (AIA) provided the Federal Aviation Administration (FAA) with a study aimed at the development of more effective methods to identify, prioritize and resolve safety-related problems occurring on commercial aircraft engines. This initial Continued Airworthiness Assessment Methodologies (CAAM) study covered a variety of propulsion system and auxiliary power unit (APU) events, presenting historical data on event frequency and severity at the airplane level. The information was used by the FAA Engine and Propeller Directorate to help identify and prioritize responses to individual engine, propeller and APU safety concerns. It also proved vital to the development of effective safety initiatives in the propulsion community.

Between 1994 and 2002, the FAA developed a common process, for use by both the Engine & Propeller Directorate and the Transport Airplane Directorate, to assess propulsion safety concerns in service, and to determine what corrective action each concern might merit. This common process, based in part on the CAAM study, was formalized in AC39.xx. It became apparent during the disposition of public comments to the draft AC39.xx (1999 version, eventually published as AC39-8) that the CAAM database needed to be updated to support full use of the AC, and that the spectrum of events addressed needed to be expanded, to address the safety concerns of FAA TAD. An AIA group was tasked with this update in 2001, and collected the data presented in the second CAAM report, published in 2005.

In 2012, the FAA asked the AIA to form a group tasked with a third update to the CAAM database, and provide a report. This third report provides historical safety data that document propulsion system and APU-related aircraft safety hazards, for the time period 2001 to 2012 inclusive. Due to the availability of credible data, the scope is limited to the propulsion systems (including APUs) of western-built transport category airplanes. The event characterization (hazard level) used follows the general practice of the first and second CAAM reports, except in those cases where use of the hazard levels had disclosed major anomalies and inconsistencies. The updated CAAM hazard levels are defined in Appendix 1 of this report, with documented rationale for changes from the hazard level definitions used in the first and second reports.

In this third CAAM Report, twelve years of engine, propeller and APU events are analyzed and grouped by event cause (i.e., uncontainment, fire, etc.) and hazard level. Data is presented on safety-significant event quantities, hazard ratios, rates and generic summaries for severe and serious events. The causes are also ranked, in terms of their contribution to the overall propulsion-related accident rate.

III. SCOPE

The data collection for level 3 and higher events covered the time period 2001-2012 inclusive. Data collection for some of the most numerous events, such as In Flight Shutdowns (IFSDs) and Rejected Take Offs (RTOs), was limited in some cases to a one-year sample, and the event incidence over twelve years was then extrapolated.

The fleet covered was western-built transport category airplanes. A complete categorical listing of airplane types is provided in Appendix 5. It should be recognized that data reporting is most complete from the fleets of major commercial operators; many of the smaller airplane models listed in Appendix 5 may not have had a single event reported to a CAAM committee member. Reporting of events on out-of-production airplanes was also problematic.

Military airplanes, even those certified with commercial type-certificates, were excluded on the grounds that the operational environment of military aircraft was not typical of the commercial fleet.

IV. DISCUSSION

The data contained in the initial CAAM report and in the CAAM2 report have been used by the FAA's Engine and Propeller Directorate since 1994, and have become an important part of the safety management process. This third report updates that data to cover the time period 2001 through 2012 and further refines the scope of data collected to optimize its usage by the FAA's Transport Airplane Directorate. The report also refines and includes the relevant definitions and descriptions integral to the analyses.

CONCLUSIONS/RECOMMENDATIONS

The conclusions/recommendations developed are as follows:

1. The data should be used to prioritize safety-related industry studies, research and regulatory development activities.

2. The data continue to demonstrate the importance of human factors in propulsion-related flight safety, especially in the turboprop fleet, and the need for early industry consideration of how these issues can best be addressed. Additionally, reduction of multiple-engine powerloss events, focusing upon the turboprop fleet and also upon fuel exhaustion, deserves continued industry attention.

3. The data will be beneficial to safety professionals within industry in placing the various propulsion system and APU-related flight safety issues into proper context and in guiding decision making related to potential hazards associated with the defined propulsion system and APU malfunctions.

4. The CAAM3 team recommends that OEMs continue data collection to support the next CAAM data update. The CAAM3 team will provide a data collection template, using the lessons learned from this latest update, to facilitate collection of events in the desired format as they occur. This will greatly shorten the time needed to capture and process data for the next update, and has a potential for allowing more frequent updates. It is recognized that there is a desire to shorten the CAAM update interval; however, significant resources are required on a CAAM data update as a whole, and therefore steps outlined above will streamline OEM collection, sanitization and coordination with engine & airframers counterparts to accomplish an update.

5. The process of collecting data to provide context for in-service events should be considered for the entire aircraft.

6. Efforts to harmonize the implementation of Continued Airworthiness between the FAA and foreign authorities should receive continuing attention.

7. It is generally recommended that follow-on studies, addressing a topic in more detail, precede any decision to take regulatory action based on this report.

DATA ANALYSIS METHODS

Hazard ratios (conditional probabilities) were generally not calculated for events with no occurrences in the numerator (i.e., no events at the designated hazard level or above.) There should be no assumption that hazard ratios in those instances are 0. See AC39-8 (CAAM AC), Appendix 3, for a discussion of methods for estimating the hazard ratio.

The data in this report are organized into the following categories:

1. Turboprop,
2. Low bypass ratio (LBPR) turbofan engines, and
3. High bypass ratio (HBPR) turbofan engines.

Note: For significant events, the HBPR data was also organized by generation. Some events could not be characterized by generation because of lack of information.

Where appropriate, non-revenue service events have been included to add information applicable to the calculation of hazard ratios. These events are not counted in the rates per flight summarized in the Pareto charts below (and in Figures 58 through 65).

Much of the information in the second CAAM Report was included, without details, in AC39-8 (CAAM AC), Appendix 8. That AC was issued on September 9, 2003. In the time since the AC was issued and the second CAAM Report was prepared, additional information was provided that either added new events or revised the information (especially, the reported severity) of certain events.

HAZARD LEVEL 4 AND 5 EVENT STATISTICAL SUMMARY

For easy reference, tables of all hazard level 4 and 5 events is presented here in Pareto format, together with the fleet exposure for 2001 through 2012. Figure 1 contains the Pareto for the high bypass turbofan-powered aircraft fleet. Figure 2 contains the Pareto for the combined high bypass and low bypass turbofan-powered aircraft fleet. Figure 3 contains the Pareto for turboprop-powered aircraft. These three figures are mirrored in Appendix 4 in Figures 59, 61, and 63 on pages 139, 141, and 143 respectively. The combined data for all aircraft models in the CAAM3 study is shown in Pareto format in Figure 65, page 145. Additionally, Pareto charts for events including hazard level 3 as well as hazard level 4 and 5 events are included in Appendix 4 in Figures 58 through 65, pages 138-145. More detailed analysis of each category is available in Appendix 3, Propulsion System and APU-Related Safety Hazards.

FIGURE 1. PARETO OF ALL HAZARD LEVEL 4 AND 5 EVENTS (HIGH BYPASS TURBOFAN AIRCRAFT)

REVENUE SERVICE 2001 THROUGH 2012

(Mirrored in Figure 59)

MALFUNCTIONS	NUMBER EVENTS		RATE PER A/C FLIGHT
MULTI-ENGINE POWERLOSS – NON-FUEL		15	4.78E-08
Other	*6*		
Environmental - Non-Bird	*4*		
Environmental - Birds	*4*		
Maintenance	*1*		
FUEL LEAK		6	1.91E-08
CREW ERROR		5	1.59E-08
MULTI-ENGINE POWERLOSS – FUEL		4	1.28E-08
Fuel exhaustion	*3*		
Fuel mismanagement	*1*		
OTHER - HUMAN INGESTION		4	1.28E-08
PSMRR		3	9.57E-09
UNCONTAINED - ALL		3	9.57E-09
Disk	*1*		
Blades / Stators	*1*		
Other/Unknown	*1*		
FUEL TANK RUPTURE/EXPLOSION		1	3.19E-09
STRUT / PYLON FIRE		1	3.19E-09
CASE BURNTHROUGH		0	
CASE RUPTURE		0	
COWL SEPARATION		0	
ENGINE SEPARATION		0	
REVERSER/BETA – INFLIGHT DEPLOY		0	
TAILPIPE FIRE		0	
UNDER-COWL FIRE		0	
TOTAL - HIGH BYPASS TURBOFANS		42	1.34E-07
All High Bypass Turbofan A/C flights 2001-2012:		313,534,579	

FIGURE 2. PARETO OF ALL HAZARD LEVEL 4 AND 5 EVENTS
(ALL TURBOFAN AIRCRAFT – HIGH BYPASS AND LOW BYPASS)
REVENUE SERVICE 2001 THROUGH 2012
(Mirrored in Figure 61)

MALFUNCTIONS	NUMBER of EVENTS		RATE PER A/C FLIGHT
MULTI-ENGINE POWERLOSS – NON-FUEL		17	5.06E-08
Other	*8*		
Environmental - Non-Bird	*4*		
Environmental - Birds	*4*		
Maintenance	*1*		
PSMRR		7	2.08E-08
FUEL LEAK		7	2.08E-08
CREW ERROR		6	1.79E-08
MULTI-ENGINE POWERLOSS – FUEL		5	1.49E-08
Fuel exhaustion	*4*		
Fuel mismanagement	*1*		
OTHER - HUMAN INGESTION		4	1.19E-08
UNCONTAINED - ALL		3	8.93E-09
Disk	*1*		
Blades / Stators	*1*		
Other / Unknown	*1*		
FUEL TANK RUPTURE/EXPLOSION		1	2.98E-09
STRUT / PYLON FIRE		1	2.98E-09
CASE BURNTHROUGH		0	
CASE RUPTURE		0	
COWL SEPARATION		0	
ENGINE SEPARATION		0	
REVERSER/BETA – INFLIGHT DEPLOY		0	
TAILPIPE FIRE		0	
UNDER-COWL FIRE		0	
SUBTOTAL TURBOFANS		51	1.52E-07
Turbofan A/C flights 2001-2012		335,896,903	

FIGURE 3. PARETO OF ALL HAZARD LEVEL 4 AND 5 EVENTS (TURBOPROP AIRCRAFT)
REVENUE SERVICE 2001 THROUGH 2012
(Mirrored in Figure 63)

MALFUNCTIONS		NUMBER EVENTS	RATE PER A/C FLIGHT
PSMRR		7	1.89E-07
MULTI POWER LOSS - NON-FUEL		5	1.35E-07
Environmental	*1*		
Other	*4*		
Maintenance	*0*		
CREW ERROR		3	8.08E-08
MULTI POWER LOSS - FUEL		3	8.08E-08
Fuel exhaustion	*2*		
Fuel mismanagement	*1*		
HUMAN FATAL CONTACT		2	5.39E-08
PROPELLER MALFUNCTION		1	2.69E-08
AUTOFEATHER/PITCH LOCK		0	
ENGINE FIRE		0	
FUEL LEAK		0	
PROPELLER SEPARATION/DEBRIS		0	
REVERSER/BETA - INFLIGHT DEPLOY		0	
TAILPIPE FIRE		0	
TOTAL TURBOPROPS		21	5.66E-07
Turboprop A/C flights 2001-2012		37,130,431	

V. RELATIONSHIP TO PREVIOUS CAAM DATA

A complete comparison of the definitions and definitional changes and associated rationale for each iteration of the CAAM report is contained in Table 1, Historical Comparison of Severity Level Descriptions and Rationale for CAAM3 Changes, pages 21-38.

CAAM data has been collected over a series of three time periods. Subsequent to the initial CAAM1 report, CAAM2, and now CAAM3, the team has taken the opportunity to review and revise the definitions used to both classify the event categories themselves and to grade the severity of the individual events. These definition revisions have been made based on lessons learned from using the data in practice. The result of these changes is that data categories in CAAM3 have the potential to be, to some degree, more or less encompassing than the same titled data categories in CAAM1 and/or CAAM2. Additionally, changes to the severity grading of events results in some events that could be graded more or less severe if they had been evaluated in different reporting periods.

As a result, some of the event categories in CAAM3, while retaining the naming conventions of the previous studies, may not be directly combined with similar data categories in the previous CAAM reports. In these instances the data in categories which are affected by these changes should be analyzed as "stand-alone" datasets.

While care should be taken to review definitions to determine applicability before combining data from the different CAAM reports for any category, the committee has identified the following categories where this warning may be especially applicable:

1. Undercowl fires: While the basic definition of an undercowl fire has not substantially changed across the reports, it was noted that two of the Hazard Level 3 events captured in the CAAM2 report involve fuel leaks from the strut/pylon area. Strut/Pylon fires have been specifically broken out as their own category in the CAAM3 report where no such category existed in CAAM2 or CAAM1. It is unknown if any of the lower level undercowl fires from the CAAM1 or CAAM2 reports would have been categorized differently from the new CAAM3 Pylon/Strut fire category.

2. Tailpipe fires: Tailpipe fire data was not specifically captured in its own category in the CAAM1 report, although the "Other" category contains four Hazard Level 3 events that appear consistent with Tailpipe fires. CAAM2 and CAAM3 both capture Tailpipe fire data, however, clarification to the Level 3 uncontrolled fire definition may have resulted in some Tailpipe fires in the CAAM3 report being graded differently from CAAM2.

3. Fuel Leaks: The CAAM3 report includes a definition for a Hazard Level 3.h. Fuel Leak. As this definition did not exist in the CAAM2 report, caution should be exercised in comparing this data category between reports.

4. Reverser/Beta Malfunction – In-Flight Deploy: The CAAM1 report contained only a "Reverser" category. In the CAAM2 report this was divided into Reverser/Beta Malfunction – In-Flight Deploy and Reverser/Beta Malfunction – Failure to Deploy categories. The CAAM3 report only collected data in the Reverser/Beta Malfunction – In-Flight Deploy category. The result is that caution should be exercised in utilizing the CAAM1 Reverser category in combination with the CAAM2 and/or CAAM3 Reverser/Beta Malfunction categories.

VI. GENERAL NOTES AND COMMENTS

Note 1. It is recognized that not all of the events that have occurred during the time period 2001-2012 on the applicable fleet were known to the CAAM team, although it is believed that all of the most severe events (i.e., levels 4 and 5) and most of the substantial damage events (i.e., level 3) were captured. Furthermore, the CAAM committee recognizes that not all events may make their way into the reporting organizations' databases. As a result, the data presented here may not represent a completely comprehensive dataset for the less severe events. Therefore, the hazard ratios developed in this document may be more severe than in actuality; conversely, if rates are developed for lower-level events, these may underestimate the true occurrence rate.

Note 2. The expansion of the data collection to cover a much broader range of events has inevitably created overlap within the event categorization. A single event might be counted as a fuel leak, as an IFSD, and as a fire. On no account should the reader sum events or calculate rates and then sum them; this would likely overstate the total number of events or the overall event rate. Where total event counts and total event rates are presented in this Report, this has been taken into account.

Note 3. This database provides data to supplement engineering judgment. The user is cautioned to make every effort to confirm that the data is indeed applicable to the individual situation being considered by the user, with due regard to installation effects, type-specific architecture and other technical considerations.

Note 4. No attempt was made to collect data on type of operation (passenger, non-revenue, cargo, etc.), as it was apparent from earlier studies that this data was unavailable for the majority of lower-level events.

Note 5. The collection of data on the flight phase in which the event occurred was sporadic, and the lack of consistent data on flight phases precludes useful analyses.

Note 6. A conscious decision was made in CAAM2 not to attempt to collect data on maintenance errors. The committee considered that maintenance error was a causal factor, and that the focus of the CAAM database was in collecting events and their airplane-level effects, not their causes. CAAM3 maintains this consideration and did not attempt to collect these data. If maintenance error was involved in a level 3 or higher event, it was so noted in the narrative.

Note 7. The following datasets which were collected in CAAM2 were not collected in CAAM3, since they have not been used in practice, and do not appear to present a significant hazard level 3/4/5 potential. The team felt that there was sufficient data in the CAAM2 report to understand these perceived threats, and that the effort required to capture this data in CAAM3 would not justify the benefit of having this additional data.

- Fumes/cabin smoke. CAAM2 developed criteria for smoke/fumes inside the airplane. Recent events have seen significant external smoke on start up that impaired visibility of flight deck to ground crew operations. The CAAM3 team agreed that this type of event, which did not occur inflight, was not frequent, and data did not need to be collected at this time.
- Engine overspeed (overspeed events resulting in disk burst are reported under uncontainment)
- False/misleading engine indication
- Oil/ hydraulic fluid leak
- Hot air leak
- Failure to deploy reverser
- Uncontrollable high thrust – see Appendix 6 for discussion and rationale.

Note 8. When safety and risk assessment involve the airplane system indication and warning features required by Title 14, Code of Federal Regulations Part 25, such as in the case of fuel leaks, the user is requested to coordinate with the airplane OEM to ensure credit for indication and warning thresholds are provided in the assessment.

Note 9. In the context of this report, the high bypass turbofans engine generations are considered to be as defined in the AIA Project Report on High Bypass Ratio Turbine Engine Uncontained Rotor Events, page 21, published in January 2010, with CAAM3 clarifications as noted below:

> **First generation high bypass turbofan.** Those designed in the late 1960s, such as the JT9D, RB211-22B, CF6-6 and CF6-50. The CF34-3 is also assigned to this group.
>
> **Second generation high bypass turbofan.** Those designed in the 1980s with the understanding and incorporation of lessons learned from the first generation. Usage is consistent with SAE report AIR 4770 and the first and second CAAM reports. These include the ALF502, ALF507, AE3007, CFE738, CF34-8, TFE731-20/40/60, CF6-80A, CF6-80C and later CF6 models, CFM56-2, CFM56-3 and CFM56-5 models, V2500, PW2000, RB211-535C, RB211-524B4 and later RB211 models, RR Tay and PW4000-94.
>
> **Third generation high bypass turbofan.** Those designed to incorporate the lessons learned from the second generation. Third generation engines include the GE90-94"/ 115", CFM56-7, CF34-10, PW4000 100"/112" fan, PW6000, Trent500, Trent700, Trent800, BR710, and BR715.
>
> **Fourth generation high bypass turbofan.** Those designed to incorporate the Lessons Learned from the third generation. Fourth generation engines include GEnx, GP7000, Trent 900, Trent 1000, and BR725.

Note 10. As in previous CAAM reports and noted above, data was not collected on unintended reverser deploy on the ground. There may be other failure event scenarios where the potential for a catastrophic outcome is evident, but no such outcome has occurred as yet. Collection of data on the number of lower-level events of this nature may be considered in future activities, with due regard given to the capability of the data-collection system to observe and record such an event.

Note 11. As safety-significant events in certain categories are reducing, the events counts are as well. Users are cautioned that when combining events from CAAM1, CAAM2, and CAAM3 reports to generate an overall hazard ratio, the user must ensure that the assessment of the events are of similar or like nature, and that the definitions of events are consistent.

Note 12. Turboprop events which are included in the numerical analyses and summaries in Appendix 3 are also captured in the Turboprop Events section, beginning on page 124.

VII. FLEET UTILIZATION

FIGURE 4. FLEET UTILIZATION DURING CAAM STUDIES

	TURBOPROP			JET/LOW BYPASS PRESSURE RATIO (LBPR)			ALL HIGH BYPASS PRESSURE RATIO (HBPR)		
TIME PERIOD	**1982 - 1991**	**1992 – 2000**	**2001-2012**	**1982 - 1991**	**1992 – 2000**	**2001-2012**	**1982 - 1991**	**1992 - 2000**	**2001-2012**
ENGINE HOURS	See NOTE 1	43.6E6	8.32E7	19.4E7	10.6E7	6.7E7	23.1E7	51.4E7	123.4E7
ENGINE CYCLES	See NOTE 1	50.6E6	7.58E7	24.3E7	13.9E7	4.6E7	9.3E7	22.8E7	62.8E7
AIRPLANE FLIGHTS	78.3E7	25.3E6	3.79E7	8.1E7	4.5E7	2.2E7	3.9E7	10.1E7	31.4E7

	1ST GENERATION HIGH BYPASS RATIO			2ND GENERATION HIGH BYPASS RATIO (See NOTE 2)			3RD/4TH GENERATION HIGH BYPASS RATIO (See NOTE 3)		
TIME PERIOD	**1982 - 1991**	**1992 - 2000**	**2001-2012**	**1982 - 1991**	**1992 – 2000**	**2001-2012**	**1982 - 1991**	**1992 - 2000**	**2001-2012**
ENGINE HOURS	15.3E7	11E7	3.3E7	7.8E7	40.2E7	106.2E7	-	-	11.8E7
ENGINE CYCLES	4.5E7	3E7	1.8E7	4.9E7	19.8E7	57.3E7	-	-	3.4E7
AIRPLANE FLIGHTS	1.4E7	0.9E7	5.7E6	2.3E7	9.2E7	29.0E7	-	-	1.7E7

NOTE 1: Engine hours and cycles for turboprop aircraft were not collected for the CAAM1 time period.

NOTE 2: CAAM2 did not break out differences between 2nd and 3rd generation HBTF engines, which were combined in the 2nd generation total.

NOTE 3: CAAM3 does not break out differences between 3rd and 4th generation HBTF engines. 3rd and 4th generation HBTF engines are separate from 1st generation and 2nd generation HBTF engines in CAAM3.

VIII. CAAM3 TEAM MEMBERS (signatures on file)

Sarah Knife (co-chair) GE	Van Winters (co-chair) Boeing
Geoffrey Armstrong Bombardier	Ann Azevedo FAA
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Ian Thatcher Rolls-Royce	Dennis Tilzey Boeing
Phillippe Vigarios Airbus	Doug Zabawa Pratt & Whitney

Les McVey's (GE) contributions to this report, and to the safety of engines from bird ingestion, are remembered by his colleagues and the industry. RIP.

The team also expresses appreciation to Eduardo Cerdeir of Embraer, Fabien Darsonval of ATR, Johann Hervault of Airbus, Robin Lau of Transport Canada, G. K. (Chip) Quietzsch of FAA, Ian Roberts of Rolls-Royce, and Michael Trott of GE for their contributions to this effort.

IX. APPENDICES

APPENDIX 1

Standardized Aircraft Event Hazard Levels and Definitions

This appendix outlines the definitions of propulsion system and auxiliary power unit (APU) malfunctions or related incidents, in certain cases coupled with crew error or other aircraft system malfunctions, resulting in the following consequences to the aircraft or its passengers/crew. Although level 1 and level 2 are not controlled in the regulatory requirements for Continued Airworthiness, it is recognized that some manufacturers have found it useful to discriminate between level 1 events and level 2 events; thus, the level 1 and level 2 definitions are presented here. This presentation does not imply that FAA Transport Airplane Directorate concurs with these definitions. These definitions do not necessarily align with certification regulations.

It is important to emphasize that all event classification is based on what actually occurred rather than what might have occurred. It is inappropriate to inflate the hazard level for an event in the name of conservatism; such a practice is likely to lead to confusion and dissension, as well as a reduction in the ability to differentiate between the risks posed by different unsafe conditions.

The definitions below have been changed in some cases from previous CAAM updates to create a stronger link between the assigned severity and the airplane consequence. **Changes from previous CAAM definitions are shown in bold font;** the historical relationship with previous CAAM studies and the rationale behind the changes is provided in the section titled Rationale for Changes in Severity Levels, summarized in Table 1, which follows the hazard level definitions**.**

<u>LEVEL 0 – CONSEQUENCES WITH NO SAFETY EFFECT.</u>

a. In-flight shutdown of a single engine with no airplane-level effect other than loss of thrust and associated services, above **the standard 1500 ft. take-off/climb transition altitude as defined by § 25.111 Takeoff Path.**.

b. Casing uncontained engine failure, contained within the nacelle.

c. Malfunctions or failures that result in smoke and/or fumes that have no effect on crew or passengers beyond their notice of the event. The production of smoke or fumes as a consequence of some failures or malfunctions is an expected condition for which the airplane is designed and crew procedures are established and no unsafe condition exists.

d. Rejected takeoff with no runway excursion or overrun.

e. Fuel leak with no operational effect beyond an IFSD, or of which the crew remained unaware throughout the flight (may have been noticed post-flight).

LEVEL 1 - MINOR CONSEQUENCES.

a. Uncontained nacelle damage confined to affected nacelle/APU area.

b. Uncommanded power increase, or decrease, at an airspeed above V1 and occurring at an altitude **below 1500 ft.**[1] (includes IFSDs).[2]

c. Multiple propulsion system **thrust loss of 10% or more (at the engine level) (ref. FAA AC 33.28)**, temporary in nature while engine self-recovers, where normal functioning is restored on all propulsion systems and the propulsion systems function normally for the rest of the flight. Includes common cause environmental hazard-induced events.

d. Separation of propeller**, cowling, nacelle, or other** components which cause no other damage.

e. Uncommanded propeller feather.

f. Propulsion system (engine or propeller) malfunctions resulting in severe vibration. In this context, high vibration is a load and frequency spectrum which exceeds the level demonstrated for compliance with §§ 33.23, 25.361, or 25.903(c) or their equivalent (e.g., engine malfunctions resulting in an imbalance exceeding the level of imbalance demonstrated under § 33.94 or its equivalent).

g. Rejected takeoff (RTO) resulting in runway excursion or overrun with no airplane damage beyond brake overheat/tire burst.

h. Fuel leak with noticeable imbalance but no operational effect beyond an IFSD.

i. Tailpipe fire of very short duration, or very small size, such as a candle flame at the centerbody.

LEVEL 2 - SIGNIFICANT CONSEQUENCES.

a. Nicks, dents and small penetrations in any aircraft principal structural element[3].

b. Slow depressurization.

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[1] 1500 feet is the standard takeoff/climb transition altitude as defined by § 25.111

[2] The concern regarding such power changes is pilot workload. Power changes affecting controllability are considered to be more severe.

[3] The CAAM1 definition related to "aircraft primary structure". CAAM2 clarified the definition as shown.

c. Controlled fires (i.e., inside fire zones[4]). Tailpipe fires that do not **cause thermal damage or require removal/replacement of airplane structure or control surfaces** or present an ignition source to normally present flammable material. **Sooting or smoke residue are acceptable without thermal damage.**

d. (1) Flammable fluid leaks that present a fire concern[5]. Specifically fuel leaks in the presence of an ignition source and of sufficient magnitude to produce a large fire.

(2) Fuel leaks presenting a range concern **so that the flight crew makes an operational decision to turn back or divert to protect fuel range capability. Crew is aware of the leak and manages operational aspects appropriately.**

(3) Holes or punctures less than 2 square inches in the low pressure fuel system or tank, caused by uncontained or cowl loss events.

e. Minor injuries.

f. Multiple propulsion system **thrust loss of 10% or greater (at the engine level)** where one engine remains shutdown but continued safe flight at an altitude 1,000 feet above terrain along the intended route is possible. This carries with it an assumption that the aircraft is at least under partial power for any length of time longer than transient events (see note associated with level 3.e.)

g. Rejected takeoff (RTO) resulting in runway excursions or overrun with airplane damage (not substantial).

h. **Separation of engine, strut, or pylon.** Separation of propulsion system, inlet, reverser blocker door, translating sleeve or similar substantial pieces of aerodynamic surface **which impact the airplane to leave nicks, dents, or scratches.** Separations on the ground in the process of cycling the reverser are excluded (i.e., low speed, post-thrust reversal.)

i. Partial in-flight reverser deployment or propeller pitch change malfunction without level 3 consequences.

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[4] The CAAM1 definition stated that controlled fires were those which were extinguished by normal on-board fire extinguishing equipment. This led to the classification of a number of events as uncontrolled fires that did not appear to the committee to meet the intent of the definition. For instance, fires which could easily have been extinguished by the onboard system had the pilot chosen to use it, small fires which were immediately extinguished by ground crew so that the pilot had no opportunity to use the onboard system, and fires which due to their location were not extinguishable by the onboard system but nevertheless presented no threat to the aircraft (such as grass fires) – all of these were categorized as "uncontrolled" according to the previous definition. The CAAM2 committee concluded that a better definition of the term "controlled" was whether the fire had impinged upon, or could have impinged upon, the remainder of the airplane. Tailpipe fire definition was refined by CAAM3 and included herein.

[5] It is recognized that the words "present a concern" initially appear inconsistent with the philosophy of deciding hazard levels according to what actually happened. The qualifiers for 2.d. were found to be necessary to eliminate those fuel leaks that were so small that, although outside maintenance manual limits, they had no airplane-level effect. Further consideration confirms that the severity level for 2.d. is based on the actual fuel leak, not on the potential consequence of uncontrolled fire or fuel exhaustion.

j. Malfunctions or failures that result in smoke or toxic fumes that cause minor impairment or minor injuries to crew and/or passengers.[6]

LEVEL 3 - SERIOUS CONSEQUENCES.

a. Substantial damage to the aircraft or second unrelated system.

(1) "Substantial damage[7]" in this context means damage or structural failure that adversely affects the limit loads capability of a primary structural element, the performance or flight characteristics of the aircraft, and that would normally require major repair or replacement of the affected components. (Typically not considered “substantial damage” are engine failure damage limited to the engine or mount system, bent fairings or cowlings, dented skin, small puncture holes in the skin or fabric, or damage to landing gear associated with runway departures, wheel, tires, flaps, engine accessories on the failed engine, brakes or wing tips).

(2) Damage to a second unrelated system must impact the ability to continue safe flight and landing. **“Unrelated” means not associated with or served by the engine having the initial malfunction.** Coordination and agreement between the engine/propeller/APU manufacturer and the airframe manufacturer may be required to properly categorize events related to second system damage.

(3) [**Removed**]

(4) Damage to a second engine (cross-engine debris) which results in a significant loss of thrust or an operational problem requiring pilot action to reduce power. Minor damage which was not observed by the crew during flight and which did not affect the ability of the engine to continue safe operation for the rest of the flight is excluded, being considered a level 2 event.

b. Uncontrolled fires – Fires which escape the fire zone and impinge flames onto the wing or fuselage, or act as ignition sources for flammable material anticipated to be present outside the fire zone. **Includes tailpipe fires which cause thermal damage or require the affected structure or control surface to be replaced or repaired.**

c. Rapid depressurization of the cabin.

d. Permanent loss of thrust or power greater than one propulsion system.

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[6] A level 2 event may result in an emergency being declared to initiate ATC priority sequencing. This does not inherently imply that the event was a level 3.

[7] This definition departs somewhat from the NTSB definition. Clarification was found advisable by the team after some difficulties in using the NTSB definition.

e. Temporary **loss of thrust greater than one propulsion system**. Note: For multiple-engine events that resulted in temporary total power loss, the following criteria were considered to place an event within level 3.e.: occurrence below 10,000 feet AGL or the loss of more than 5,000 feet altitude (as in situations wherein the airplane must descend to a suitable altitude prior to attempting restart). Consideration of transitory events of total power loss below 10,000 feet should consider length of transient vs. closeness to the ground as part of this evaluation.

f. Any temporary or permanent impairment of aircraft controllability caused by propulsion system malfunction, thrust reverser in-flight deployment, propeller control malfunction, or propulsion system malfunction coupled with aircraft control system malfunction, abnormal aircraft vibration, or crew error. **Events within the normal spectrum of crew response in requiring crew control inputs to regain the airplane flight path are not included.**

g. Malfunctions or failures that result in smoke or other fumes on the flight deck that result in a serious impairment. Serious impairment includes the loss of crew's ability to see flight deck instrumentation or perform expected flight duties. Purely psychological aspects of the concern of odors, etc., are not to be included; nor are concerns about long-term exposure.

h. Fuel leak resulting in a declared landing priority or Mayday due to low fuel state. Any leak resulting in landing with fuel below reserve (minimum) fuel level. Holes or punctures in aircraft fuel lines or tanks, greater than 2 square inches, caused by uncontained or cowl loss events.

LEVEL 4 - SEVERE CONSEQUENCES.

a. Forced landing. Forced landing is defined as the inability to continue flight where imminent landing is obvious but aircraft controllability is not necessarily lost (e.g., total powerloss due to fuel exhaustion will result in a "forced landing"). An air turn back or diversion due to a malfunction is not a forced landing, since there is a lack of urgency and the crew has the ability to select where they will perform the landing.[8] However, off-airport landings are almost always forced landings.

b. Actual loss of aircraft (as opposed to economic) while occupants were on board[9].

[8] Where it is unclear whether the landing was forced, it may be helpful to consider whether the pilot had any alternative to landing at the closest airport.

[9] Hull losses where the airplane could have been repaired, but repair would not have been cost effective, are excluded. Additionally, hull losses that occurred well after the event because appropriate action was not taken to further mitigate damage (i.e., fire breaking out because no fire equipment was available) are not considered hull losses for the purposes of this threat evaluation. Some degree of judgment may be required in determining whether the hull loss qualifies for inclusion.

c. Serious injuries or fatalities.[10]

d. Fatal injury due to ingestion or propeller contact.

LEVEL 5 - CATASTROPHIC CONSEQUENCES.

Catastrophic outcome[11]. An occurrence resulting in multiple fatalities, usually with the loss of the airplane.

GENERAL NOTES APPLICABLE TO ALL EVENT HAZARD LEVELS.

a. The severity of aircraft damage is based on the consequences and damage that actually occurred.

b. Injuries resulting from an emergency evacuation rather than from the event that caused the evacuation are not considered in evaluating the severity of the event. It is recognized that emergency evacuations by means of the slides can result in injuries, without regard to the kind of event precipitating the evacuation.

c. It is recognized that there is some overlap between the definitions of hazard levels and the characterization of events, particularly for the lower hazard levels. Efforts were made to develop more objective hazard level definitions, rather than defining by example; these efforts were not successful.

RATIONALE FOR CHANGES IN SEVERITY LEVELS

It had been frequently pointed out that the hazard levels assigned to the less severe events did not seem equivalent. For example, the risk associated with a rejected takeoff at 110 knots (CAAM2 hazard level 2.g.) seemed much lower than that associated with a disk burst for which large pieces did not happen to hit the airplane (hazard level 2.a.). The apparent discrepancy created a perception that the severity of an event was heavily influenced by pure chance, and raised questions over the validity of considering event severity.

[10] In this context, serious injuries are intended as injuries of a life-threatening nature. This is different from the NTSB definition, which would include most simple fractures.

[11] Extension of the use of the CAAM database to the entire propulsion system was associated with a desire to discriminate between the kind of events that resulted in a small number of serious injuries or fatalities, and those that resulted in serious injuries or fatalities to most or all of the airplane occupants. This was felt to be a useful discriminator by Transport Airplane Directorate. CAAM Level 4, as defined in the original report, was therefore split into two levels (level 4 and level 5) in CAAM2. This convention has been retained in CAAM3.

The hazard levels appeared appropriate at the time when the first CAAM team developed their definitions, with the accident record of the 1980s in their minds. Since then, changes to the operational environment and to the products have changed the kinds of propulsion accidents occurring, and the understanding of risk has changed in step. It was also apparent, after 20 years use of the CAAM process, that the great majority of the lower level events had negligible safety impacts. Bookkeeping them as level 1 or 2 distracted attention from the more safety-relevant level 2 events (e.g., disk bursts with minimal airplane damage, undercowl fires.) The industry wanted an opportunity to use level 1 and 2 statistics as an indicator of safety risk, in a proactive manner; improved consistency in severity was felt to be helpful in this approach.

The CAAM3 team took the opportunity to review the severity levels carefully to see whether they reflected the current understanding of risk. Changes were made to a number of severity level descriptions. The history of the relationship of these severity level descriptions to previous CAAM Report descriptions is provided in Table 1, "Historical Comparison of Severity Level Descriptions and Rationale for CAAM3 Changes". As above, changes from previous CAAM definitions are shown in **bold font.**

Table 1. Historical Comparison of Severity Level Descriptions and Rationale for CAAM3 Changes

Level 0 - Consequences with no safety effect			
CAAM 1	**CAAM 2**	**CAAM 3**	**Rationale for CAAM 3 Changes**
	a. In-flight shutdown of a single engine with no airplane-level effect other than loss of thrust and associated services, above <u>an altitude of 3000 feet</u>.	a. In-flight shutdown of a single engine with no airplane-level effect other than loss of thrust and associated services, above **the standard 1500 ft take-off/climb transition altitude as defined by § 25.111 Takeoff Path.**	**(Levels 0a, 1b) IFSD with no effect** The 3000 ft. altitude does not align with any version of "the critical phase of flight". CAAM intended the 1b event severity to apply to a high workload flight phase. Aligning the 1b definition with a more accepted "critical phase of flight" would make it more useful in responding to safety questions.
	b. Casing uncontained engine failure, contained within the nacelle.	b. Casing uncontained engine failure, contained within the nacelle.	
	c. Malfunctions or failures that result in smoke and/or fumes […] that have no effect on crew or passengers beyond their notice of the event. The production of smoke or fumes as a consequence of some failures or malfunctions is an expected condition for which the airplane is designed and crew procedures are established and no unsafe condition exists.	c. Malfunctions or failures that result in smoke and/or **fumes in the cabin or cockpit** that have no effect on crew or passengers beyond their notice of the event. The production of smoke or fumes as a consequence of some failures or malfunctions is an expected condition for which the airplane is designed and crew procedures are established and no unsafe condition exists.	Clarification that the smoke and fumes are inside the aircraft in areas providing environment support to the passengers or flight crew.

Level 0 - Consequences with no safety effect			
CAAM 1	**CAAM 2**	**CAAM 3**	**Rationale for CAAM 3 Changes**
		d. Rejected takeoff with no runway excursion or overrun.	**(Levels 0d, 1g, 2g) Rejected Takeoff (RTO) with no effect** The definitions for the severity of RTO are tied to the actual airplane effect, rather than an arbitrary ground speed. Operational effect was ranked in increasing severity: 0 - airplane stays on runway with no damage; 1- runway excursion/overrun with no damage beyond brake/tires; 2 - runway excursion with airplane damage (less than substantial). *See footnote 12 for additional discussion.*
		e. Fuel leak with no operational effect beyond an IFSD.	**(Levels 0e, 1h, 2d 3h) Fuel Leak with IFSD** The severity of fuel leaks forming a range concern was tied to the actual operational effect on that flight (e.g., IFSD, notable fuel imbalance, diversion for range issues, declared emergency, etc.) rather than the potential effect. *See footnote 13 for additional discussion.*

[12] **(Levels 0d, 1g, 2g) Rejected Takeoff (RTO)**
In the CAAM 3 definitions the severity of RTO is tied to the actual airplane effect, rather than an arbitrary ground speed. The original concern over RTOs was based on a number of events in the 1970s and 1980s where a heavy transport airplane near MTOGW rejected a takeoff above V1 and overran the runway, typically with considerable damage. Previous teams had been focused on the airplane speed relative to V1, but the event reporting did not support this level of detail (the reporting individual typically did not know V1 for that flight). A compromise was reached of defining "high speed RTO" as being above 100 knots. It became evident as the data was collected over decades that the 100 knot RTO was a relatively low-risk event, and was not of comparable severity to other level 2 events. It was also apparent that a number of factors had reduced the incidence of the events of concern. In keeping with the philosophy of documenting actual severity rather than potential severity, the team modified the RTO severity definitions to reflect the actual operational effect to the airplane, without reference to the ground speed. Actual operational effect was ranked in increasing severity, as: 0 -airplane stays on runway with no damage, 1- runway excursion/overrun with no damage beyond brake/tires,2- runway excursion with airplane damage (less than substantial)

[13] **(Levels 0e, 1h, 2d 3h) Fuel leak**
The team was unable to define a fuel leak size which would "be a range concern". The answer would depend upon the airplane, the planned flight, the timing and nature of flight deck indication and the crew response. The team also observed that very few fuel leaks – even large ones – were quantified. Therefore, the severity of fuel leaks forming a range concern was tied to the actual operational effect on that flight (e.g., IFSD, notable fuel imbalance, diversion for range issues, declared emergency, etc. rather than the potential effect. It was noted that many fuel leaks are discovered while the airplane is at the gate, and so operational effects are avoided. The final definition is still ambiguous, in drawing a distinction between an ATB for a leak "for convenience" and the same sequence of events with "a range concern". It is recognized that the minimal circumstantial description available for some events may make them hard to classify.

Level 1 - Minor Consequences			
CAAM 1	**CAAM 2**	**CAAM 3**	**Rationale for CAAM 3 Changes**
a. Uncontained nacelle damage confined to affected nacelle/APU area.	a. Uncontained nacelle damage confined to affected nacelle/APU area.	a. Uncontained nacelle damage confined to affected nacelle/APU area.	
b. Uncommanded power increase, or decrease, at an airspeed above V1 and occurring at an altitude below 3,000 feet (includes in-flight shutdowns (IFSD) below 3,000 feet).	b. Uncommanded power increase, or decrease, at an airspeed above V1 and occurring at an altitude below 3,000 feet (includes in-flight shutdowns (IFSD) below 3,000 feet)[1].	b. Uncommanded power increase, or decrease, at an airspeed above V1 and occurring at an altitude below **the standard take-off/climb transition altitude of 1,500 feet as defined by § 25.111 Takeoff Path**, (includes IFSDs)[1].	**(Level 1b) Uncommanded power change during critical phase of flight** The intent of the definition change is to align the classification where the event severity is higher due to the high work load environment of takeoff, and final approach. *See footnote 14 for additional discussion.*
c. Multiple propulsion system malfunctions or related events, temporary in nature, where normal functioning is restored on all propulsion systems and the propulsion systems function normally for the rest of the flight. Includes common cause environmental hazard-induced	c. Multiple propulsion system malfunctions or related events, temporary in nature, where normal functioning is restored on all propulsion systems and the propulsion systems function normally for the rest of the flight. Includes common cause environmental hazard induced events.	c. Multiple propulsion system **thrust loss of 10% or more (ref FAA AC 33.28)**, temporary in nature, where normal functioning is restored on all propulsion systems and the propulsion systems function normally for the rest of the flight. Includes common cause environmental hazard-induced events.	**(Level 1c, 2f, 3f) Multiple engine thrust loss** The original definition of multiple engine thrust loss did not give a clear understanding of how long the temporary event could be, or how much thrust loss was important. In particular, it was not clear how to classify an event as a 1.c. vs. a 3.e. The team established that a thrust loss of less than 10% per engine was not to be addressed.

[14] **(Level 1b) Uncommanded power change during critical phase of flight**
The team discussed the fact that the 3000 ft. altitude does not align with any version of "the critical phase of flight". The 1b event severity was intended to apply to a high workload flight phase. Aligning the level 1b definition with a more accepted "critical phase of flight" would make it more useful in responding to safety questions. § 25.111 identifies the takeoff path as follows: "(a) The takeoff path extends from a standing start to a point in the takeoff at which the airplane is 1,500 feet above the takeoff surface, or at which the transition from the takeoff to the en route configuration is completed and V_{FTO} is reached, whichever point is higher."

Level 1 - Minor Consequences			
CAAM 1	**CAAM 2**	**CAAM 3**	**Rationale for CAAM 3 Changes**
d. Separation of propeller/components which cause no other damage.	d. Separation of propeller/components which cause no other damage.	d. Separation of **propeller, cowling, nacelle or other components** which cause no other airplane damage.	**(Level 1d, 2h) Component separation** In the interest of consistency, and addressing actual rather than potential effects, separation of large items from the airplane without damage is now reclassified as a level 1d event. If the item hits the airplane it may be a level 2a or worse effect, depending on the nature of the damage caused. *See footnote 15 for additional discussion.*
e. Uncommanded propeller feather.	e. Uncommanded propeller feather.	e. Uncommanded propeller feather.	
f. Propulsion system (engine or propeller) malfunctions resulting in […] a load and frequency spectrum which exceeds the level demonstrated for compliance with §§ 33.23, 25.361, or 25.903(c) or their equivalent (e.g., engine malfunctions resulting in an imbalance exceeding the level of imbalance demonstrated under § 33.94 or its equivalent).	f. Propulsion system (engine or propeller) malfunctions resulting in severe vibration. In this context, high vibration is a load and frequency spectrum which exceeds the level demonstrated for compliance with §§ 33.23, 25.361, or 25.903(c) or their equivalent (e.g., engine malfunctions resulting in an imbalance exceeding the level of imbalance demonstrated under § 33.94 or its equivalent).	f. Propulsion system (engine or propeller) malfunctions resulting in severe vibration. In this context, high vibration is a load and frequency spectrum which exceeds the level demonstrated for compliance with §§ 33.23, 25.361, or 25.903(c) or their equivalent (e.g., engine malfunctions resulting in an imbalance exceeding the level of imbalance demonstrated under § 33.94 or its equivalent).	

[15] **(Level 1d, 2h) Component separation with or without damage**
The original definition of 2h was associated with the potential for a separating cowl to cause airplane damage, even if it did not cause damage. The team noted that a separating disk fragment, with far more energy, would be considered a level 1 event if it caused no airplane damage. In the interest of consistency, and addressing actual rather than potential effects, separation of large items from the airplane without damage is now reclassified as a level 1d event. If the item hits the airplane it may be a level 2a or worse effect, depending on the nature of the damage caused. The team discussed whether to exclude smaller items of a few pounds should be included or not. There was no commonly accepted lower bound for the weight/size of items which might be a concern. Including the smaller items would result in collection of more data, although smaller items would likely be under-reported – but would also make the hazard ratio of questionable validity for the larger items. The final consensus was to omit the smaller items (size undetermined).

Level 1 - Minor Consequences			
CAAM 1	**CAAM 2**	**CAAM 3**	**Rationale for CAAM 3 Changes**
		g. Rejected takeoff resulting in runway excursion or overrun with no airplane damage beyond brake overheat/tire burst.	**(Levels 0d, 1g, 2g) RTO with runway excursion minimal damage** The severity of RTO is tied to the actual airplane effect, rather than an arbitrary ground speed. Operational effect was ranked in increasing severity: 0 - airplane stays on runway with no damage; 1- runway excursion/overrun with no damage beyond brake/tires; 2 - runway excursion with airplane damage (less than substantial). *See footnote 10 for additional discussion.*
		h. Fuel leak with noticeable imbalance but no operational effect beyond an IFSD	**(Levels 0e, 1h, 2d 3h) Fuel Leak with IFSD and imbalance** The severity of fuel leaks forming a range concern was tied to the actual operational effect on that flight (e.g., IFSD, notable fuel imbalance, diversion for range issues, declared emergency, etc.) rather than the potential effect. *See footnote 11 for additional discussion.*

Level 2 – Significant Consequences			
CAAM 1	**CAAM 2**	**CAAM 3**	**Rationale for CAAM 3 Changes**
a. Nicks, dents and small penetrations in aircraft primary structure.	a. Nicks, dents and small penetrations in any aircraft principal structural element[2].	a. Nicks, dents and small penetrations in any aircraft principal structural element[2].	
b. Slow depressurization.	b. Slow depressurization.	b. Slow depressurization.	
c. Controlled fires (i.e., extinguished by on-board aircraft systems).	c. Controlled fires (i.e., inside fire zones[3]). Tailpipe fires that do not […] <u>impinge upon aircraft</u> structure […], or present an ignition source to co-located flammable material, are considered level 2 also.	c. Controlled fires (i.e., inside fire zones[3]). Tailpipe fires that do not **cause thermal damage or require replacement/repair (outside of cleaning) of airplane structure or control surfaces** or present an ignition source to co-located flammable material, are considered level 2 also. **Sooting or smoke residue are acceptable without thermal damage.**	**(Level 2c 3b) Tailpipe fires with no thermal damage** Frequently there are no eyewitness recorded stating whether flames impinged upon the airplane and witness marks must be used to establish that. Soot can be deposited on an airplane surface without flames having impinged upon the surface and with no thermal damage. The definition was modified to clarify that level 3 events were those where the surface had actually been heat-damaged by the flames. *See footnote 16 for additional discussion.*
d. Fuel leaks <u>beyond normal extinguishing capabilities, if fire had resulted. (Note: "All fuel leaks resulting from aircraft fuel cell or fuel line penetrations.")</u>	d.(1) Flammable fluid leaks that present a fire concern[4]. Specifically fuel leaks in the presence of an ignition source and of sufficient magnitude to produce a large fire.	d.(1) Flammable fluid leaks that present a fire concern[4]. Specifically fuel leaks in the presence of an ignition source and of sufficient magnitude to produce a large fire.	

[16] **(Level 2c, 3b) Tailpipe fires with or without thermal damage**

There was some ambiguity in the existing tailpipe fire definition so that it was difficult to discriminate between level 2 and level 3. Tailpipe fires do originate in fire zones, so the criterion “escapes the fire zone” did not apply, but rather “escape from the exhaust, potentially causing damage”. Frequently there are no eyewitness recorded stating whether flames impinged upon the airplane and witness marks must be used to establish that. Soot can be deposited on an airplane surface without flames having impinged upon the surface and with no thermal damage. The definition was modified to clarify that level 3 events were those where the surface had actually been heat-damaged by the flames. Note: CAAM1 and CAAM2 had different definitions for “uncontrolled fire”.

Level 2 – Significant Consequences			
CAAM 1	**CAAM 2**	**CAAM 3**	**Rationale for CAAM 3 Changes**
	d.(2) Fuel leaks that present a range concern for the airplane.	d.(2) Fuel leaks presenting a range concern **so that the flight crew makes an operational decision to turn back or divert to protect fuel range capability. Crew is aware of the leak and manages operational aspects appropriately.**	**(Levels 0e, 1h, 2d 3h) Fuel Leak with diversion or turn back** The severity of fuel leaks forming a range concern was tied to the actual operational effect on that flight (IFSD, notable fuel imbalance, diversion for range issues, declared emergency, etc.) rather than the potential effect. *See footnote 12 for additional discussion.*
		d.(3) Holes or punctures less than 2 square inches in the aircraft fuel lines or aircraft fuel tanks, caused by uncontained or cowl loss events.	
e. Minor injuries.	e. Minor injuries.	e. Minor injuries.	
f. Multiple propulsion system/APU malfunctions, or related events, where one engine remains shutdown but continued safe flight at an altitude 1,000 feet above terrain along the intended route is possible. […]	f. Multiple propulsion system or <u>APU malfunctions</u> […], or related events, where one engine remains shutdown but continued safe flight at an altitude 1,000 feet above terrain along the intended route is possible. This carries with it an assumption that the aircraft is at least under partial power for any length of time longer than transient events (see note associated with level 3.e.)	f. Multiple propulsion system **thrust loss of 10% or greater** or related events, where one engine remains shutdown but continued safe flight at an altitude 1,000 feet above terrain along the intended route is possible. This carries with it an assumption that the aircraft is at least under partial power for any length of time longer than transient events (see note associated with level 3.e.)	**(Level 1c, 2f, 3f) Multiple engine thrust loss** The original definition of multiple engine thrust loss did not give a clear understanding of how long the temporary event could be, or how much thrust loss was important. In particular, it was not clear how to classify an event as a 1.c vs. a 3e. The team established that a thrust loss of less than 10% per engine was not to be addressed.

Level 2 – Significant Consequences			
CAAM 1	**CAAM 2**	**CAAM 3**	**Rationale for CAAM 3 Changes**
g. Any high-speed takeoff abort (usually 100 knots or greater).	g. Any high-speed takeoff abort (usually 100 knots or greater).	**g. Rejected takeoff resulting in runway excursion or overrun with airplane damage (not substantial)**	**(Levels 0d, 1g, 2g) RTO with minor damage** The definitions the severity of RTO is tied to the actual airplane effect, rather than an arbitrary ground speed. Operational effect was ranked in increasing severity: 0 - airplane stays on runway with no damage; 1- runway excursion/overrun with no damage beyond brake/tires; 2 - runway excursion with airplane damage (less than substantial). *See footnote 11 for additional discussion.*
h. Separation of propulsion system, inlet, reverser blocker door, translating sleeve […] in-flight without level 3 damage consequences to the aircraft structure or systems (separations on the ground […] are excluded).	h. […] Separation of propulsion system, inlet, reverser blocker door, translating sleeve or similar substantial pieces of aerodynamic surface […] without level 3. Separations on the ground in the process of cycling the reverser are excluded (i.e., low speed, post-thrust reversal.)	h. **Separation of engine, strut or pylon.** Separation of propulsion system, inlet, reverser blocker door, translating sleeve or similar substantial pieces of aerodynamic surface **which impact the airplane to leave nicks, dents or scratches.** Separations on the ground in the process of cycling the reverser are excluded (i.e., low speed, post-thrust reversal.)	**(Levels 1d, 2h) Component separation with damage** In the interest of consistency, and addressing actual rather than potential effects, separation of large items from the airplane without damage is now reclassified as a level 1d event. If the item hits the airplane it may be a level 2a or worse effect, depending on the nature of the damage caused. *See footnote 14 for additional discussion*
i. Partial in-flight reverser deployment or propeller pitch change malfunction(s) which does not result in loss of aircraft control or damage to aircraft primary structure.	i. Partial in-flight reverser deployment or propeller pitch change malfunction without level 3 consequences.	i. Partial in-flight reverser deployment or propeller pitch change malfunction without level 3 consequences.	

Level 2 – Significant Consequences			
CAAM 1	**CAAM 2**	**CAAM 3**	**Rationale for CAAM 3 Changes**
	j. Malfunctions or failures that result in smoke or toxic fumes that cause minor impairment or minor injuries to crew and/or passengers[5].	j. Malfunctions or failures that result in smoke or toxic fumes that cause minor impairment or minor injuries to crew and/or passengers[5].	

Level 3 – Serious Consequences			
CAAM 1	**CAAM 2**	**CAAM 3**	**Rationale for CAAM 3 Changes**
a. Substantial damage to the aircraft or second unrelated system.	a. Substantial damage to the aircraft or second unrelated system.	a. Substantial damage to the aircraft or second unrelated system.	
a.(1) The National Transportation Safety Board (NTSB) definition of "substantial damage[…]" means damage or structural failure that adversely affects the structural strength, performance or flight characteristics of the aircraft, and that would normally require major repair or replacement of the affected components. ([…]Not considered "substantial damage" are engine failure damage limited to the engine […], bent fairings or cowlings, dented skin, small puncture holes in the skin or fabric, or damage to landing gear […], wheel, tires, flaps, engine accessories […], brakes or wing tips).	a.(1) "Substantial damage[6]" in this context means damage or structural failure that adversely affects the limit loads capability of a primary structural element, the performance or flight characteristics of the aircraft, and that would normally require major repair or replacement of the affected components. (Typically not considered "substantial damage" are engine failure damage limited to the engine or mount system, bent fairings or cowlings, dented skin, small puncture holes in the skin or fabric, or damage to landing gear associated with runway departures, wheel, tires, flaps, engine accessories on the failed engine, brakes or wing tips).	a.(1) "Substantial damage[6]" in this context means damage or structural failure that adversely affects the limit loads capability of a primary structural element, the performance or flight characteristics of the aircraft, and that would normally require major repair or replacement of the affected components. (Typically not considered "substantial damage" are engine failure damage limited to the engine or mount system, bent fairings or cowlings, dented skin, small puncture holes in the skin or fabric, or damage to landing gear associated with runway departures, wheel, tires, flaps, engine accessories on the failed engine, brakes or wing tips).	

Level 3 – Serious Consequences			
CAAM 1	**CAAM 2**	**CAAM 3**	**Rationale for CAAM 3 Changes**
a.(2) Damage to a second unrelated system must impact the ability to continue safe flight and landing. Coordination and agreement between the engine/propeller/APU manufacturer and the airframe manufacturer may be required to properly categorize events related to second system damage. In general, aircraft are designed to be dispatched with one part of a redundant system inoperative with no effect on flight-safety. Therefore, an uncontained rotor event which severed an unrelated hydraulic system line without significantly degrading the ability to continue safe flight should not be considered a level 3.a. event.	a.(2) Damage to a second unrelated system must impact the ability to continue safe flight and landing. […] Coordination and agreement between the engine/propeller/APU manufacturer and the airframe manufacturer may be required to properly categorize events related to second system damage.	a.(2) Damage to a second unrelated system must impact the ability to continue safe flight and landing. **“Unrelated” means not associated with/ served by the engine having the initial malfunction.** Coordination and agreement between the engine/propeller/APU manufacturer and the airframe manufacturer may be required to properly categorize events related to second system damage.	a.(2) “Unrelated means not associated with or served by the engine having the initial malfunction.

Level 3 – Serious Consequences			
CAAM 1	**CAAM 2**	**CAAM 3**	**Rationale for CAAM 3 Changes**
a.(3) Small penetrations of aircraft fuel lines or aircraft fuel tanks, where the combined penetration areas exceed two square inches […], is a level 3.a. classification. Assistance of the airframe manufacturer should be sought when questions arise.	a.(3) Small penetrations of aircraft fuel lines or aircraft fuel tanks, where the combined penetration areas exceed two square inches[7]. Assistance of the airframe manufacturer should be sought when questions arise.	a.(3) Small penetrations of aircraft fuel lines or aircraft fuel tanks, where the combined penetration areas exceed two square inches[7]. Assistance of the airframe manufacturer should be sought when questions arise.	
a.(4) Damage to a second engine (cross-engine debris) which results in a significant loss of thrust or an operational problem requiring pilot action to reduce power is a level 3.a. event. Minor damage which was not observed by the crew during flight and which did not affect the ability of the engine to continue safe operation for the rest of the flight is a level 2 event.	a.(4) Damage to a second engine (cross-engine debris) which results in a significant loss of thrust or an operational problem requiring pilot action to reduce power. Minor damage which was not observed by the crew during flight and which did not affect the ability of the engine to continue safe operation for the rest of the flight is excluded, being considered a level 2 event.	a.(4) Damage to a second engine (cross-engine debris) which results in a significant loss of thrust or an operational problem requiring pilot action to reduce power. Minor damage which was not observed by the crew during flight and which did not affect the ability of the engine to continue safe operation for the rest of the flight is excluded, being considered a level 2 event.	

Level 3 – Serious Consequences			
CAAM 1	**CAAM 2**	**CAAM 3**	**Rationale for CAAM 3 Changes**
b. Uncontrolled fires - not extinguished by on-board aircraft systems. Note: internal tailpipe fires that hazard the aircraft are considered uncontrolled fires.	b. Uncontrolled fires – which escape the fire zone and impinge flames onto the wing or fuselage, or act as ignition sources for flammable material anticipated to be present outside the fire zone.	b. Uncontrolled fires – Fires which escape the fire zone and impinge flames onto the wing or fuselage, or act as ignition sources for flammable material anticipated to be present outside the fire zone. **Includes tailpipe fires which impinge on airplane structure which cause thermal damage or require the affected structure or control surface to be replaced.**	**(Levels 2c, 3b) Tailpipe fires with thermal damage** The definition was modified to clarify that level 3 events were those where the surface had actually been heat-damaged by the flames.
c. Rapid depressurization of the cabin.	c. Rapid depressurization of the cabin.	c. Rapid depressurization of the cabin.	
d. Permanent loss of thrust or power greater than one propulsion system.	d. Permanent loss of thrust or power greater than one propulsion system.	d. Permanent loss of thrust or power greater than one propulsion system.	

Level 3 – Serious Consequences			
CAAM 1	**CAAM 2**	**CAAM 3**	**Rationale for CAAM 3 Changes**
e. Temporary or permanent inability to climb and fly 1000 feet above terrain (increased threat from terrain, inclement weather, etc.) along the intended route which results in restricted capability (i.e., multiple propulsion system malfunctions or single propulsion system malfunctions and/or other aircraft system malfunction or crew error). […]	e. Temporary or permanent inability to climb and fly 1000 feet above terrain (increased threat from terrain, inclement weather, etc.) along the intended route. Note: For multiple-engine events that resulted in temporary total powerloss, the following criteria were considered to place an event within level 3.e.: occurrence below 10,000 feet AGL or the loss of more than 5,000 feet altitude (as in situations wherein the airplane must descend to a suitable altitude prior to attempting restart). Consideration of transitory events of total powerloss below 10,000 feet should consider length of transient vs. closeness to the ground as part of this evaluation.	e. Temporary **loss of thrust greater than one propulsion system**. Note: For multiple-engine events that resulted in temporary total powerloss, the following criteria were considered to place an event within level 3.e.: occurrence below 10,000 feet AGL or the loss of more than 5,000 feet altitude (as in situations wherein the airplane must descend to a suitable altitude prior to attempting restart). Consideration of transitory events of total powerloss below 10,000 feet should consider length of transient vs. closeness to the ground as part of this evaluation.	The risk in multi-engine power loss events is the departure from the intended flight path. The new definition captures the cause of this departure without the need to define actual aircraft performance under this condition.

Level 3 – Serious Consequences			
CAAM 1	**CAAM 2**	**CAAM 3**	**Rationale for CAAM 3 Changes**
f. Any temporary or permanent impairment of aircraft controllability caused by propulsion system malfunction, thrust reverser in-flight deployment, propeller control malfunction, or propulsion system malfunction coupled with aircraft control system malfunction, abnormal aircraft vibration, or crew error.	f. Any temporary or permanent impairment of aircraft controllability caused by propulsion system malfunction, thrust reverser in-flight deployment, propeller control malfunction, or propulsion system malfunction coupled with aircraft control system malfunction, abnormal aircraft vibration, or crew error. […]	f. Any temporary or permanent impairment of aircraft **control** caused by propulsion system malfunction, thrust reverser in-flight deployment, propeller control malfunction, or propulsion system malfunction coupled with aircraft control system malfunction, abnormal aircraft vibration, or crew error. **Events within the normal spectrum of crew response in requiring crew control inputs to regain the airplane flight path are not included.**	**(Level 1c, 2f, 3f) Multiple engine thrust loss** The original definition of multiple engine thrust loss did not give a clear understanding of how long the temporary event could be, or how much thrust loss was important. In particular, it was not clear how to classify an event as a 1.c vs. a 3e. The team established that a thrust loss of less than 10% per engine was not to be addressed.
	g. Malfunctions or failures that result in smoke or other fumes on the flight deck that result in a serious impairment. Serious impairment includes the loss of crew's ability to see flight deck instrumentation or perform expected flight duties. Purely psychological aspects of the concern of odors, etc., are not to be included; nor are concerns about long-term exposure.	g. Malfunctions or failures that result in smoke or other fumes on the flight deck that result in a serious impairment. Serious impairment includes the loss of crew's ability to see flight deck instrumentation or perform expected flight duties. Purely psychological aspects of the concern of odors, etc., are not to be included; nor are concerns about long-term exposure.	

Level 3 – Serious Consequences			
CAAM 1	**CAAM 2**	**CAAM 3**	**Rationale for CAAM 3 Changes**
		h. Fuel leak resulting in a declared landing priority or Mayday due to low fuel state. Any leak resulting in landing with fuel below reserve (minimum) fuel level. Holes or punctures in aircraft fuel lines or tanks, greater than 2 square inches, caused by uncontained or cowl loss events.	**0e (Levels 0e, 1h, 2d 3h) Fuel Leak with emergency declaration** The severity of fuel leaks forming a range concern was tied to the actual operational effect on that flight (e.g., IFSD, notable fuel imbalance, diversion for range issues, declared emergency, etc.) rather than the potential effect. *See footnote 12 for additional discussion.*

Level 4 – Severe Consequences			
CAAM 1	**CAAM 2**	**CAAM 3**	**Rationale for CAAM 3 Changes**
a. Forced landing. Forced landing is defined as the inability to continue flight due to the consequences of damage, uncontrolled fire or thrust loss where imminent landing is obvious but aircraft controllability is not necessarily lost (i.e., total powerloss due to fuel exhaustion will result in a "forced landing"). The term "emergency landing" may also be used to mean a forced landing if there is an urgent requirement to land. An air turn back or diversion due to a malfunction is not a forced landing, since there is a lack of urgency and the crew has the ability to select where they will perform the landing. However, off-airport landings are almost always forced landings.	a. Forced landing. Forced landing is defined as the inability to continue flight where imminent landing is obvious but aircraft controllability is not necessarily lost (e.g., total powerloss due to fuel exhaustion will result in a "forced landing"). An air turn back or diversion due to a malfunction is not a forced landing, since there is a lack of urgency and the crew has the ability to select where they will perform the landing.[8] However, off-airport landings are almost always forced landings.	a. Forced landing. Forced landing is defined as the inability to continue flight where imminent landing is obvious but aircraft controllability is not necessarily lost (e.g., total powerloss due to fuel exhaustion will result in a "forced landing"). An air turn back or diversion due to a malfunction is not a forced landing, since there is a lack of urgency and the crew has the ability to select where they will perform the landing.[8] However, off-airport landings are almost always forced landings.	
b. […] Loss of aircraft (hull loss).	b. Actual loss of aircraft (as opposed to economic) while occupants were on board[9].	b. Actual loss of aircraft (as opposed to economic) while occupants were on board[9].	

Level 4 – Severe Consequences			
CAAM 1	**CAAM 2**	**CAAM 3**	**Rationale for CAAM 3 Changes**
c. Serious injuries or fatalities. The National Transportation Safety Board (NTSB) definition of "serious injury" means any injury that: (1) Requires hospitalization for more than 48 hours, commencing within seven days from the date the injury was received; (2) results in the fracture of any bone (except simple fractures of fingers, toes or nose);	c. Serious injuries or fatalities.[10]	c. Serious injuries or fatalities.[10]	
		d. Fatal injury due to ingestion or propeller contact.	Category definition added.

Level 5 – Catastrophic Consequences			
CAAM 1	**CAAM 2**	**CAAM 3**	**Rationale for CAAM 3 Changes**
	Catastrophic outcome[11]. An occurrence resulting in multiple fatalities, usually with the loss of the airplane.	Catastrophic outcome[11]. An occurrence resulting in multiple fatalities, usually with the loss of the airplane.	

APPENDIX 2

Event Definitions

1. PURPOSE. This appendix outlines the major propulsion system malfunction definitions and the aircraft hazard matrix, as developed by the Aerospace Industries Association (AIA) Committee on Continued Airworthiness Assessment Methodologies (CAAM), PC342.

2. MISCELLANEOUS.

a. Hazard level. Levels of threat, as defined by their effect on the airplane, passengers and crew. Appendix 1 provides a definition of these established hazard levels.

b. Hazard ratio. The conditional probability that a particular powerplant installation failure mode will result in an event of a specific hazard level.

3. SINGLE PROPULSION SYSTEM EVENT.

a. Uncontained. A significant safety event that initiates from an uncontained release of debris from a rotating component malfunction (blade, disk, spacer, impeller, drum/spool). In order to be categorized as uncontained, the debris must pass completely through the nacelle envelope. Parts that puncture the nacelle skin but do not escape or pass completely through are considered contained. Fragments that pass out of the inlet or exhaust opening without passing through any structure are not judged to be "uncontained.” Starter and gearbox (accessory) uncontainments are specifically excluded.

b. Case rupture. A significant safety event that initiates from a sudden rupture of a high-pressure vessel or case with the resultant release of high-pressure gases into the under-cowl cavity. Case ruptures resulting from uncontained release of debris from a rotating component malfunction are excluded. Case ruptures include those events that propagate from fatigue-type cracks as well as ruptures related to secondary malfunctions (e.g., flame impingement). See 3.c. below.

c. Case burnthrough. Case burnthrough is defined as a local case penetration that initiates from local overtemperature of the case external wall due to an internal engine malfunction (e.g., fuel nozzle leakage, internal bearing compartment fires, titanium fires). Burnthroughs are distinguished from ruptures by their lack of an explosive release of high-pressure gas. A common cause of case burnthrough is localized penetration due to fuel nozzle malfunction. Events involving accessory component cases also contribute to this category; for example, sump fires that propagate internally and result in burnthrough of piping or that initiate gearbox fires. The key aspect, whether in the primary gas path or accessories, is that fire initiates from an internal malfunction and proceeds to burn through a case, tube or gearbox to reach external regions.

d. Under-cowl fire. A safety-significant propulsion system fire-related event involving combustion external to the engine casings. Under-cowl fires are those that occur within the nacelle and on the engine side of the strut or installation fire barrier/wall. Internal pylon fires, including events where fuel leaks from the pylon and initiates a fire under the cowl, are to be excluded. Under-cowl may be within fire zones or flammable fluid zones. Tailpipe fires, and hot air leaks resulting in fire warnings, without combustion, are excluded from the definition and documented separately. Fires that remain internal to the engine casing are excluded[17].

e. Pylon/Strut Fire. A safety-significant fire event which initiates in/around the pylon/strut attachment area above the engine compartment in the flammable fluid leak zone and is not associated directly with engine causes or with wing fuel tank issues.

f. Flammable fluid leak. Leak of fuel, oil or hydraulic fluid into the pylon or dry bay, or under the engine cowls, which could credibly lead to a fire **or range/exhaustion concern.**[18] Leaks collected from shrouds and components and drained directly overboard by a dedicated drain were excluded from those leaks under consideration due to their lack of being fire safety concerns. Drips and seeps were also excluded. In-tank leakage was excluded.

g. Compartment overheat/air leak. High-pressure or temperature air leaks due to casing or high-pressure /temperature air duct system malfunctions within the nacelle or in the pylon.

h. Engine separation. Separation of the engine, with or without the strut/pylon. Events resulting from ground contact are excluded.

i. Cowl separation. Separation of nacelle components such as inlets, cowls, thrust reversers, exhaust nozzles, tail plugs, etc. Separation of relatively small sections of skin, blow-out panels or other small pieces that are unlikely to hazard continued safe flight and landing are excluded. Events resulting from ground contact are excluded.

j. Propulsion system malfunction recognition and response (PSMRR). *(NOTE: This category was previously denoted by Propulsion System Malfunction plus Inappropriate Crew Response (PSM+ICR). The title has been altered in this CAAM document to be consistent with current industry definitions).* A significant safety event initiating from a single propulsion system malfunction

[17] Interest was expressed during the previous CAAM2 in collecting information on internal engine fires, since they might result in shaft or disk failures. However, since data was already being collected on uncontained events – regardless of the originating failure leading to the uncontainment – this approach was not pursued in CAAM2 or CAAM3.

[18] Previous CAAM attempts to categorize the leaks by the location of the leak, the nature of the leaked fluid, the pressure of the leakage source and the magnitude of the leakage rate were somewhat unsuccessful due to the level of detail in the event records.. As before, efforts to reach consensus on the quantity of leakage presenting a fuel exhaustion concern were also unsuccessful. Data in this category was therefore not presented.

(excluding propeller system), which, by itself, does not hazard the aircraft, but is compounded by inappropriate crew response (i.e., crew did not execute checklist/normal flying duties). A typical example of PSMRR is an IFSD followed by inappropriate crew response that caused the aircraft to crash. Not counted are cases of gross error negligence (such as deciding to take off with an engine known to be inoperative). See the joint AIA and European Association of Aerospace Industries (AECMA) Project Report on Propulsion System Malfunction plus Inappropriate Crew Response (PSM+ICR), dated November, 1998, for additional examples.

k. Crew error. A significant safety event caused by a propulsion system malfunction or improper operation that was caused by an inappropriate crew action, excluding sabotage, gross negligence and suicide. Not counted are events where inappropriate crew action causes a propulsion system malfunction through very indirect means such as flying the airplane into the ground or running the airplane into equipment on the taxiway/runway.

l. Reverser/beta malfunction – in-flight deploy. A significant safety event wherein a thrust reverser deploys in-flight, or a propeller enters beta mode in-flight (exclusive of design intent).

m. Reverser/beta malfunction – failure to deploy. A significant safety event resulting from the failure of a thrust reverser to deploy or a propeller to enter beta mode when commanded.

n. Fuel tank rupture/explosion. A burst failure of a fuel tank or explosion within a fuel tank.

o. Tailpipe fire. Fire within the tailpipe, where visible sustained flames exit the tailpipe, including very short duration fires or fires of very small size, such as a candle flame at the centerbody. Engine surge/stall events and events resulting from deicing fluid ingestion[19] are excluded.

p. False/misleading indication. Indication that was appreciably different from reality, to the point where an indication difference was noticed by the pilot or subsequent investigation.[20] This included parameters that were higher than actuality, lower than actuality or completely absent, and also discrete warnings or alerts that were falsely present or absent.[21] Individual Engine Indications Crew Alerting System (EICAS) messages were excluded since these were very type-specific and numerous.

q. Fatal human ingestion/propeller contact. A condition where a maintenance crew member is ingested into a running engine or comes into contact with a running propeller.

[19] A limited volume of deicing fluid is available for combustion; hence, these events were not considered "hazardous".

[20] Undetected false /misleading indications were not collected in CAAM2 or CAAM3.

[21] No initial assumptions were made over whether a false indication would in fact be misleading. Individual Engine Indications Crew Alerting System (EICAS) messages (as opposed to mandated indications) were excluded.

4. MULTIPLE-ENGINE POWERLOSS EVENT.[22]

a. Environmental. A significant safety event initiating from essentially simultaneous power loss from multiple propulsion systems for an environmental cause (e.g., ice, rain, hail, or volcanic ash ingestion).

b. Birds. A significant safety event initiating from essentially simultaneous power loss from multiple propulsion systems due to bird ingestion.

c. Maintenance. A significant safety event initiating from multiple propulsion system power loss from clearly improper maintenance (e.g., failure to restore oil system integrity after inspection).

d. Other/unknown. A significant safety event initiating from multiple propulsion system power loss for reasons other than those characterized elsewhere, or where the initiating event(s) are unknown. This includes unrelated events of engine power loss within the same flight.

e. Fuel contamination. A significant safety event initiating from power loss from multiple propulsion systems from fuel contamination. Sequential power loss and recovery is excluded.

f. Fuel mismanagement. A significant safety event initiating from power loss from multiple propulsion systems from improper management of the airplane fuel system (e.g., tank crossfeed). Sequential power loss and recovery is excluded.

g. Fuel exhaustion. A significant safety event initiating from power loss from multiple propulsion systems from complete exhaustion of the airplane fuel reserves.

5. APU SYSTEM EVENT.

A significant APU-related safety event is as follows:

a. Uncontained. An uncontained rotating component malfunction that allows debris to exit through the APU containment casings.

b. Axial uncontained. Major rotating components that exit the APU containment casings in an axial direction (i.e., without penetrating the case).

c. Overspeed. Acceleration of a rotor beyond the speed sanctioned in the Type Certificate Data Sheet.

[22] Transient events are included if they were perceptible to the flight crew.

d. Fire. Combustion external to the APU casings. Tailpipe fire data and hot air leaks resulting in fire warnings, without combustion, are excluded from the definition and documented separately.

e. Tailpipe fire. Fires within the tailpipe and exiting the tailpipe, where flames are visible. Hot starts resulting in a "glow" are excluded.

f. Compartment overheat. High-temperature air leaks due to casing high-pressure/temperature air duct system malfunctions within the APU.

6. PROPELLER SYSTEM EVENT.

An event that initiates from a malfunction or misuse of the propeller system as follows:

a. Propeller separation/debris release. Separation of single or multiple blades, or large piece thereof, due to blade or hub malfunction. Note that events occurring after ground strike are included for their information on their threat to the aircraft or its occupants.

b. Autofeather/pitch lock. Propeller system malfunction leading to inability to control the propeller. Control hunting is excluded as a normal product behavior.

c. Propeller system malfunction recognition and response (Propeller PSMRR). A significant safety event initiating from a propeller system malfunction which, by itself, does not hazard the aircraft, passengers, or crew, but is compounded by inappropriate crew response.

d. Crew error. A significant safety event caused by a propeller system malfunction or improper operation that was caused by an inappropriate crew action, excluding sabotage, gross negligence and suicide (e.g., operation in beta mode in violation of operating instructions). Not included are events where inappropriate crew action causes a propeller system malfunction through very indirect means such as flying the airplane into the ground or running the airplane into equipment on the taxiway/runway.

7. PROPULSION SYSTEM FUME EVENT.

Significant smoke and/or fumes on the flight deck or cabin that are generated by the propulsion system. CAAM2 developed criteria for inside the airplane. Recent events have seen external smoke on start up that impaired visibility of flight deck to ground crew ops. The CAAM3 team agreed that this type of event was not frequent and data did not need to be collected at this time.

APPENDIX 3

Propulsion System and Auxiliary Power Unit (APU) Related Aircraft Safety Hazards (2001 through 2012)

UNCONTAINED BLADE[23] – 2001-2012
TURBOPROP AND JET/LOW BYPASS

FIGURE 5. UNCONTAINED BLADE – TURBOPROP AND JET/LOW BYPASS

ENGINE TYPE	TURBOPROP				JET/ LOW BYPASS			
HAZARD LEVEL	ALL	3	4	5	ALL	3	4	5
NUMBER of EVENTS BY MODULE								
FAN					6	0	0	0
Platforms					0	0	0	0
LPC	0	0	0	0	0	0	0	0
HPC / IPC	0	0	0	0	0	0	0	0
HPT / IPT	0	0	0	0	1	0	0	0
LPT/POWER TURBINE (PT)	0	0	0	0	3	0	0	0
TOTAL	**0**	**0**	**0**	**0**	**10**	**0**	**0**	**0**

UNCONTAINED BLADE TOTAL NUMBER EVENTS HAZARD LEVEL 5	= 0
UNCONTAINED BLADE TOTAL NUMBER EVENTS HAZARD LEVEL 4+5	= 0
UNCONTAINED BLADE TOTAL NUMBER EVENTS HAZARD LEVEL 3+4+5	= 0
UNCONTAINED BLADE TOTAL NUMBER EVENTS HAZARD LEVEL ALL	= 10

[23] Per AIA Project Report on High Bypass Ratio Turbine Engine Uncontained Rotor Events (published in January 2010) definitions, the Uncontained Blade category includes disk lug/post fractures.

FIGURE 6. HAZARD RATIOS FOR UNCONTAINED BLADE TURBOPROP AND JET/LOW BYPASS

ENGINE TYPE	TURBOPROP			JET/ LOW BYPASS		
HAZARD LEVEL	**(3+4+5) /ALL**	**(4+5) /ALL**	**5 /ALL**	**(3+4+5) /ALL**	**(4+5) /ALL**	**5 /ALL**
HAZARD RATIO BY MODULE						
FAN				0/6 = *	0/6 = *	0/6 = *
Platforms				0/0 = *	0/0 = *	0/0 = *
LPC	0/0 = *	0/0 = *	0/0 = *	0/0 = *	0/0 = *	0/0 = *
HPC / IPC	0/0 = *	0/0 = *	0/0 = *	0/0 = *	0/0 = *	0/0 = *
HPT / IPT	0/0 = *	0/0 = *	0/0 = *	0/1 = *	0/1 = *	0/1 = *
LPT/PT	0/0 = *	0/0 = *	0/0 = *	0/3 = *	0/3 = *	0/3 = *
ALL BLADES	0/0 = *	0/0 = *	0/0 = *	0/10 = *	0/10 = *	0/10 = *

NOTE: ALL EVENTS LIKELY UNDERREPORTED.
* HAZARD RATIO NOT CALCULATED. SEE DATA ANALYSIS METHODS, p. 4.

Event summaries – Turboprop and Jet/Low Bypass - Uncontained blade – Hazard Level 4 or 5.

Engine Type	**Event Summary**
Turboprop	**No events.**
Low Bypass	**No events.**

Event summaries – Turboprop and Jet/Low Bypass - Uncontained blade – Hazard Level 3.

Engine Type	**Event Summary**
Turboprop	**No events.**
Low Bypass	**No events.**

UNCONTAINED BLADE[23] – 2001-2012
1ST, 2ND, AND 3RD/4TH GENERATION HIGH BYPASS

FIGURE 7. UNCONTAINED BLADE – HIGH BYPASS TOTAL AND BY GENERATION – 2001 THROUGH 2012

ENGINE TYPE	ALL HIGH BYPASS				1ST GENERATION				2ND GENERATION				3RD/4TH GENERATION			
HAZARD LEVEL	**ALL**	**3**	**4**	**5**	**ALL**	**3**	**4**	**5**	**ALL**	**3**	**4**	**5**	**ALL**	**3**	**4**	**5**
NUMBER of EVENTS BY MODULE																
FAN	38	1	1	0	11	1	0	0	26	0	1	0	1	0	0	0
Platforms	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
LPC	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
HPC / IPC	1	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0
HPT / IPT	2	0	0	0	0	0	0	0	2	0	0	0	0	0	0	0
LPT/POWER TURBINE (PT)	17	0	0	0	5	0	0	0	11	0	0	0	1	0	0	0
TOTAL	58	1	1	0	16	1	0	0	40	0	1	0	2	0	0	0

UNCONTAINED BLADE TOTAL NUMBER EVENTS HAZARD LEVEL 5	= 0
UNCONTAINED BLADE TOTAL NUMBER EVENTS HAZARD LEVEL 4+5	= 1
UNCONTAINED BLADE TOTAL NUMBER EVENTS HAZARD LEVEL 3+4+5	= 2
UNCONTAINED BLADE TOTAL NUMBER EVENTS HAZARD LEVEL ALL	= 58

FIGURE 8. HAZARD RATIOS FOR UNCONTAINED BLADE HIGH BYPASS TOTAL AND BY GENERATION 2001 THROUGH 2012

ENGINE TYPE	ALL HIGH BYPASS			1ST GENERATION HBTF			2ND GENERATION HBTF			3RD/4TH GENERATION HBTF		
HAZARD LEVEL	3+4+5 /ALL	4+5 /ALL	5 /ALL	3+4+5 /ALL	4+5 /ALL	5 /ALL	3+4+5 /ALL	4+5 /ALL	5 /ALL	3+4+5 /ALL	4+5 /ALL	5 /ALL
HAZARD RATIO BY MODULE												
FAN	2/38 = .05	1/38 = .03	0/38 = *	1/11 = .09	0/11 = *	0/11 = *	1/26 = .38	1/26 = .38	0/26 = *	0/1 = *	0/1 = *	0/1 = *
Platforms	0/0 = *	0/0 = *	0/0 = *	0/0 = *	0/0 = *	0/0 = *	0/0 = *	0/0 = *	0/0 = *	0/0 = *	0/0 = *	0/0 = *
LPC	0/0 = *	0/0 = *	0/0 = *	0/0 = *	0/0 = *	0/0 = *	0/0 = *	0/0 = *	0/0 = *	0/0 = *	0/0 = *	0/0 = *
HPC / IPC	0/1 = *	0/1 = *	0/1 = *	0/0 = *	0/0 = *	0/0 = *	0/1 = *	0/1 = *	0/1 = *	0/0 = *	0/0 = *	0/0 = *
HPT / IPT	0/2 = *	0/2 = *	0/2 = *	0/0 = *	0/0 = *	0/0 = *	0/2 = *	0/2 = *	0/2 = *	0/0 = *	0/0 = *	0/0 = *
LPT/POWER TURBINE (PT)	1/17 = .06	0/17 = *	0/17 = *	0/5 = *	0/5 = *	0/5 = *	0/11 = *	0/11 = *	0/11 = *	0/1 = *	0/1 = *	0/1 = *
ALL BLADES	3/58 = .05	1/58 = .02	0/58 = *	1/16 = .06	0/16 = *	0/16 = *	1/40 = .03	1/40 = .03	0/40 = *	0/2 = *	0/2 = *	0/2 = *

* HAZARD RATIO NOT CALCULATED. SEE DATA ANALYSIS METHODS, p. 4.

Event summaries – High Bypass - Uncontained Blade – Hazard Level 4 or 5.

High Bypass	Fan blades failed leading to cabin depressurization. Fan drive shaft likely penetrated fuselage. One fatality. (Hazard Level 4.c.) 2nd generation. Twin.

Event summaries – High Bypass - Uncontained blade – Hazard Level 3.

Engine Type	**Event Summary**
High Bypass	Aircraft accumulated ice slab in inlet overnight; ingestion of slab in takeoff roll separated two fan blades below the mid-span, which were forward arc uncontained. The inlet adapter ring and bellmouth which form part of the fan fire zone boundary were destroyed. The fuel supply line, routed along the inlet, was damaged by fan blade fragments and the fuel ignited. Since the initiating event destroyed the fire zone boundaries, the fire was not limited to the fire zone. (Hazard Level 3.b.) 1st generation. Tri.

UNCONTAINED DISK[24] – 2001-2012
TURBOPROP AND JET/LOW BYPASS

FIGURE 9. UNCONTAINED DISK – TURBOPROP AND JET/LOW BYPASS

ENGINE TYPE	TURBOPROP				JET/ LOW BYPASS			
HAZARD LEVEL	ALL	3	4	5	ALL	3	4	5
NUMBER of EVENTS BY MODULE								
FAN					0	0	0	0
LPC	0	0	0	0	0	0	0	0
HPC / IPC	0	0	0	0	1	0	0	0
HPT / IPT	0	0	0	0	0	0	0	0
LPT/POWER TURBINE (PT)	0	0	0	0	1	1	0	0
TOTAL	**0**	**0**	**0**	**0**	**2**	**1**	**0**	**0**

UNCONTAINED DISK TOTAL NUMBER EVENTS HAZARD LEVEL 5	= 0
UNCONTAINED DISK TOTAL NUMBER EVENTS HAZARD LEVEL 4+5	= 0
UNCONTAINED DISK TOTAL NUMBER EVENTS HAZARD LEVEL 3+4+5	= 1
UNCONTAINED DISK TOTAL NUMBER EVENTS HAZARD LEVEL ALL	= 2

[24] Includes disks, spools, hubs, impellers.

FIGURE 10. HAZARD RATIOS FOR UNCONTAINED DISK TURBOPROP AND JET/LOW BYPASS

ENGINE TYPE	TURBOPROP			JET/ LOW BYPASS		
HAZARD LEVEL	**(3+4+5) /ALL**	**(4+5) /ALL**	**5 /ALL**	**(3+4+5) /ALL**	**(4+5) /ALL**	**5 /ALL**
HAZARD RATIO BY MODULE						
FAN				0/0 = *	0/0 = *	0/0 = *
LPC	0/0= *	0/0= *	0/0= *	0/0 = *	0/0 = *	0/0 = *
HPC / IPC	0/0= *	0/0= *	0/0= *	0/1 = *	0/1 = *	0/1 = *
HPT / IPT	0/0= *	0/0= *	0/0= *	0/0 = *	0/0 = *	0/0 = *
LPT/PT	0/0= *	0/0= *	0/0= *	1/1 = 1.0	0/1 = *	0/1 = *
ALL DISKS	0/0 = *	0/0 = *	0/0 = *	1/2 = .50	0/2 = *	0/2 = *

* HAZARD RATIO NOT CALCULATED. SEE DATA ANALYSIS METHODS, p. 4.

Event summaries – Turboprop and Jet/Low Bypass - Uncontained Disk – Hazard Level 4 or 5.

Engine Type	**Event Summary**

No events.

Event summaries – Turboprop and Jet/Low Bypass - Uncontained disk – Hazard Level 3.

Engine Type	**Event Summary**
Turboprop	No events.
Low Bypass	During takeoff inboard engine LPT uncontained disk event. Debris hit outboard engine. Both engines were reportedly on fire before returning to airport. Wing fuel tank penetrated with significant leak. **Event included in Uncontained – Disk (Primary) and Fuel Leaks**. (Hazard Level 3.a.) Quad.

UNCONTAINED DISK – 2001-2012
1ST, 2ND and 3RD/4TH GENERATION HIGH BYPASS

FIGURE 11. UNCONTAINED DISK – HIGH BYPASS TOTAL AND BY GENERATION – 2001 THROUGH 2012

ENGINE TYPE	ALL HIGH BYPASS				1ST GENERATION HBTF				2ND GENERATION HBTF				3RD/4TH GENERATION HBTF			
HAZARD LEVEL	**ALL**	**3**	**4**	**5**	**ALL**	**3**	**4**	**5**	**ALL**	**3**	**4**	**5**	**ALL**	**3**	**4**	**5**
NUMBER of EVENTS BY MODULE																
FAN	1	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0
LPC	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
HPC / IPC	2	1	0	0	0	0	0	0	2	1	0	0	0	0	0	0
HPT / IPT	3	1	1	0	1	0	0	0	1	0	1	0	1	1	0	0
LPT/POWER TURBINE (PT)	10	3	0	0	10	3	0	0	0	0	0	0	0	0	0	0
TOTAL	16	5	1	0	12	3	0	0	3	1	1	0	1	1	0	0

UNCONTAINED DISK TOTAL NUMBER EVENTS HAZARD LEVEL 5	= 0
UNCONTAINED DISK TOTAL NUMBER EVENTS HAZARD LEVEL 4+5	= 1
UNCONTAINED DISK TOTAL NUMBER EVENTS HAZARD LEVEL 3+4+5	= 6
UNCONTAINED DISK TOTAL NUMBER EVENTS HAZARD LEVEL ALL	= 16

FIGURE 12. HAZARD RATIOS FOR UNCONTAINED DISK – HIGH BYPASS TOTAL AND BY GENERATION – 2001 THROUGH 2012

ENGINE TYPE	ALL HIGH BYPASS			1ST GENERATION HBTF			2ND GENERATION HBTF			3RD/4TH GENERATION HBTF		
HAZARD LEVEL	**3+4+5 /ALL**	**4+5 /ALL**	**5 /ALL**	**3+4+5 /ALL**	**4+5 /ALL**	**5 /ALL**	**3+4+5 /ALL**	**4+5 /ALL**	**5 /ALL**	**3+4+5 /ALL**	**4+5 /ALL**	**5 /ALL**
HAZARD RATIO BY MODULE												
FAN	0/1 = *	0/1 = *	0/1 = *	0/1 = *	0/1 = *	0/1 = *	0/0 = *	0/0 = *	0/0 = *	0/0 = *	0/0 = *	0/0 = *
LPC	0/0 = *	0/0 = *	0/0 = *	0/0 = *	0/0 = *	0/0 = *	0/0 = *	0/0 = *	0/0 = *	0/0 = *	0/0 = *	0/0 = *
HPC / IPC	1/2 = .50	0/2 = *	0/2 = *	0/0 = *	0/0 = *	0/0 = *	1/2 = .50	0/2 = *	0/2 = *	0/0 = *	0/0 = *	0/0 = *
HPT / IPT	2/3 = .67	1/3 = .33	0/3 = *	0/1 = *	0/1 = *	0/1 = *	1/1 = 1.0	1/1 = 1.0	0/1 = *	1/1 = 1.0	0/1 = *	0/1 = *
LPT/POWER TURBINE (PT)	3/10 = .30	0/10 = *	0/10 = *	3/10 = .30	0/10 = *	0/10 = *	0/0 = *	0/0 = *	0/0 = *	0/0 = *	0/0 = *	0/0 = *
ALL DISKS	6/16 = .38	1/16 = .06	0/16 = *	3/12 = .25	0/12 = *	0/12 = *	2/3 = .67	1/3 = .33	0/3 = *	1/1 = 1.0	0/1 = .*	0/1 = *

* HAZARD RATIO NOT CALCULATED. SEE DATA ANALYSIS METHODS, p. 4.

Event summaries – Uncontained disk – Hazard Level 4 or 5.

Engine Type	Event Summary
High Bypass	HPT1 disk separation during maintenance ground run. Fragments impacted both LH and RH wing tanks resulting in substantial fuel leaks that ignited, resulting in hull loss. **Event included in Uncontained – Disk (primary) and Fuel Leak.** (Hazard Level 4.b.) 2nd generation. Twin.

Event summaries – Uncontained disk – Hazard Level 3.

Engine Type	Event Summary
High Bypass	HPC1 disk burst during takeoff. RTO. Fire damaged engine and impinged on wing. (Hazard Level 3.b.) 2nd generation. Twin.
	LPT1 disk uncontained during climb. Wing LE punctured, engine control cables severed. (Hazard Level 3.a.) 1st generation. Tri.
	During climb engine experienced uncontained turbine disk failure. Wing fuel tank penetration and associated fuel leak. Engine doused with foam on ground after landing but no fire. No injuries. (Hazard Level 3.a.) **Event included in Uncontained – Disk (primary) and Fuel Leak.** 3rd/4th generation. Quad.
	LPT3 disk separation; systems damage to Throttle control and fuel shutoff control to another engine (shut down with spar valve). (Hazard Level 3.a.) 1st generation. Quad.
	LPT disk spacer separation in takeoff. Disks uncontained. Hole in fuel tank access panel, <2 square inches. (Hazard Level 3.a.) 1st generation. Quad.

UNCONTAINED - OTHER[25] – 2001-2012
TURBOPROP, JET and LOW BYPASS

FIGURE 13. UNCONTAINED - OTHER – TURBOPROP AND JET/LOW BYPASS

ENGINE TYPE	TURBOPROP				JET/ LOW BYPASS			
HAZARD LEVEL	**ALL**	**3**	**4**	**5**	**ALL**	**3**	**4**	**5**
NUMBER of EVENTS BY MODULE								
FAN					0	0	0	0
LPC	0	0	0	0	0	0	0	0
HPC / IPC	0	0	0	0	0	0	0	0
HPT / IPT	0	0	0	0	0	0	0	0
LPT/POWER TURBINE (PT)	0	0	0	0	0	0	0	0
UNKNOWN	1	0	0	0	0	0	0	0
TOTAL	**1**	**0**	**0**	**0**	**0**	**0**	**0**	**0**

NOTE: ALL EVENTS LIKELY UNDERREPORTED.	
UNCONTAINED OTHER TOTAL NUMBER EVENTS HAZARD LEVEL 5	= 0
UNCONTAINED OTHER TOTAL NUMBER EVENTS HAZARD LEVEL 4+5	= 0
UNCONTAINED OTHER TOTAL NUMBER EVENTS HAZARD LEVEL 3+4+5	= 0
UNCONTAINED OTHER TOTAL NUMBER EVENTS HAZARD LEVEL ALL	= 1

[25] Includes spinners, cooling plates, spacers, air seals

FIGURE 14. HAZARD RATIOS FOR UNCONTAINED - OTHER TURBOPROP AND JET/LOW BYPASS

ENGINE TYPE	TURBOPROP			JET/ LOW BYPASS		
HAZARD LEVEL	**(3+4+5) /ALL**	**(4+5) /ALL**	**5 /ALL**	**(3+4+5) /ALL**	**(4+5) /ALL**	**5 /ALL**
HAZARD RATIO BY MODULE						
FAN				0/0= *	0/0= *	0/0= *
LPC	0/0= *	0/0= *	0/0= *	0/0= *	0/0= *	0/0= *
HPC / IPC	0/0= *	0/0= *	0/0= *	0/0= *	0/0= *	0/0= *
HPT / IPT	0/0= *	0/0= *	0/0= *	0/0= *	0/0= *	0/0= *
LPT/PT	0/0= *	0/0= *	0/0= *	0/0= *	0/0= *	0/0= *
UNKNOWN	0/1= *	0/0= *	0/0= *	0/0= *	0/0= *	0/0= *
ALL OTHER	0/1 = *	0/0 = *	0/0 = *	0/0= *	0/0= *	0/0= *

* HAZARD RATIO NOT CALCULATED. SEE DATA ANALYSIS METHODS, p. 4.

Event summaries – Turboprop and Jet/Low Bypass - Uncontained - other - Hazard level 4 or 5.

Engine Type	Event Summary
Turboprop	**No events.**
Low Bypass	**No events.**

Event summaries – Turboprop and Jet/Low Bypass - Uncontained Other – Hazard Level 3.

Engine Type	Event Summary
Turboprop	**No events.**
Low Bypass	**No events.**

UNCONTAINED - OTHER – 2001-2012
1ST, 2ND and 3RD/4TH GENERATION HIGH BYPASS

FIGURE 15. UNCONTAINED - OTHER – HIGH BYPASS TOTAL AND BY GENERATION – 2001 THROUGH 2012

ENGINE TYPE	ALL HIGH BYPASS				1ST GENERATION HBTF				2ND GENERATION HBTF				3RD/4TH GENERATION HBTF			
HAZARD LEVEL	**ALL**	**3**	**4**	**5**	**ALL**	**3**	**4**	**5**	**ALL**	**3**	**4**	**5**	**ALL**	**3**	**4**	**5**
NUMBER of EVENTS BY MODULE																
FAN	6	1	0	0	3	1	0	0	3	0	0	0	0	0	0	0
LPC	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
HPC / IPC	2	0	1	0	0	0	0	0	2	0	1	0	0	0	0	0
HPT / IPT	1	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0
LPT/POWER TURBINE (PT)	2	0	0	0	1	0	0	0	1	0	0	0	0	0	0	0
OTHER (Nozzle, etc.)	8	0	0	0	1	0	0	0	7	0	0	0	0	0	0	0
TOTAL	19	1	1	0	6	1	0	0	13	0	1	0	0	0	0	0

UNCONTAINED OTHER TOTAL NUMBER EVENTS HAZARD LEVEL 5	= 0
UNCONTAINED OTHER TOTAL NUMBER EVENTS HAZARD LEVEL 4+5	= 1
UNCONTAINED OTHER TOTAL NUMBER EVENTS HAZARD LEVEL 3+4+5	= 2
UNCONTAINED OTHER TOTAL NUMBER EVENTS HAZARD LEVEL ALL	= 19

FIGURE 16. HAZARD RATIOS FOR UNCONTAINED – OTHER - HIGH BYPASS TOTAL AND BY GENERATION – 2001 THROUGH 2012

ENGINE TYPE	ALL HIGH BYPASS			1ST GENERATION			2ND GENERATION			3RD /4TH GENERATION		
HAZARD LEVEL	3+4+5 /ALL	4+5 /ALL	5 /ALL	3+4+5 /ALL	4+5 /ALL	5 /ALL	3+4+5 /ALL	4+5 /ALL	5 /ALL	3+4+5 /ALL	4+5 /ALL	5 /ALL
HAZARD RATIO BY MODULE												
FAN	1/6 = .17	0/6 = *	0/6 = *	1/3 = .33	0/3 = *	0/3 = *	0/3 = *	0/3 = *	0/3 = *	0/0 = *	0/0 = *	0/0 = *
LPC	0/0 = *	0/0 = *	0/0 = *	0/0 = *	0/0 = *	0/0 = *	0/0 = *	0/0 = *	0/0 = *	0/0 = *	0/0 = *	0/0 = *
HPC / IPC	1/2 = .50	1/2 =.50	0/2 = *	0/0 = *	0/0 = *	0/0 = *	1/2 = .50	1/2 = .50	0/2 = *	0/0 = *	0/0 = *	0/0 = *
HPT / IPT	0/1 = *	0/1 = *	0/1 = *	0/1 = *	0/1 = *	0/1 = *	0/0 = *	0/0 = *	0/0 = *	0/0 = *	0/0 = *	0/0 = *
LPT/POWER TURBINE (PT)	0/2 = *	0/2 = *	0/2 = *	0/1 = *	0/1 = *	0/1 = *	0/1 = *	0/1 = *	0/1 = *	0/0 = *	0/0 = *	0/0 = *
OTHER (Nozzle, etc.)	0/8 = *	0/8 = *	0/8 = *	0/1 = *	0/1 = *	0/1= *	0/7 = *	0/7 = *	0/7 = *	0/0 = *	0/0 = *	0/0 = *
ALL OTHER	2/19 = .11	1/19 = .05	0/19 = *	1/6 = .17	0/6 = *	0/6 = *	1/13 = .08	1/13 = .08	0/13 = *	0/0 = *	0/0 = *	0/0 = *

* HAZARD RATIO NOT CALCULATED. SEE DATA ANALYSIS METHODS, p. 4.

Event summaries – Uncontained - other – Hazard Level 4 or 5.

High Bypass	IPC failure during cruise liberated fan blades, IPC vanes, and shaft. Stator fragments impacted fuselage and penetrated window, causing rapid depressurization and fatally injuring 1 passenger. (Hazard Level 4.c.) 2nd generation. Twin.

Event summaries – Uncontained - other – Hazard Level 3.

Engine Type	Event Summary
High Bypass	During cruise the inboard engine had a FAN disintegration failure and one of the inboard engine covers separated, striking the outboard engine. Both engines were shut down and a safe emergency landing was carried out. **Event included in Uncontained – Other (Primary). Multiple Engine Power Loss – Non-Fuel, and Cowl Separation.** (Hazard Level 3.a.) 1st generation. Quad.

UNCONTAINED - ALL PARTS – 2001-2012
ANALYSIS

FIGURE 17. UNCONTAINED - ALL – TURBOPROP AND JET/LOW BYPASS – 2001 THROUGH 2012

ENGINE TYPE	TURBOPROP				JET/ LOW BYPASS			
HAZARD LEVEL	ALL	3	4	5	ALL	3	4	5
TOTAL	1	0	0	0	12	1	0	0

FIGURE 18. UNCONTAINED - ALL – HIGH BYPASS TOTAL AND BY GENERATION – 2001 THROUGH 2012

ENGINE TYPE	ALL HIGH BYPASS				1ST GENERATION				2ND GENERATION				3RD/4TH GENERATION			
HAZARD LEVEL	ALL	3	4	5	ALL	3	4	5	ALL	3	4	5	ALL	3	4	5
TOTAL	93	7	3	0	34	5	0	0	56	1	3	0	3	1	0	0

FIGURE 19. UNCONTAINED - HIGH BYPASS COMPARISON BY GENERATION – 2001 THROUGH 2012

ENGINE TYPE	1ST GENERATION				2ND GENERATION				3RD/4TH GENERATION			
HAZARD LEVEL	ALL	3	4	5	ALL	3	4	5	ALL	3	4	5
BLADES	16	1	0	0	40	0	1	0	2	0	0	0
DISKS	12	3	0	0	3	1	1	0	1	1	0	0
OTHER	6	1	0	0	13	0	1	0	0	0	0	0
TOTAL	34	5	0	0	56	1	3	0	3	1	0	0

FIGURE 20. UNCONTAINED - HIGH BYPASS COMPARISON BY GENERATION – HAZARD RATIO

ENGINE TYPE	ALL HIGH BYPASS			1ST GENERATION			2ND GENERATION			3RD /4TH GENERATION		
HAZARD LEVEL	3+4+5 /ALL	4+5 /ALL	5 /ALL	3+4+5 /ALL	4+5 /ALL	5 /ALL	3+4+5 /ALL	4+5 /ALL	5 /ALL	3+4+5 /ALL	4+5 /ALL	5 /ALL
HAZARD RATIO BY MODULE												
BLADES	2/58 = .03	1/58 = .02	0/58 = *	1/16 = .06	0/16 = *	0/16 = *	1/40 = .03	1/40 = .03	0/40 = *	0/2 = *	0/2 = *	0/2 = *
DISKS	6/16 = .38	1/16 = .06	0/16 = *	3\12 = .25	0/12 = *	0/12 = *	2/3 = .67	1/3 = .33	0/3 = *	1/1 = 1.0	0/1 = *	0/1 = *
OTHER	2/19 = .11	1/19 = .05	0/19 = *	1/6 = .17	0/6 = *	0/6 = *	1/13 = .08	1/13 = .08	0/13 = *	0/0 = *	0/0 = *	0/0 = *
ALL	10/93 = .11	3/93 = .03	0/93 = *	5/34 = .15	0/34 = *	0\34 = *	4/56 = .07	3/56 = .05	0/56 = *	1/3 = .33	0/3 = *	0/3 = *

UNCONTAINED EVENTS RELATIONSHIP AMONG HIGH BYPASS ENGINE GENERATIONS

A total of ninety-three (93) uncontained events were collected for the high bypass fleet for CAAM3. None of these events were categorized as Hazard Level 5. Of the 93 events, 36.6% of those were on 1st generation engines, which accumulated 1.8% of the airplane fleet departures in the period. 60.2% of the events were on 2nd generation engines, which accumulated 92.5% of the airplane fleet departures in the period. A total of 3 events (3.2%) occurred on the 3rd/4th generation engines, which accumulated 5.9% of the airplane fleet departures in the period. This comparison is shown in Figure 21 below. It is important to note that the 2nd generation engine models have experienced the highest number of uncontained events during the CAAM3 period, but these engine models have also had the highest utilization during the period. Hence these events must be weighed based on rates, not on the raw numbers. The actual rate of uncontained event occurrence on 1st generation engine models is significantly higher than the newer engine models.

FIGURE 21. COMPARISON OF NUMBER OF UNCONTAINED EVENTS WITH FLEET UTILIZATION (Airplane Departures)

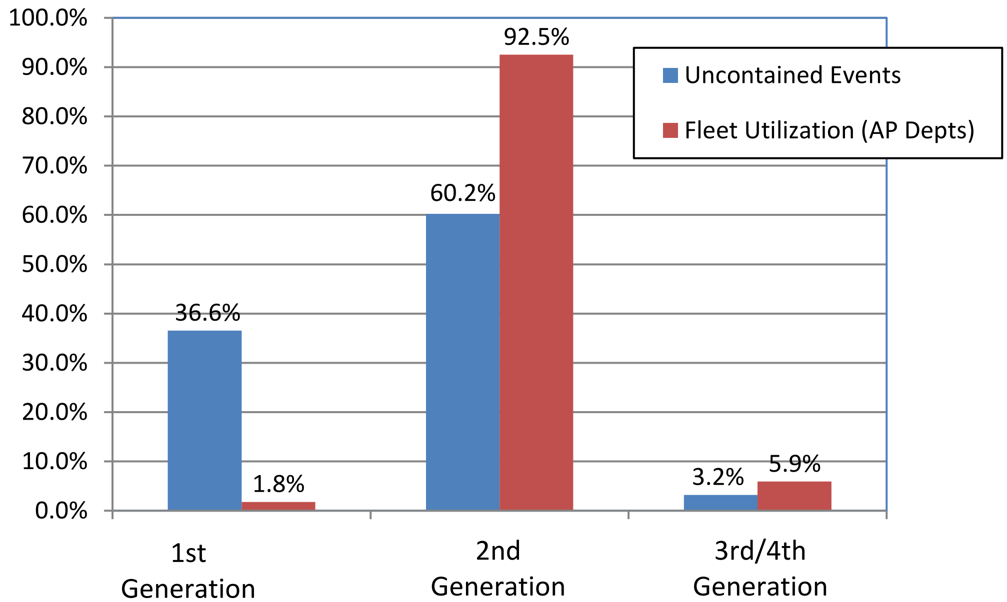


FIGURE 22. UNCONTAINED - HAZARD LEVEL 3, 4, AND 5 – JET AND LOW BYPASS DISTRIBUTION BY FLIGHT PHASE 2001 THROUGH 2012

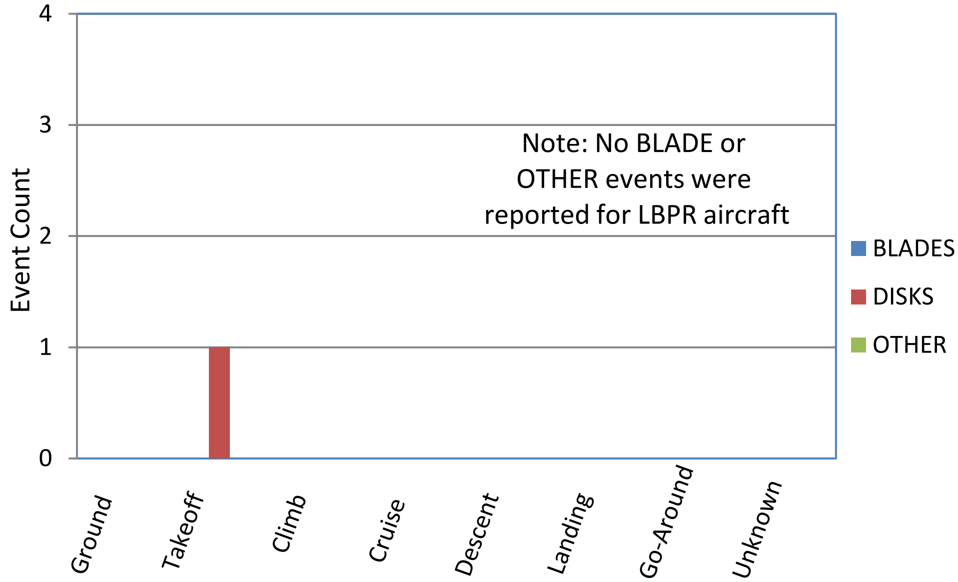
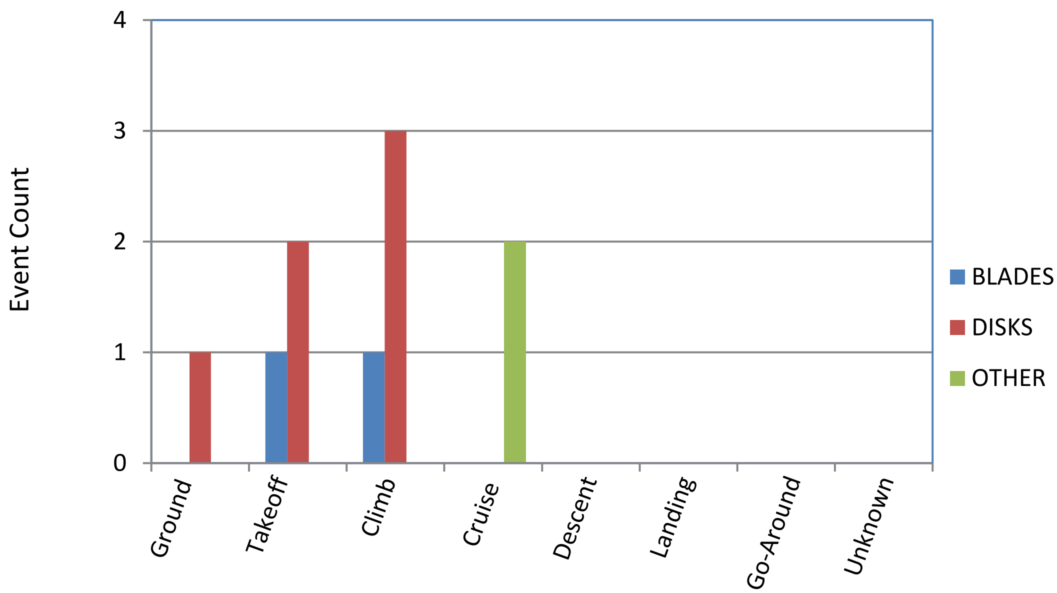


FIGURE 23. UNCONTAINED - HAZARD LEVEL 3, 4, AND 5 – HIGH BYPASS DISTRIBUTION BY FLIGHT PHASE 2001 THROUGH 2012



NOTE 1: Lower level uncontained events were not reported by flight phase for CAAM3. Hazard level 3, 4, and 5 events were reported and tallied in the plots in Figures 18 and 19.

NOTE 2: No hazard level 3, 4, or 5 uncontained events were reported for turboprop aircraft.

CASE RUPTURE

FIGURE 24. CASE RUPTURE - 2001 THROUGH 2012

ENGINE TYPE	TURBOPROP				JET/LOW BYPASS				ALL HIGH BYPASS			
HAZARD LEVEL	ALL	3	4	5	ALL	3	4	5	ALL	3	4	5
NUMBER EVENTS	0	0	0	0	0	0	0	0	2	0	0	0

ENGINE TYPE	1st Generation HBTF				2nd Generation HBTF				3rd/4th Generation HBTF			
HAZARD LEVEL	ALL	3	4	5	ALL	3	4	5	ALL	3	4	5
NUMBER of EVENTS	0	0	0	0	2	0	0	0	0	0	0	0

TOTAL NUMBER EVENTS HAZARD LEVEL 5	= 0
TOTAL NUMBER EVENTS HAZARD LEVEL 4+5	= 0
TOTAL NUMBER EVENTS HAZARD LEVEL 3+4+5	= 0
TOTAL NUMBER EVENTS HAZARD LEVEL ALL	= 2

FIGURE 25. HAZARD RATIOS FOR CASE RUPTURE

ENGINE TYPE	TURBOPROP	JET/LOW BYPASS	ALL HIGH BYPASS
LVL 5/ALL	0/0 = *	0/0 = *	0/2 = *
LVL (4+5)/ALL	0/0 = *	0/0 = *	0/2 = *
LVL(3+4+5)/ALL	0/0 = *	0/0 = *	0/2 = *

ENGINE TYPE	1st Generation HBTF	2nd Generation HBTF	3rd/4th Generation HBTF
LVL.5/ALL	0/0 = *	0/2 = *	0/0 = *
LVL.4+5/ALL	0/0 = *	0/2 = *	0/0 = *
LVL.3+4+5/ ALL	0/0 = *	0/2 = *	0/0 = *

* HAZARD RATIO NOT CALCULATED. SEE DATA ANALYSIS METHODS, p. 4.

Event summaries - Case rupture - Hazard level 4 or 5.

Engine Type	Event Summary
Turboprop	No events.
Low Bypass	No events.
High Bypass	No events.

Event summaries – Case Rupture – Hazard Level 3.

Engine Type	Event Summary
Turboprop	No events.
Low Bypass	No events.
High Bypass	No events.

CASE BURNTHROUGH

FIGURE 26. CASE BURNTHROUGH - 2001 THROUGH 2012

ENGINE TYPE	TURBOPROP				JET/LOW BYPASS				ALL HIGH BYPASS			
HAZARD LEVEL	ALL	3	4	5	ALL	3	4	5	ALL	3	4	5
NUMBER EVENTS TOTAL	4	0	0	0	3	0	0	0	21	0	0	0

ENGINE TYPE	1st Generation HBTF				2nd Generation HBTF				3rd/4th Generation HBTF			
HAZARD LEVEL	ALL	3	4	5	ALL	3	4	5	ALL	3	4	5
NUMBER EVENTS TOTAL	**	0	0	0	**	0	0	0	**	0	0	0

** High Bypass Generations not differentiated in data collection for lower level events

TOTAL NUMBER EVENTS HAZARD LEVEL 5	= 0
TOTAL NUMBER EVENTS HAZARD LEVEL 4+5	= 0
TOTAL NUMBER EVENTS HAZARD LEVEL 3+4+5	= 0
TOTAL NUMBER EVENTS HAZARD LEVEL ALL	= 28

FIGURE 27. HAZARD RATIOS FOR CASE BURNTHROUGH

ENGINE TYPE	TURBOPROP	JET/LOW BYPASS	ALL HIGH BYPASS
LVL 5/ALL	0/4 = *	0/3 = *	0/21 = *
LVL (4+5)/ALL	0/4 = *	0/3 = *	0/21 = *
LVL(3+4+5)/ALL	0/4 = *	0/3 = *	0/21 = *

ENGINE TYPE	1st Generation HBTF	2nd Generation HBTF	3rd/4th Generation HBTF
LVL 5/ALL	**	**	**
LVL (4+5)/ALL	**	**	**
LVL(3+4+5)/ALL	**	**	**

* HAZARD RATIO NOT CALCULATED. SEE DATA ANALYSIS METHODS, p. 4.

** High Bypass Generations not differentiated in data collection for lower level events

Many case burnthroughs were detected during routine maintenance activity because the volume of hot air released was insufficient to cause a fire detector or overheat loop indication.

Event summaries - Case Burnthrough - Hazard level 4 or 5.

Engine Type	Event Summary
Turboprop	No events.
Low Bypass	No events.
High Bypass	No events.

Event summaries – Case Burnthrough – Hazard Level 3.

Engine Type	Event Summary
Turboprop	No events.
Low Bypass	No events.
High Bypass	No events.

UNDER-COWL FIRE

FIGURE 28. UNDER-COWL FIRE - 2001 THROUGH 2012

ENGINE TYPE	TURBOPROP				JET/LOW BYPASS				ALL HIGH BYPASS			
HAZARD LEVEL	ALL	3	4	5	ALL	3	4	5	ALL	3	4	5
NUMBER EVENTS	93	0	0	0	18	0	0	0	83	7	0	0

ENGINE TYPE	1st Generation HBTF				2nd Generation HBTF				3rd/4th Generation HBTF			
HAZARD LEVEL	ALL	3	4	5	ALL	3	4	5	ALL	3	4	5
NUMBER EVENTS	32	2	0	0	34	4	0	0	17	1	0	0

TOTAL NUMBER EVENTS HAZARD LEVEL 5	= 0
TOTAL NUMBER EVENTS HAZARD LEVEL 4+5	= 0
TOTAL NUMBER EVENTS HAZARD LEVEL 3+4+5	= 7
TOTAL NUMBER EVENTS HAZARD LEVEL ALL	= 194

FIGURE 29. HAZARD RATIOS FOR UNDER-COWL FIRE

ENGINE TYPE	TURBOPROP	JET/LOW BYPASS	ALL HIGH BYPASS
LVL 5/ALL	0/93 = *	0/18 = *	0/83 = *
LVL (4+5)/ALL	0/93 = *	0/18 = *	0/83 = *
LVL(3+4+5)/ALL	0/93 = *	0/18 = *	7/83 = .08

ENGINE TYPE	1st Generation HBTF	2nd Generation HBTF	3rd/4th Generation HBTF
LVL 5/ALL	0/32 = *	0/34 = *	0/17 = *
LVL (4+5)/ALL	0/32 = *	0/34 = *	0/17 = *
LVL(3+4+5)/ALL	2/32 = .06	4/34 = .12	1/17 = .06

* HAZARD RATIO NOT CALCULATED. SEE DATA ANALYSIS METHODS, p. 4.

It should be noted that undercowl fires resulting from flammable fluid leakage onto hot surfaces in the nacelle were primarily observed at low altitudes (below 10,000 ft.), where surface temperatures were highest (from high takeoff/climb power settings) and ambient pressure was high. All of the level 3 fires occurred below 10,000 ft.

Event summaries – Under-cowl fire – Hazard Level 4 or 5.

Turboprop	No events.
Low Bypass	No events.
High Bypass	No events.

Event summaries – Under-cowl fire – Hazard Level 3.

Engine Type	**Event Summary**
Turboprop	No events.
Low Bypass	No events.
High Bypass	Fuel imbalance noticed during flight. Fuel leak from bleed actuator muscle line (chafed/fractured due to improper clipping arrangement). Fuel accumulated in bypass duct (not drained) and ignited during thrust reverse outside fire zone. Wind may have blown flames towards airplane. Airplane tailcone burned. **Included in Fuel Leak (primary) and Under-Cowl Fire.** (Hazard Level 3.b.) 2nd generation. Twin.
	Fire warning light illuminated during flight, aircraft returned to departure airport. Inspection found a seized air turbine starter, which was the origin of the fire. Hole in lower cowl, and thermal damage to composite outer bypass duct. (Hazard Level 3.b.) 2nd generation. Twin.
	External fuel leak, aircraft had fuel range issue caused by undercowl leak; diversion. Ignition of leaked fuel during landing rollout. Pressure pulse during ignition broke core cowl hinge, allowing fire to exit the fire zone. **Event included in Fuel Leak (Primary) and Under-Cowl Fire.** (Hazard Level 3.b.) 1st generation. Tri.

Aircraft accumulated ice slab in inlet overnight; ingestion of slab in takeoff roll separated two fan blades below the mid-span, which were forward arc uncontained. The inlet adapter ring and bellmouth which form part of the fan fire zone boundary were destroyed. The fuel supply line, routed along the inlet, was damaged by fan blade fragments and the fuel ignited. Since the initiating event destroyed the fire zone boundaries, the fire was not limited to the fire zone. **Included in Uncontained Blade (primary) and Under-Cowl Fire.** (Hazard Level 3.b.) 1st generation. Tri.

Hung start during taxi out to departure runway, with tail winds of 23 knots gusting to 29. Trailing flight crew reported flames and smoke coming out of the intake and exhaust, and torching the fuselage. The crew discharged fire bottles. Inspection found thermal damage to fan bypass vanes, outer bypass duct, and engine wiring harness. (Hazard Level 3.b.) 2nd generation. Twin.

HPC1 disk burst during takeoff; RTO. Fire damaged engine and impinged on wing. **Included in Uncontained Disk (primary) and Under-Cowl Fire.** (Hazard Level 3.b.) 2nd generation. Twin.

Fire warning at rotation. IFSD and ATB due to starter failure. Undercowl oil fire spread to Left Hand Fan Reverser causing burn through. Fire burned out through cowl. (Hazard Level 3.b.) 3rd generation. Twin.

STRUT / PYLON FIRE

FIGURE 30. STRUT / PYLON FIRE - 2001 THROUGH 2012

ENGINE TYPE	TURBOPROP				JET/LOW BYPASS				ALL HIGH BYPASS			
HAZARD LEVEL	ALL	3	4	5	ALL	3	4	5	ALL	3	4	5
NUMBER EVENTS	-	0	0	0	-	0	0	0	-	3	1	0

ENGINE TYPE	1st Generation HBTF				2nd Generation HBTF				3rd/4th Generation HBTF			
HAZARD LEVEL	ALL	3	4	5	ALL	3	4	5	ALL	3	4	5
NUMBER EVENTS	-	1	1	0	-	2	0	0	-	0	0	0

TOTAL NUMBER EVENTS HAZARD LEVEL 5	= 0
TOTAL NUMBER EVENTS HAZARD LEVEL 4+5	= 1
TOTAL NUMBER EVENTS HAZARD LEVEL 3+4+5	= 4
TOTAL NUMBER EVENTS HAZARD LEVEL ALL	= **

NOTE: Hazard Ratios not calculated.

Event summaries – Strut / Pylon Fire – Hazard Level 4 or 5.

Turboprop	No events.
Low Bypass	No events.
High Bypass	A fuel leak from a fuel line coupling at #3 engine strut was determined as the cause of the fire/accident. The coupling was incorrectly assembled, most probably during the aircraft's last C-check, completed 6 months prior to the accident. (Hazard Level 4.b.) 1st generation. Quad.

Event summaries – Strut / Pylon Fire – Hazard Level 3.

Engine Type	**Event Summary**
Turboprop	No events.
Low Bypass	No events.
High Bypass	No. 1 engine fire on ground. Fire started at fuel shutoff valve in strut area. Engine had experienced fuel leak previously on this engine and maintenance action had been performed just prior to flight. Fire damage/surface charring of the under wing from the wing tip to just outboard of the No. 2 engine pylon that spanned the entire surface from wing leading edge to trailing edge. Leading edge slats charred and blackened, flap fairing pods burned. Flaps had minor surface charring. **Included in Fuel Leak (primary) and Strut/Pylon Fire categories.** (Hazard Level 3.b.) 2nd generation. Quad. Fuel leak on #4 engine from O-ring at front wing spar. Smoke from strut panel after landing. Strut fire blackened the diagonal brace. (Hazard Level 3.b.) 1st generation. Quad. Fuel leak in the #1 engine fuel feed system due to loose coupling assembly – located in the aircraft pylon. Fire occurred when fuel leaked onto core exhaust nozzle. (Hazard Level 3.b.) 2nd generation. Twin.

FUEL LEAK

NOTE: Oil Leaks and Hydraulic Fluid Leaks are not included in this category.

FIGURE 31. FUEL LEAK - 2001 THROUGH 2012

ENGINE TYPE	**TURBOPROP**				**JET/LOW BYPASS**				**ALL HIGH BYPASS**			
HAZARD LEVEL	**ALL**	**3**	**4**	**5**	**ALL**	**3**	**4**	**5**	**ALL**	**3**	**4**	**5**
NUMBER EVENTS TOTAL	*	0	0	0	10	1	0	0	318	6	7	0

ENGINE TYPE	**1st Generation HBTF**				**2nd Generation HBTF**				**3rd/4th Generation HBTF**			
HAZARD LEVEL	**ALL**	**3**	**4**	**5**	**ALL**	**3**	**4**	**5**	**ALL**	**3**	**4**	**5**
NUMBER EVENTS TOTAL	14	2	1	0	302	4	6	0	2	0	0	0

* THE EVENT COUNT FOR ALL EVENTS IS LIKELY SIGNIFICANTLY UNDERREPORTED.

TOTAL NUMBER EVENTS HAZARD LEVEL 5	= 0
TOTAL NUMBER EVENTS HAZARD LEVEL 4+5	= 7
TOTAL NUMBER EVENTS HAZARD LEVEL 3+4+5	= 14
TOTAL NUMBER EVENTS HAZARD LEVEL ALL	= 328**

** The total number of Fuel Leaks shown in Figure 31 does not include the Hazard Level 0 fuel leaks. More than 15,000 Hazard Level 0 fuel leaks were reported in the CAAM3 time frame – the true number is likely significantly higher. The wide variation in circumstances of the fuel leak (flow, location, etc.) makes an overall hazard ratio meaningless. The CAAM3 team recommends that manufacturers develop situation-specific datasets.

The relationship between undercowl fire and leaks is analyzed in the CAAM2 Report, Appendix 7. This discussion is not included in this CAAM3 report.

Event summaries – Fuel leak – Hazard level 4 or 5.

[NOTE: There is a significant overlap between the Fuel Leak category and the Multi-Engine Power Loss, Fuel Exhaustion category, as noted in the summaries below.]

Turboprop No events.

Low Bypass No events.

High Bypass Decreasing fuel quantity during cruise due to fuel leak at HP fuel pump. Flight diverted but crashed short of airfield due to fuel starvation. No fatalities. **Event included in Fuel Leak (Primary) and Multi-Engine Power Loss, Fuel Exhaustion.** (Hazard Level 4.a.) 2nd generation. Twin.

Fuel unbalance developed. Crew diverted due to fuel shortage. Both engines flamed out due to fuel exhaustion. Aircraft landed at remote airfield. Structural damage to airframe. **Event included in Fuel Leak (Primary) and Multi-Engine Power Loss, Fuel Exhaustion.** (Hazard Level 4.a.) 2nd generation. Twin.

Improper assembly of main fuel line coupling at engine strut led to fuel leak and fire during reverse thrust application during Landing Roll. Fire initiated external to cowling. Damage to engine strut and wing made airplane beyond economical repair. **Event included in Fuel Leak (Primary) and Pylon Fire.** (Hazard Level 4.b.) 2nd generation. Quad.

Aircraft was critical on fuel and crashed in river when both engines flamed out. **Event included in Fuel Leak (Primary)** and **Multi-Engine Power Loss – Fuel Exhaustion.** (Hazard Level 4.a., 4.b.) 1st generation. Twin.

Decreasing fuel quantity during cruise due to fuel leak at HP fuel pump. No fatalities. Crew diverted due to fuel shortage. Both engines flamed out due to fuel exhaustion. Aircraft landed off-airfield. Structural damage to airframe. **Event included in Fuel Leak (Primary) and Multi-Engine Power Loss – Fuel Exhaustion.** (Hazard Level 4.a.) 2nd generation. Twin.

HPT Stage 1 Disk separation during maintenance ground run. Fragments impacted both LH and RH wing tanks resulting in substantial fuel leaks that ignited, resulting in Hull Loss. **Event included in Uncontained (Primary) and Fuel Leak.** (Hazard Level 4.b.) 2nd generation. Twin.

Large fuel leak from external fuel tank penetration during landing roll. Engine fire ignited by streaming fuel. After stop, fuel pooled under aircraft and flames engulfed the fuselage. Aircraft hull loss**.** (Hazard Level 4.b.) 2nd generation. Twin.

<u>Event summaries – Fuel leak – Hazard level 3.</u>

<u>Engine Type</u>	**<u>Event Summary</u>**
Turboprop	No events reported.
Low Bypass	During Takeoff engine experienced uncontained LPT disk. Debris hit adjacent engine. Both engines were reportedly on fire before returning to airport. Also reported penetration of wing fuel tank with significant leak. **Event included in Uncontained Disk (primary) and Fuel Leak categories**. (Hazard Level 3.a.) Quad.
High Bypass	Fuel imbalance noticed during flight. Fuel leak from bleed actuator muscle line (chafed/fractured due to improper clipping arrangement). Fuel accumulated in bypass duct and ignited during thrust reverse outside fire zone. Wind may have blown flames towards airplane. Airplane tailcone burned. **Event included in Fuel Leak (Primary) and Under-Cowl Fire.** (Hazard Level 3.b.) 2nd generation. Twin.
	External fuel leak, aircraft had fuel range issue caused by undercowl leak; diversion. Ignition of leaked fuel during landing rollout. Pressure pulse during ignition broke core cowl hinge, allowing fire to exit the fire zone. **Event included in Fuel Leak (Primary) and Under-Cowl Fire.** (Hazard Level 3.b.) 1st generation. Tri.
	Engine fire on ground due to loose fuel feed coupling on the strut side of the firewall. Engine had experienced fuel leak previously on this engine and maintenance action had been performed just prior to flight. Fire damaged underside surface of the wing from the wing tip to just outboard of the adjacent engine pylon, spanning the entire surface from wing leading edge to trailing edge. The leading edge slats were charred and blackened. The two flap fairing pods were burned. The flaps had minor surface charring. Fire initiated external to cowling. (Hazard Level 3.b.) 1st generation. Quad.
	Three hours after T/O engine fuel consumption was noted as higher than normal. Aircraft landed with fuel remaining, but was unable to continue to final destination due to low fuel. (Hazard Level 3.h.) 2nd generation. Quad.

HPT Stage 1 Disk separation during maintenance ground run. Fuel leak led to fire, resulting in heavy damage to aircraft. **Event included in Uncontained Disk (Primary) and Fuel Leak.** (Hazard Level 3.h.) 2nd generation. Twin.

Fire warning noted during climb and flight returned. Diagnosed with fuel leak due to missing bolt on fuel discharge tube flange following fuel flow transmitter replacement. Fire damage to engine and cowl. **Event included in Fuel Leak (Primary) and Under-Cowl Fire categories**. (Hazard Level 3.b.) 2nd generation. Twin.

ENGINE SEPARATION

FIGURE 32. ENGINE SEPARATION - 2001 THROUGH 2012

ENGINE TYPE	TURBOPROP				JET/LOW BYPASS				ALL HIGH BYPASS			
HAZARD LEVEL	ALL	3	4	5	ALL	3	4	5	ALL	3	4	5
NUMBER of EVENTS	0	0	0	0	2	0	1	0	1	0	0	0

ENGINE TYPE	1st Generation HBTF				2nd Generation HBTF				3rd/4th Generation HBTF			
HAZARD LEVEL	ALL	3	4	5	ALL	3	4	5	ALL	3	4	5
NUMBER of EVENTS	1**	0	0	0	0	0	0	0	0	0	0	0

** The majority of engine separation events have involved the departure of an engine that is producing thrust. This specific data point is of an engine that was not producing thrust. Caution is advised in the use of this data point with respect to the different airplane hazards that may exist between separation of an engine that is producing thrust and one that is not. For example, an engine producing thrust may have an ability to fly in a trajectory that would impact other areas of the airplane whereas an engine not producing thrust may be more likely to immediately start to fall towards the ground.

TOTAL NUMBER of EVENTS HAZARD LEVEL 5	= 0
TOTAL NUMBER of EVENTS HAZARD LEVEL 4+5	= 1
TOTAL NUMBER of EVENTS HAZARD LEVEL 3+4+5	= 1
TOTAL NUMBER of EVENTS HAZARD LEVEL ALL	= 3

FIGURE 33. HAZARD RATIOS FOR ENGINE SEPARATION

ENGINE TYPE	TURBOPROP	JET/LOW BYPASS	ALL HIGH BYPASS
LVL.5/ALL	0/0 = *	0/2 = *	0/1 = *
LVL.4+5/ALL	0/0 = *	1/2 = 0.50	0/1 = *
LVL.3+4+5/ ALL	0/0 = *	1/2 = 0.50	0/1 = *

ENGINE TYPE	1st Generation HBTF	2nd Generation HBTF	3rd/4th Generation HBTF
LVL.5/ALL	0/1 = *	0/0 = *	0/0 = *
LVL.4+5/ALL	0/1 = *	0/0 = *	0/0 = *
LVL.3+4+5/ ALL	0/1 = *	0/0 = *	0/0 = *

* HAZARD RATIO NOT CALCULATED. SEE DATA ANALYSIS METHODS, p. 4.

Event summaries – Engine separation - Hazard Level 4 or 5.

Engine Type	Event Summary
Turboprop	No events.
Low Bypass	#2 engine separated during takeoff roll and impacted fan cowl of #1 engine. Airplane departed side of runway and was destroyed by post-crash fire. All crew members survived. (Hazard Level 4.a.) Quad. *NOTE: This was a public use aircraft being operated under part 91 of the Federal Regulations. It is included for the Hazard Ratio data but is not used for rate calculations.*
High Bypass	No events.

Event summaries – Engine separation - Hazard Level 3.

Engine Type	Event Summary
Turboprop	No events.
Low Bypass	No events.
High Bypass	No events.

COWL SEPARATION

FIGURE 34. COWL SEPARATION - 2001 THROUGH 2012

ENGINE TYPE	TURBOPROP				JET/LOW BYPASS				ALL HIGH BYPASS			
HAZARD LEVEL	ALL	3	4	5	ALL	3	4	5	ALL	3	4	5
NUMBER of EVENTS	6*	0	0	0	17	0	0	0	96	2	0	0

ENGINE TYPE	1st Generation HBTF				2nd Generation HBTF				3rd/4th Generation HBTF			
HAZARD LEVEL	ALL	3	4	5	ALL	3	4	5	ALL	3	4	5
NUMBER of EVENTS	27	2	0	0	58	0	0	0	11	0	0	0

* EVENT COUNT FOR ALL EVENTS MAY BE UNDERREPORTED.

TOTAL NUMBER EVENTS HAZARD LEVEL 5	= 0
TOTAL NUMBER EVENTS HAZARD LEVEL 4+5	= 0
TOTAL NUMBER EVENTS HAZARD LEVEL 3+4+5	= 2
TOTAL NUMBER EVENTS HAZARD LEVEL ALL	= 119

FIGURE 35. HAZARD RATIOS FOR COWL SEPARATION

ENGINE TYPE	TURBOPROP	JET/LOW BYPASS	ALL HIGH BYPASS
LVL.5/ALL	0/6 = *	0/17 = *	0/96 = *
LVL.4+5/ALL	0/6 = *	0/17 = *	0/96 = *
LVL.3+4+5/ ALL	0/6 = *	0/17 = *	2/96 = .02

ENGINE TYPE	1st Generation HBTF	2nd Generation HBTF	3rd/4th Generation HBTF
LVL.5/ALL	0/27 = *	0/58 = *	0/11 = *
LVL.4+5/ALL	0/27 = *	0/58 = *	0/11 = *
LVL.3+4+5/ ALL	2/27 = .08	0/58 = *	0/11 = *

* HAZARD RATIO NOT CALCULATED. SEE DATA ANALYSIS METHODS, p. 4.

Event summaries – Cowl separation - Hazard Level 4 or 5.

Engine Type	Event Summary
Turboprop	No events.
Low Bypass	No events.
High Bypass	No events.

Event summaries – Cowl separation - Hazard Level 3.

Turboprop	No events.
Low Bypass	No events.
High Bypass	Loud bang and bright flash reported, uneventful emergency landing. Both upper and lower cowl doors were missing from engine. Engine was covered in soot and showed signs of fire, with impact damage to vertical and horizontal stabilizers. **Event included in Cowl Separation (Primary) and Under-Cowl Fire.** (Hazard Level 3.a.) 1st generation. Twin. During cruise the inboard engine had a FAN disintegration failure and one of the inboard engine covers separated, striking the outboard engine. Both engines were shut down and a safe emergency landing was carried out. **Event included in Uncontained – Other (Primary), Multiple Engine Power Loss – Non-Fuel, and Cowl Separation.** (Hazard Level 3.a.) 1st generation. Quad.

PROPULSION SYSTEM MALFUNCTION RECOGNITION AND RESPONSE (PSMRR)

FIGURE 36. PSMRR - 2001 THROUGH 2012

ENGINE TYPE	TURBOPROP				JET/LOW BYPASS				ALL HIGH BYPASS			
HAZARD LEVEL	ALL	3	4	5	ALL	3	4	5	ALL	3	4	5
NUMBER of EVENTS	*	2†	4	3	*	0	0	4	*	3	2	1

ENGINE TYPE	1st Generation HBTF				2nd Generation HBTF				3rd/4th Generation HBTF			
HAZARD LEVEL	ALL	3	4	5	ALL	3	4	5	ALL	3	4	5
NUMBER of EVENTS	*	1	2	1	*	2	0	0	*	0	0	0

* TOTAL EVENTS UNKNOWN.
† LEVEL 3 EVENTS LIKELY UNDER-REPORTED.

TOTAL NUMBER EVENTS HAZARD LEVEL 5	= 8
TOTAL NUMBER EVENTS HAZARD LEVEL 4+5	= 14
TOTAL NUMBER EVENTS HAZARD LEVEL 3+4+5	= 19
TOTAL NUMBER EVENTS HAZARD LEVEL ALL	= *

Event summaries – PSMRR - Hazard Level 4 or 5.

Engine Type	Event Summary
Turboprop	Single engine power surge on approach causing loss of control and pilots inability to accommodate. Severe landing with hull loss, no fatalities. (Hazard Level 4.b.) Twin.
	Accumulation of ice in inlet, auto ignition off and pilots distracted, resulting in fatalities and hull loss. (Hazard Level 5) Twin.
	Fire warning indication led to IFSD. Continued indication, so crew pulled fire handle on second (good) engine, resulting in crash. (Hazard Level 4.b.) Twin.
	In-flight selection of ground beta and malfunction in anti-skid unit preventing automatic protection. Asymmetric forces caused loss of a/c control. Pilot mishandling of propeller controls. (Hazard Level 4.b.) Twin. (Similar event as below)
	Engine failure occurred at V1, takeoff continued. During takeoff airplane banked/rolled into good engine and crashed. (Hazard Level 5) Twin.
	Engine lost power at 100 ft. Engine feathered, but aircraft could not maintain altitude and crashed during attempted air return. Fire, hull loss, minor injuries. (Hazard Level 4.b.) Twin.
	Aircraft was destroyed just after takeoff. Engine lost torque. Flight crew attempted to return to departure airport but crashed into an open field during approach. 16 fatalities. (Hazard Level 5) Twin.
Low Bypass	#1 engine power loss at rotation; airplane climbed to 400 feet, lost speed progressively, stalled and crashed. #2 engine had been pulled back to idle for unexplained reasons. Crew response and coordination after engine event during critical phase of flight cited during investigation. Airplane destroyed. 102 fatal, 1 survivor. **Event included in PSMRR (Primary) and Multiple Engine Power Loss - Non-Fuel.** (Hazard Level 5). Twin.
	Crew reported loss of power in one engine during climb and initiated a return to the departure airport. Airplane descended and collided with terrain 3 miles from the departure airport during missed

approach. Airplane destroyed. 116 fatal, 1 survivor (Hazard Level 5). Twin.

Crew initiated an Aborted Takeoff around 100 knots due to a #1 engine power loss. No indications that engine event threatened safety of flight. Airplane overran runway into a marketplace. Airplane destroyed, 3 fatalities onboard, 37 on ground. Runway had been shortened by lava flow from a volcano. (Hazard Level 5). Twin.

Side cowls separated from #4 engine during takeoff. Aircraft was poorly maintained, cowls were probably not latched correctly, resulting in PT7 line separating and giving false indication of #4 engine power loss. Cowl separation and indication issues themselves did not affect safety of flight. Crew could not maintain control of airplane during return to departure airport. Airplane crashed and was destroyed. 6 fatal (all crew). **Event included in PSMRR (Primary) and Cowl Separation.** (Hazard Level 5). Quad.

High Bypass

Aborted Takeoff due to apparent #1 engine turbine event, no indication that engine event itself affected safety of flight. Crew reported the decision to abort was above 130 knots. Airplane overran end of runway and was destroyed, no fatalities. (Hazard Level 4.b.) 1st generation. Quad.

Crew initiated Aborted Takeoff at 150 knots (12 knots above V1) due to #3 engine recoverable compressor stall after ingesting a bird. Crew had less runway available than planned due to starting take-off from an intersection instead of the end of the runway. Runway excursion (overrun), airplane destroyed, no fatalities. (Hazard Level 4.b.) 1st generation. Quad.

Crew experienced an IFSD 3 minutes after Takeoff. Flight returned to departure airport. During approach, pilot lost control after applying additional power to the operating engine. Multiple fatalities. Aircraft lost. Engine was found to be improperly maintained with regards to cycle accounting. As a result, the maximum number of cycles had been considerably exceeded. (Hazard Level 5.) 1st generation. Twin.

Event summaries – PSMRR - Hazard Level 3.

Engine Type	Event Summary
Turboprop	The aircraft had a runway excursion on landing, and veered to the right. Aircraft went over a ditch and came to a stop on taxiway with substantial damage to nose wheel. Probable cause was power asymmetry during application of reverse thrust. The control levers were jammed in one position. (Hazard Level 3.f.) Twin.
	During final approach, crew observed engine propeller speed stuck at 70%. During landing, the aircraft veered off the runway to the right and suffered damage to the nose landing gear. (Hazard Level 3.a.) Twin.
Low Bypass	No events.
High Bypass	Bird ingestion during takeoff. High speed RTO and runway excursion (overrun). (Hazard Level 3.a.) 2nd generation. Twin.
	While on final approach at 1,000ft, red oil pressure & quantity readings were noted due to bearing failure. Engine was left running for many minutes before commanded IFSD. After landing, a fire was noticed in the tailpipe. Passengers and crew evacuated. Fire department foamed core nozzle. Some heat damage noted on pylon aft fairing, and blackened wing was reported. **Event included in Tailpipe Fires (Primary) and PSMRR.** (Hazard Level 3.b.) 3rd generation. Twin.
	During landing rollout, thrust reverser was not deployed. Thrust levers were then advanced, resulting in asymmetric thrust. Aircraft departed left hand side of the runway. **Event included in PSMRR (Primary) and Reverser Malfunction.** (Hazard Level 3.a.) 2nd generation. Quad.
	Just after T/O, flight crew was unable to reduce power on the #1 engine. Flight returned to departure airport. The engine was not shutdown using the Quick Reference Handbook (QRH) checklist for a "Thrust Lever Jammed". Aircraft landed after the 2nd attempt with the #1 engine at or near full power. Aircraft taxied to the terminal and was deplaning under these same conditions when the aircraft jumped the parking chock and crashed into the airport passenger terminal. (Hazard Level 3.f.) 1st generation. Twin.

CREW ERROR

FIGURE 37. CREW ERROR - 2001 THROUGH 2012

ENGINE TYPE	TURBOPROP				JET/LOW BYPASS				ALL HIGH BYPASS			
HAZARD LEVEL	ALL	3	4	5	ALL	3	4	5	ALL	3	4	5
NUMBER EVENTS	*	2†	1	2	*	1	0	0	*	3	3	3

ENGINE TYPE	1st Generation HBTF				2nd Generation HBTF				3rd/4th Generation HBTF			
HAZARD LEVEL	ALL	3	4	5	ALL	3	4	5	ALL	3	4	5
NUMBER EVENTS	*	0	1	0	*	2	2	3	*	1	0	0

* TOTAL EVENTS UNKNOWN.
† LEVEL 3 EVENTS LIKELY UNDER-REPORTED.

TOTAL NUMBER EVENTS HAZARD LEVEL 5	= 5
TOTAL NUMBER EVENTS HAZARD LEVEL 4+5	= 9
TOTAL NUMBER EVENTS HAZARD LEVEL 3+4+5	= 15
TOTAL NUMBER EVENTS HAZARD LEVEL ALL	= *

Event summaries – Crew error - Hazard Level 4 or 5.

Engine Type	Event Summary
Turboprop	Flight crashed and burned short of the runway when landing in fog. In-flight selection of ground beta and malfunction in anti-skid unit prevented automatic protection. Asymmetric forces caused loss of aircraft. Caused by pilot mishandling of propeller controls. 20 fatalities. (Hazard Level 5.) Twin. **Event included in Crew Error (Primary) and Reverser/Beta Malfunction – Inflight Deploy.**
	Pilot selected flight idle during simulated engine failure in take-off training. Asymmetric forces caused loss of aircraft control due to pilot mishandling of propeller controls. 2 fatalities. (Hazard Level 4.) Twin.
	Aircraft crashed on final approach. Flight crew inadvertently selected ground beta and anti-skid unit malfunctioned, preventing automatic protection. Asymmetric forces caused loss of aircraft control. 43 fatalities. (Hazard Level 5.) Twin.
Low Bypass	No events.
High Bypass	Dual engine stall after operation outside flight envelope during ferry flight. All engine flameout. Forced landing. (Hazard Level 4.a.,) 1st generation. Twin.
	Crew did not command full reverse on landing. Airplane went off the end of the runway and through fence, colliding with automobile. Fatality (car passenger). (Hazard Level 4.c.) 2nd generation. Twin.
	Pilot inadvertently bumped #1 engine throttle forward during landing roll, causing an increase in forward thrust. The #1 engine thrust reverser had been locked out. Airplane departed side of runway and impacted structure and buildings. Airplane destroyed, 125 fatalities. (Hazard Level 5). 2nd generation. Twin.
	Crew left #2 engine at climb power resulting in an increase in forward thrust during landing roll, #2 engine thrust reverser had been locked out. Airplane overran runway end, impacted buildings, and was destroyed. 187 fatalities on the airplane and an additional 12 fatalities on the ground. (Hazard Level 5). 2nd generation. Twin.

During take-off roll, crew failed to set take-off thrust. The airplane never reached the speed required to attain sufficient lift and get airborne. Airplane overran end of runway and was destroyed. All 3 crew members were fatally injured. (Hazard Level 5). 2nd generation. Tri.

Dual engine thrust loss resulting in return to departure airport. **Event included in Multiple Engine Power Loss – Non-Fuel – Other (primary) and Crew Error.** (Hazard Level 4.a.**)** 2nd generation. Twin.

Event summaries – Crew error - Hazard Level 3.

Engine Type	Event Summary
Turboprop	Aircraft slipped off the runway following pilot-induced reverse setting. RH prop/engine did not respond correctly to the reverse signal. FDR readout indicates that prop beta mode was activated. No injuries or casualties during the event and subsequent emergency evacuation. NLG fractured and fuselage damaged. (Hazard Level 3.a.) Twin.
	Aircraft was substantially damaged during takeoff roll as a result of a power loss. Aircraft veered left and departed runway when pilot deselected nose wheel steering at approximately 60 kts. (Hazard Level 3.a.) Twin.
Low Bypass	During cruise at FL330 ice crystal accumulation in inlet probes of both engines resulted in a false engine power indication. Both engines rolled back and stalled. Flight crew did not verify engine indications with autopilot and autothrottles engaged and did not recognized drop in airspeed due to loss of engine power. #2 engine restarted at FL170, #1 engine shortly thereafter. Safe landing at Diversion airport. **Event included in Crew Error (Primary) and Multi-Engine Power Loss, Non-Fuel.** (Hazard Level 3.e.) Twin.
High Bypass	Thrust transient asymmetry during start, crew did not wait to stabilize thrust at idle, offside runway during takeoff. (Hazard Level 3.a.) 2nd generation. Twin.

Dual engine flameout during cruise at FL380 - fuel pumps had not been turned on. Airplane lost 6,000 feet altitude before engines were restarted. Uneventful landing at diversion airport. **Event included in Crew Error (Primary) and Multiple Engine Power Loss - Fuel Related.** (Hazard Level 3.e.) 2nd generation. Twin.

Crew (training) cut-off fuel to both engines while experimenting with switch function below 10,000 feet above ground level. (Hazard Level 3.a.) 3rd generation. Twin.

HAZARD RATIOS FOR CREW ERROR

Preparation of Hazard Ratios for crew error was not possible given the unknown incidence of lower-level events.

REVERSER/BETA MALFUNCTION – IN-FLIGHT DEPLOY

FIGURE 38. REVERSER/BETA MALFUNCTION – IN-FLIGHT DEPLOY 2001 THROUGH 2012

ENGINE TYPE	TURBOPROP				JET/LOW BYPASS				ALL HIGH BYPASS			
HAZARD LEVEL	ALL	3	4	5	ALL	3	4	5	ALL	3	4	5
NUMBER of EVENTS	*	0	0	2	0	0	0	0	6	0	0	0

ENGINE TYPE	1st Generation HBTF				2nd Generation HBTF				3rd/4th Generation HBTF			
HAZARD LEVEL	ALL	3	4	5	ALL	3	4	5	ALL	3	4	5
NUMBER of EVENTS	1	0	0	0	5	0	0	0	0	0	0	0

* THE EVENT COUNT FOR ALL EVENTS IS UNKNOWN.

TOTAL NUMBER EVENTS HAZARD LEVEL 5	= 2
TOTAL NUMBER EVENTS HAZARD LEVEL 4+5	= 2
TOTAL NUMBER EVENTS HAZARD LEVEL 3+4+5	= 2
TOTAL NUMBER EVENTS HAZARD LEVEL ALL	= 8*

FIGURE 39. HAZARD RATIOS FOR REVERSER/BETA - IN-FLIGHT DEPLOY

ENGINE TYPE	TURBOPROP	JET/LOW BYPASS	ALL HIGH BYPASS
LVL.5/ALL	2/2 = †	0/0 = *	0/6 = *
LVL.4+5/ALL	2/2 = †	0/0 = *	0/6 = *
LVL.3+4+5/ALL	2/2 = †	0/0 = *	0/6 = *

ENGINE TYPE	1st Generation HBTF	2nd Generation HBTF	3rd Generation HBTF
LVL.5/ALL	0/1 = *	0/5 = *	0/0 = *
LVL.4+5/ALL	0/1 = *	0/5 = *	0/0 = *
LVL.3+4+5/ALL	0/1 = *	0/5 = *	0/0 = *

* HAZARD RATIO NOT CALCULATED. SEE DATA ANALYSIS METHODS, p. 4.
† HAZARD RATIO NOT CALCULATED DUE TO INCOMPLETE REPORTING.

Event Summaries – Reverser/beta malfunction - in-flight deploy - Hazard level 4 or 5.

Engine Type	Event Summary
Turboprop	Flight crashed and burned short of the runway when landing in fog. In-flight selection of ground beta and malfunction in anti-skid unit prevented automatic protection. Asymmetric forces caused loss of aircraft. Caused by pilot mishandling of propeller controls. 20 fatalities. (Hazard Level 5.) Twin. **Event included in Crew Error (Primary) and Reverser/Beta Malfunction – Inflight Deploy.** Aircraft crashed on final approach. Flight crew inadvertently selected ground beta and anti-skid unit malfunctioned, preventing automatic protection. Asymmetric forces caused loss of aircraft control. 43 fatalities. (Hazard Level 5.) Twin. **Event included in Crew Error (Primary) and Reverser/Beta Malfunction – Inflight Deploy.**
Low Bypass	No events.
High Bypass	No events.

Event Summaries – Reverser/beta malfunction - in-flight deploy - Hazard level 3.

Engine Type	Event Summary
Turboprop	No events.
Low Bypass	No events.
High Bypass	No events.

FUEL TANK RUPTURE/EXPLOSION

FIGURE 40. FUEL TANK RUPTURE/EXPLOSION - 2001 THROUGH 2012

ENGINE TYPE	TURBOPROP				JET/LOW BYPASS				ALL HIGH BYPASS			
HAZARD LEVEL	ALL	3	4	5	ALL	3	4	5	ALL	3	4	5
NUMBER EVENTS	0	0	0	0	0	0	0	0	1	0	1	0

ENGINE TYPE	1st Generation HBTF				2nd Generation HBTF				3rd/4th Generation HBTF			
HAZARD LEVEL	ALL	3	4	5	ALL	3	4	5	ALL	3	4	5
NUMBER EVENTS	0	0	0	0	1	0	1	0	0	0	0	0

TOTAL NUMBER EVENTS HAZARD LEVEL 5	= 0
TOTAL NUMBER EVENTS HAZARD LEVEL 4+5	= 1
TOTAL NUMBER EVENTS HAZARD LEVEL 3+4+5	= 1
TOTAL NUMBER EVENTS HAZARD LEVEL ALL	= 1

FIGURE 41. HAZARD RATIOS FOR FUEL TANK RUPTURE/EXPLOSION

ENGINE TYPE	TURBOPROP	JET/LOW BYPASS	ALL HIGH BYPASS
LVL.5/ALL	0/0 = *	0/0 = *	0/1 = 0
LVL.4+5/ALL	0/0 = *	0/0 = *	1/1 = 1.0
LVL.3+4+5/ALL	0/0 = *	0/0 = *	1/1 = 1.0

ENGINE TYPE	1st Generation HBTF	2nd Generation HBTF	3rd/4th Generation HBTF
LVL.5/ALL	0/0 = *	0/1 = 0	0/0 = *
LVL.4+5/ALL	0/0 = *	1/1 = 1.0	0/0 = *
LVL.3+4+5/ALL	0/0 = *	1/1 = 1.0	0/0 = *

* HAZARD RATIO NOT CALCULATED. SEE DATA ANALYSIS METHODS, p. 4.

Event summaries – Fuel tank rupture/explosion – Hazard Level 4 or 5.

Engine Type	Event Summary
Turboprop	No events.
Low Bypass	No events.
High Bypass	Center wing fuel tank explosion while parked at gate due to center wing tank fuel boost pumps left on after airplane parked at gate. Center wing tank did not have usable fuel. Hull loss, 1 fatality. (Hazard Level 4.b., 4.c.) 2^{nd} generation. Twin.

Event summaries – Fuel tank rupture/explosion – Hazard Level 3.

Turboprop	No events.
Low Bypass	No events.
High Bypass	No events.

TAILPIPE FIRE

FIGURE 42. TAILPIPE FIRE - 2001 THROUGH 2012

ENGINE TYPE	TURBOPROP				JET/LOW BYPASS				ALL HIGH BYPASS			
HAZARD LEVEL	ALL	3	4	5	ALL	3	4	5	ALL	3	4	5
NUMBER EVENTS TOTAL	29	0	0	0	54	0	0	0	386	21	0	0

ENGINE TYPE	1st Generation HBTF				2nd Generation HBTF				3rd/4th Generation HBTF			
HAZARD LEVEL	ALL	3	4	5	ALL	3	4	5	ALL	3	4	5
NUMBER EVENTS TOTAL	8	2	0	0	218	16	0	0	160	3	0	0

* THE EVENT COUNT FOR ALL TAILPIPE FIRE EVENTS IS LIKELY SIGNIFICANTLY UNDERREPORTED.

TOTAL NUMBER EVENTS HAZARD LEVEL 5	= 0
TOTAL NUMBER EVENTS HAZARD LEVEL 4+5	= 0
TOTAL NUMBER EVENTS HAZARD LEVEL 3+4+5	= 21
TOTAL NUMBER EVENTS HAZARD LEVEL ALL	= 469

FIGURE 43. HAZARD RATIOS FOR TAILPIPE FIRE

ENGINE TYPE	TURBOPROP	JET/LOW BYPASS	ALL HIGH BYPASS
LVL 5/ALL	0/29 = *	0/54 = *	0/386 = *
LVL (4+5)/ALL	0/29 = *	0/54 = *	0/386 = *
LVL(3+4+5)/ALL	0/29 = *	0/54 = *	21/386 = 0.05

ENGINE TYPE	1st Generation HBTF	2nd Generation HBTF	3rd/4th Generation HBTF
LVL 5/ALL	0/8 = *	0/218 = *	0/160 = *
LVL (4+5)/ALL	0/8 = *	0/218 = *	0/160 = *
LVL(3+4+5)/ALL	2/8 = .25	16/218 = .08	3/160 = .02

* HAZARD RATIO NOT CALCULATED. SEE DATA ANALYSIS METHODS, p. 4.

The majority of tailpipe fires occur when the engine is below idle speed (start-up or shut down).

Event summaries – Tailpipe fire - Hazard Level 4 or 5.

Turboprop	No events.
Low Bypass	No events.
High Bypass	No events.

Event summaries – Tailpipe fire - Hazard Level 3.

Engine Type	**Event Summary**
Turboprop	No events.
Low Bypass	No events.
High Bypass	Tailpipe fire occurred after stowing Thrust Reverser, and was extinguished by airport fire department. Walk around inspection revealed heat discoloration on the tailpipe, pylon aft fairing and wing skin behind engine exhaust. Flaps were in good condition suggesting that the fire did not reach this far. (Hazard Level 3.b.) 1st generation. Twin. Tailpipe fire occurred while performing a post installation run. Fire significantly damaged the aircraft wing area, including aileron and spar. Determination was made that fuel system had not been properly preserved. (Hazard Level 3.b.) 2nd generation. Tri. During maintenance troubleshooting, airplane was configured such that fuel was accumulating in burner and turbine areas for between 8 and 13.5 hours (estimated between 15 to 24 gallons). During subsequent start fuel was blown rearward onto the wing and strut surfaces and was ignited by tailpipe fire. The fire was extinguished by the airport fire trucks. Airplane damage: pylon aft strut fairing severely burned, inboard flap track fairing severely burned, center flap track fairing scorched, inboard flap severely burned and burned through in areas, underside of wing scorched, main gear outer door scorched. (Hazard Level 3.b.) 2nd generation. Twin. Engine flameout and tailpipe fire during Thrust Reverse. Blackened airframe surface at wing lower fixed panel, wing lower skin, and pylon skin. (Hazard Level 3.b.) 1st generation. Twin.

Tailpipe fire during maintenance ground run. Composite panels including the pylon panels, flap track fairings, and flaps are burned beyond repair. (Hazard Level 3.b.) 2nd generation. Twin.

Tailpipe fire during starting for maintenance ground run. Inboard aileron sustained scorching and blistering to the lower surface and failed conductivity tests. Less severe paint blistering was present on the underside of the wing, forward of the aileron. (Hazard Level 3.b.) 2nd generation. Tri.

Crew rejected Takeoff and shut down engine due to surge. Inspection revealed metal in tail pipe, heat damage on pylon area and lower surface of the wing. (Hazard Level 3.b.) 3rd generation. Twin.

Tailpipe fire during start impinged on wing, flaps, and pylon. (Hazard Level 3.b.) 2nd generation. Twin.

Tailpipe fire during engine start sequence. Damage to aileron and flaps on the left wing. (Hazard Level 3.b.) 2nd generation. Twin.

Tailpipe fire during fire handle shutdown test. Both engine fire extinguisher bottles were used, as well as fire extinguisher from ground and engine cranked. Damage reported to flaps and surrounding aircraft structure. (Hazard Level 3.b.) 2nd generation. Twin.

While on final approach at 1,000ft, red oil pressure & quantity readings were noted due to bearing failure. Engine was left running for many minutes before commanded IFSD. After landing, a fire was noticed in the tailpipe. Passengers and crew evacuated. Fire department foamed core nozzle. Some heat damage noted on pylon aft fairing, and blackened wing was reported. (Hazard Level 3.b.) **Event included in Tailpipe Fires (Primary) and PSMRR.** 3rd generation. Twin.

Tailpipe fire occurred during engine start. Heat-related damage to flap actuator housings and pylon aft of the engine. Several wing panels sagging and rippled, others blackened and discolored. (Hazard Level 3.b.) 2nd generation. Twin.

Tailpipe fire during engine start. Damage to flap canoe fairing and lower wing composite panel. (Hazard Level 3.b.) 2nd generation. Twin.

During engine start tailpipe fire started. Inboard aileron surrounding panels and trailing edge of inboard flap damaged. DFDR data shows fuel flow spiking to 6464 pph in 2-4 seconds. (Hazard Level 3.b.) 2nd generation. Twin.

After aircraft landed, fire damage was noted to underside of right hand wing aft of #3 engine. Trailing edge of skin on the outboard trailing edge of the flap fairing had detached from the fairing structure. (Hazard Level 3.b.) 2nd generation. Tri.

After reaching the gate and shutting down both engines, the left hand engine experienced a tailpipe fire. The fuel came from a leak in the engine fuel feeder system (loose coupling assembly; maintenance error) located in the aircraft pylon. The external fire occurred after leaking fuel came into contact with the engine's core exhaust nozzle. Flight crew initiated an evacuation of the aircraft via the emergency slides. No injuries were reported. Ground technician and airport fire department extinguished the external engine fire. (Hazard Level 3.b.) 2nd generation. Twin.

Tailpipe fire during shutdown after maintenance ground run. Visual inspection revealed damage to the engine exhaust cone, the aircraft pylon and internal flaps due to high temperature. (Hazard Level 3.b.) 2nd generation. Twin.

Tailpipe fire during starting after engine change. Underside of wing damaged. (Hazard Level 3.b.) 2nd generation. Twin.

Engine was removed following tailpipe fire incident. Found lower surface of wing outboard of engine pylon covered in soot and fixed trailing edge skin panels delaminated with fastener missing. (Hazard Level 3.b.) 2nd generation. Twin.

Tailpipe fire during post-maintenance ground run extinguished by airport firefighting. Thermal damage to pylon and wing. (Hazard Level 3.b.) 3rd generation. Twin.

HPC event during takeoff resulting in tailpipe fire. Wing fairing damaged. (Hazard Level 3.b.) 2nd generation. Twin.

MULTIPLE-ENGINE POWERLOSS – NON-FUEL

FIGURE 44. MULTIPLE-ENGINE POWERLOSS – NON-FUEL –2001 THROUGH 2012

ENGINE TYPE	TURBOPROP				JET/LOW BYPASS				ALL HIGH BYPASS			
HAZARD LEVEL	ALL *	3	4	5	ALL	3	4	5	ALL	3	4	5
NUMBER of EVENTS BY CONDITION												
Environmental – Non-Bird	1	0	0	0	5	1	0	0	24	0	3	1
Environmental – Birds	0	0	0	0	0	0	0	0	29	0	4	0
Maintenance	1	0	0	1	2	1	1	0	2	0	1	0
Other/Unknown	9	2	4	0	6	0	0	3	50	5	5	1
NUMBER of EVENTS TOTAL	11	2	4	1	13	2	1	3	105	5	13	2

ENGINE TYPE	1st Generation HBTF				2nd Generation HBTF				3rd/4th Generation HBTF			
HAZARD LEVEL	ALL	3	4	5	ALL	3	4	5	ALL	3	4	5
NUMBER of EVENTS BY CONDITION												
Environmental – Non-Bird	7	0	1	0	16	0	2	1	1	0	0	0
Environmental - Birds	5	0	1	0	16	0	2	0	8	0	1	0
Maintenance	0	0	0	0	2	0	1	0	0	0	0	0
Other/unknown	13	1	4	1	31	2	1	0	6	2	0	0
NUMBER of EVENTS TOTAL	25	1	6	1	65	2	6	1	15	2	1	0

* THE EVENT COUNT FOR ALL EVENTS IS LIKELY UNDERREPORTED.

TOTAL NUMBER EVENTS HAZARD LEVEL 5	= 6
TOTAL NUMBER EVENTS HAZARD LEVEL 4+5	= 24
TOTAL NUMBER EVENTS HAZARD LEVEL 3+4+5	= 33
TOTAL NUMBER EVENTS HAZARD LEVEL ALL	= 129

FIGURE 45. HAZARD RATIOS FOR MULTIPLE-ENGINE POWERLOSS – NON-FUEL

ENGINE TYPE	TURBOPROP			JET/LOW BYPASS			ALL HIGH BYPASS		
HAZARD LEVEL	(3+4+5) /ALL	(4+5) /ALL	5/ALL	(3+4+5) /ALL	(4+5) /ALL	5/ALL	(3+4+5) /ALL	(4+5) /ALL	5/ALL
HAZARD RATIO BY CONDITION									
Environmental – Non-Bird	0/1 = *	0/1 = *	0/1 = *	1/5 = .20	0/5 = *	0/5 = *	4/24 = .17	4/24 = .17	1/24 = .04
Environmental -Birds	0/0 = *	0/0 = *	0/0 = *	0/0 = *	0/0 = *	0/0 = *	4/29 = .14	4/29 = .14	0/29 = *
Maintenance	1/1 = 1.0*	1/1 = 1.0*	1/1 = 1.0*	2/2= 1.0	1/2 = .50	0/2 = *	1/2 = .50	1/2 = .50	0/2 = *
Other/unknown	6/9 = .67*	4/9 = .44*	0/9 = .11*	3/6= .50	3/6 = .50	3/6 = .50	11/50 = .22	6/50 = .12	1/50 = .02
TOTAL	7/11 = .64	5/11 = .45	1/11 = .09	6/13= .46	4/13 = .31	3/13= .23	20/105 = .20	15/105 = .14	2/105 = .02

ENGINE TYPE	1st Generation HBTF			2nd Generation HBTF			3rd/4th Generation HBTF		
HAZARD LEVEL	(3+4+5) /ALL	(4+5) /ALL	5/ALL	(3+4+5) /ALL	(4+5) /ALL	5/ALL	(3+4+5) /ALL	(4+5) /ALL	5/ALL
HAZARD RATIO BY CONDITION									
Environmental – Non-Bird	1/7 = .14	1/7 = .14	0/7 = *	3/16 = .19	3/16 = .19	1/16 = .06	0/1 = *	0/1 = *	0/1 = *
Environmental - Birds	1/5 = .20	1/5 = .20	0/5 = *	2/16 = .13	2/16 = .13	0/16 = *	1/8 = .13	1/8 = .13	0/8 = *
Maintenance	0/0 = *	0/0 = *	0/0 = *	1/2 = .50	1/2 = .50	0/2 = *	0/0 = *	0/0 = *	0/0 = *
Other/unknown	6/13 = .46	5/13 = .38	1/13 = .08	3/31 = .10	1/31 = .03	0/31 = *	2/6 = .33	0/6 = *	0/6 = *
TOTAL	8/25 = .32	7/25 = .28	1/25 = .04	9/65 = .14	7/65 = .11	1/65 = .02	3/15 = .20	1/15 = .07	0/15 = *

* HAZARD RATIO NOT CALCULATED. SEE DATA ANALYSIS METHODS, p. 4.

EVENT SUMMARIES – MULTIPLE-ENGINE POWERLOSS – NON-FUEL - Hazard Level 4 or 5.

CATEGORY

Engine Type	**Event Summary**

ENVIRONMENTAL – NON-BIRD

Turboprop	No events.
Low Bypass	No events.
High Bypass	Flight descended through icing conditions with engine and airframe anti-ice systems switched on. Vibration noted, followed by dual power loss and forced landing short of airfield due to icing. Nose gear was torn off. Minor injuries. (Hazard Level 4.a.) 2nd generation. Twin. Dual Engine Flameout during descent in severe weather (rain and hail). Relight attempted but battery was exhausted due to maintenance issue with battery. Forced Landing in River. 1 Fatality. (Hazard Level 4.a., 4.b., 4.c.). 2nd generation. Twin**.** Landing gear issues, multi-engine flameout while circling, possible engine icing. (Hazard Level 5) 2nd generation. Twin. Dual engine sub-idle event at 50 ft. during landing in icing conditions. Landed safely without power. (Hazard Level 4.a.) 1st generation. Twin.

ENVIRONMENTAL – BIRDS

Turboprop	No events.
Low Bypass	No events.
High Bypass	Multiple engine bird ingestion during takeoff, crashed in field, burned. No fatalities. (Hazard Level 4.a., 4.b.) 1st generation. Twin. Multiple bird ingestion on takeoff, forced landing off runway, substantial damage. (Hazard Level 4.a.) 2nd generation. Twin**.** After T/O during initial climb aircraft encountered a dual engine bird strike which resulted in loss of power in both engines. Aircraft accomplished a successful ditching in river. No fatalities. (Hazard Level 4.a., 4.b.) 2nd generation. Twin.

Multi-engine bird strike on short approach. Crew initiated a go-around but encountered heavy smell, vibration and no engine response. Continued with landing, resulting in a hard landing and subsequent LMG collapse. (Hazard Level 4.a.) 3rd generation. Twin.

MAINTENANCE

Turboprop Dual engine flame out due to ice accumulation in inlet overnight, failure to install engine covers overnight in snow storm. 2 fatalities. (Hazard Level 5.) Twin.

Low Bypass #2 engine separated during takeoff and impacted the fan cowl of the #1 engine. Resulting loss of the #1 engine fan cowl had the effect of losing thrust on that engine also. Directional control could not be maintained and the Captain perceived that the airplane would not be able to climb and decided to put it back on the ground. Airplane departed side of runway and was destroyed by post-crash fire, all 3 crew members survived. **Event included in Engine Separation (primary), Multi-Engine Powerloss, Non-Fuel/Maintenance, and Cowl Separation categories.** *(This was a public use aircraft being operated under part 91 of the Federal Regulations, It is included for the Hazard Ratio data but will not be used for rate calculations.)* (Hazard Level 4.b.) Quad.

High Bypass Airplane had been parked overnight during a sand storm. At 200 feet on takeoff, both engines began to surge and pilot retarded throttles. Airplane would not climb and Captain declared emergency and returned to airport. Investigation found both HPTs and LPTs had severe thermal damage due to sand ingestion resulting in clogged cooling holes. (Hazard Level 4.a.) 2nd generation. Twin.

OTHER/UNKNOWN

Turboprop Crash on Final Approach after Emergency Landing Request - false fire warning on one engine, shut down #1 engine, continued false fire warning led crew to shut down remaining engine. (Hazard Level 4.a.) Twin.

Low oil pressure indication on the left engine during approach led to go-around decision. #1 engine was shutdown. During climb out, right engine ECU indication came on, followed by oil pressure and uncommanded shutdown. Flight landed in field. (Hazard Level 4.a.) Twin.

Multi-engine flameout during ferry flight, forced landing. (Hazard Level 4.a., 4.b.) Twin.

	Unspecified engine problems during flight, crashed on the way to airstrip. (Hazard Level 4.a., 4.b., 4.c.) Twin.
Low Bypass	#1 engine power loss at rotation; airplane climbed to 400 feet, lost speed progressively, stalled and crashed. #2 engine had been pulled back to idle for unexplained reasons. Crew response and coordination after engine event during critical phase of flight cited during investigation. Airplane destroyed, 102 fatalities and 1 survivor. Investigation of #1 engine did not yield a safety of flight issue. **Event included in PSMRR (primary) and Multi-Engine Power Loss – Non-Fuel – Other/Crew Error.** (Hazard Level 5). Twin.
	Report not yet available**, circumstances may be consistent with fuel related issue**. Airplane lost power in both engines during descent and crashed into a crowded area about 2-3 miles short of the destination airport during the forced landing. Airplane destroyed with 153 fatalities and at least 10 more on ground. Investigation may not definitively identify reason for multi-engine powerloss, but appears to be common-cause related. (Hazard Level 5). Twin.
	Engine #1 & #3 experienced unrecoverable surge during descent one minute before end of Flight Data Recorder recording. Airplane was destroyed with 77 fatalities, 27 survivors. (Hazard Level 5). Tri.
High Bypass	Throttle quadrant wear, dual engine flameout on landing after ferry flight. (Hazard Level 4.a., 4.b.) 1st generation. Twin.
	Flameout while power reduced in approach. Hard landing on runway. Worn throttle quadrant. (Hazard Level 4.a.) 1st Generation. Twin**.**
	Airplane crashed after independent events in 2 engines (#4 engine lost power with airplane going through V2 speed and #1 engine lost power at 600 feet). Airplane was destroyed, 2 ground fatalities, none onboard. (Hazard Level 4.b.) 1st generation. Quad.
	ATB and dual engine thrust loss; crew error. **Event included in Multiple Engine Power Loss – Non-Fuel and Crew Error.** (Hazard Level 4.a.) 2nd generation. Twin.
	Customer air force - dual engine flameout, landed short, no fatalities. (Hazard Level 4.a.) 1st Generation. Twin**.**
	Dual engine stall after operation outside airplane flight envelope. (Hazard Level 5.) 1st Generation. Twin.

EVENT SUMMARIES – MULTIPLE-ENGINE POWERLOSS – NON-FUEL - Hazard Level 3.

Engine Type	**Event Summary**
ENVIRONMENTAL – NON-BIRD	
Turboprop	No events.
Jet/Low Bypass	During cruise at FL330, ice crystal accumulation in inlet probes of both engines resulted in a false engine power indication. Both engines rolled back and stalled. Flight crew did not verify engine indications with autopilot and autothrottles engaged and did not recognized drop in airspeed due to loss of engine power. #2 engine restarted at FL170, #1 engine shortly thereafter. Safe landing at diversion airport. **Event included in Crew Error (primary) and Multi-Engine Power Loss – Non-Fuel - Environmental.** (Hazard Level 3.e.). Twin.
High Bypass	No events.
ENVIRONMENTAL – BIRDS	
	No events.
MAINTENANCE	
Turboprop	
Jet/Low Bypass	Multi-engine powerloss from independent turbine events. #1 engine event occurred at 500-600 feet, #3 engine event occurred 5-6 seconds after No.1 powerloss. Both engine powerloss events were non-restartable shutdowns. Safe single engine landing at departure airport. Engines poorly maintained and highly deteriorated. (Hazard Level 3.d.) Tri.
High Bypass	No events.
OTHER/UNKNOWN	
Turboprop	Landing gear issue (no stow) during climb caused dual engine surge. (Hazard Level 3.e.) Twin.

During a ferry flight, shortly after T/O at 400', the #2 engine lost power. The crew returned to the departure airport and during the downwind leg, the #1 engine torque and parameters started to fluctuate. The crew apparently shut the #1 down and managed to land on the runway. (Hazard Level 3.d.) Twin.

Jet/Low Bypass No events.

High Bypass During Take-off and initial climb both engines surged sequentially (#1 engine just after main gear left ground, #2 at 384 feet) reducing thrust to idle on both. Aircraft reached 456 feet then began descending. Full thrust restored on #1 engine descending through 96 feet, aircraft continued to descend to 66 feet before beginning to climb again, full thrust restored on #2 engine as the crew climbed back though 118 feet. Time from initial surge until recovery of full thrust on both engines was 62 seconds. Returned to safe landing at departure airport. (Hazard Level 3.e.) 2nd generation. Twin.

Engine #4 shutdown in cruise. Later Engine #2 had vibration indication and shutdown. Diverted. No attempt to restart either engine was made. (Hazard Level 3.d.) 2nd generation. Quad.

At approximately 12,000 feet during climb, the #2 engine experienced N1 oscillations with #1 engine oscillations initiating about 30 seconds later. Both engines experienced a momentary overspeed. The crew disconnected the autothrottle and returned. During the return, the #2 engine rolled sub-idle as the oscillations continued at flight idle and EGT rose above the 725C limit. After approximately 80 seconds, the crew cut fuel to the #2 engine. No restart was attempted. The crew reported sluggish operation of the #1 engine during the return to uneventful landing. DFDR data review did not indicate any abnormalities in the operation of the #1 engine after the momentary oscillations and overspeed. (Hazard Level 3.e.) 3rd generation. Twin.

Crew (training) cut-off fuel to both engines while experimenting with switch function below 10,000 feet above ground level. **Event included in Crew Error (primary) and Multi-Engine Power Loss – Non-Fuel - Environmental.** (Hazard Level 3.e.) 3rd generation. Twin.

During cruise, the inboard engine had a FAN disintegration failure and one of the inboard engine covers separated, striking the outboard engine. Both engines were shut down and a safe emergency landing was carried out. **Event included in Uncontained – Other (Primary). Multiple Engine Power Loss – Non-Fuel, and Cowl Separation.** (Hazard Level 3.a.) 1st generation. Quad.

MULTIPLE-ENGINE POWERLOSS – FUEL-RELATED

FIGURE 46. MULTIPLE-ENGINE POWERLOSS – FUEL-RELATED – 2001 THROUGH 2012

ENGINE TYPE	TURBOPROP				JET/LOW BYPASS				ALL HIGH BYPASS			
HAZARD LEVEL	ALL	3	4	5	ALL	3	4	5	ALL	3	4	5
NUMBER of EVENTS BY CONDITION												
Contamination	0	0	0	0	0	0	0	0	8	0	1	0
Mismanagement	1	0	1	0	0	0	0	0	6	2	0	0
Exhaustion	2	0	1	1	1	0	1	0	6	0	6	0
NUMBER of EVENTS TOTAL	3†	0	2	1	1	0	1	0	20	2	7	0

ENGINE TYPE	1st Generation HBTF				2nd Generation HBTF				3rd/4th Generation HBTF			
HAZARD LEVEL	ALL	3	4	5	ALL	3	4	5	ALL	3	4	5
NUMBER of EVENTS BY CONDITION												
Contamination	3	0	0	0	2	0	0	0	3	0	1	0
Mismanagement	2	0	0	0	3	1	0	0	1	1	0	0
Exhaustion	3	0	3	0	3	0	3	0	0	0	0	0
NUMBER of EVENTS TOTAL	8	0	3	0	8	1	3	0	4	1	1	0

† SUSPECTED UNDER-REPORTING.

TOTAL NUMBER EVENTS HAZARD LEVEL 5	= 1
TOTAL NUMBER EVENTS HAZARD LEVEL 4+5	= 11
TOTAL NUMBER EVENTS HAZARD LEVEL 3+4+5	= 13
TOTAL NUMBER EVENTS HAZARD LEVEL ALL	= 24

FIGURE 47. HAZARD RATIOS FOR MULTIPLE-ENGINE POWERLOSS – FUEL-RELATED*

ENGINE TYPE	TURBOPROP			JET/LOW BYPASS			ALL HIGH BYPASS		
HAZARD LEVEL	(3+4+5) /ALL	(4+5) /ALL	5/ALL	(3+4+5) /ALL	(4+5) /ALL	5/ALL	(3+4+5) /ALL	(4+5) /ALL	5/ALL
HAZARD RATIO BY CONDITION									
Contamination	0/0 = *	0/0 = *	0/0 = *	0/0 = *	0/0 = *	0/0 = *	0/7 = *	0/7 = *	0/7 = *
Mismanagement	1/1 = 1.0	1/1 = 1.0	0/1 = *	0/0 = *	0/0 = *	0/0 = *	2/6 = .33	0/6 = *	0/6 = *
Exhaustion	2/2 = 1.0	2/2 = 1.0	1/2 = .50	1/1 = 1.0	1/1 = 1.0	0/1 = *	7/7 = 1.0	7/7 = 1.0	0/7 = *
TOTAL	3/3 = 1.0	3/3 = 1.0	1/3 = .33	1/1 = 1.0	1/1 = 1.0	0/1 = *	9/20 = .45	7/20 = .35	0/20 = *

ENGINE TYPE	1st Generation HBTF			2nd Generation HBTF			3rd/4th Generation HBTF		
HAZARD LEVEL	(3+4+5) /ALL	(4+5) /ALL	5/ALL	(3+4+5) /ALL	(4+5) /ALL	5/ALL	(3+4+5) /ALL	(4+5) /ALL	5/ALL
HAZARD RATIO BY CONDITION									
Contamination	0/3 = *	0/3 = *	0/3 = *	0/2 = *	0/2 = *	0/2 = *	0/2 = *	0/2 = *	0/2 = *
Mismanagement	0/2 = *	0/2 = *	0/2 = *	1/3 = .33	0/3 = *	0/3 = *	1/1 = 1.0	0/1 = *	0/1 = *
Exhaustion	3/3 = 1.0	3/3 = 1.0	0/3 = *	3/3 = 1.0	3/3 = 1.0	0/3 = *	1/1 = 1.0	1/1 = 1.0	0/1 = *
TOTAL	3/8 = .38	3/8 = .38	0/8 = *	4/8 = .50	3/8 = .38	0/8 = *	2/4 = .50	1/4 = .25	0/4 = *

* HAZARD RATIO NOT CALCULATED. SEE DATA ANALYSIS METHODS, p. 4.

EVENT SUMMARIES – MULTIPLE-ENGINE POWERLOSS – FUEL RELATED - Hazard Level 4 or 5.

[NOTE: There is a significant overlap between the Fuel Leak category and the Multi-Engine Power Loss, Fuel Exhaustion category, as noted in the summaries below.]

CATEGORY **Engine Type**	**Event Summary**
CONTAMINATION	
Turboprop	No events.
Low Bypass	No events.
High Bypass	No events.
MISMANAGEMENT	
Turboprop	Aircraft lost power to all engines on approach. (Hazard Level 4.a.) Twin.
Low Bypass	No events.
High Bypass	Aircraft was unable to maintain altitude on approach due to dual power loss because of fuel icing. Landed short of runway and collapsed all landing gear. One major injury. No fire and no fatalities. (Hazard Level 4.a., 4.b.) 3rd generation. Twin.
EXHAUSTION	
Turboprop	Crashed short on approach. Fuel tanks found dry. Hull loss, no fatalities. (Hazard Level 4.a.) Twin.
	Fuel exhaustion forced sea ditching due to incorrect replacement of fuel quantity indicating unit prior to flight. 16 fatalities and 23 survivors. (Hazard Level 5). Twin.
Low Bypass	Off-airport forced landing after airplane ran out of fuel during descent to a diversion airport after multiple missed approaches to the destination airport. Airplane destroyed, no fatalities. (Hazard Level 4.a., 4.b.). Tri.

High Bypass Decreasing fuel quantity during cruise due to fuel leak at HP fuel pump. Flight diverted but crashed short of airfield due to fuel starvation. No fatalities. **Event included in Multi-Engine Power Loss, Fuel Exhaustion (Primary) and Fuel Leaks.** (Hazard Level 4.a.). 2nd Generation. Twin.

Fuel unbalance developed. Crew diverted due to fuel shortage. Both engines flamed out due to fuel exhaustion. Aircraft landed at remote airfield. Structural damage to airframe. **Event included in Fuel Leaks (Primary) and Multi-Engine Power Loss – Fuel Exhaustion.** (Hazard Level 4.a.) 2nd Generation. Twin.

Aircraft was critical on fuel and crashed in river when both engines flamed out. **Event included in Fuel Leak (Primary)** and **Multi-Engine Power Loss – Fuel Exhaustion.** (Hazard Level 4.a., 4.b.) 1st generation. Twin.

Fuel exhaustion in approach. Crash landed in cornfield. 1 fatality. (Hazard Level 4.a.). 1st Generation. Twin.

Fuel exhaustion, landed on taxiway, wingtip hit another plane. (Hazard Level 4.a.). 1st Generation. Twin.

Decreasing fuel quantity during cruise due to fuel leak at HP fuel pump. No fatalities. Crew diverted due to fuel shortage. Both engines flamed out due to fuel exhaustion. Aircraft landed off-airfield. Structural damage to airframe. **Event included in Fuel Leak (Primary) and Multi-Engine Power Loss – Fuel Exhaustion.** (Hazard Level 4.a.) 2nd generation. Twin.

EVENT SUMMARIES – MULTIPLE-ENGINE POWERLOSS – FUEL RELATED - Hazard Level 3.

CONTAMINATION

Turboprop No events.

Low Bypass No events.

High Bypass No events.

MISMANAGEMENT

Turboprop No events.

Low Bypass No events.

High Bypass Dual engine flameout during cruise - fuel pumps had not been turned on. Airplane lost 6,000 feet altitude before engines were restarted. Uneventful landing at Diversion airport. **Event included in Crew Error (Primary) and Multi-Engine Power Loss – Fuel Mismanagement.** (Hazard Level 3.e.). 2nd Generation. Twin.

Crew (training) cut-off fuel to both engines while experimenting with switch function. **Event included in Crew Error (primary) and Multiple-Engine Power Loss – Fuel Related.** (Hazard Level 3.e.) 3rd Generation. Twin.

EXHAUSTION

Turboprop No events.

Low Bypass No events.

High Bypass No events.

FATAL HUMAN INGESTION / PROPELLER CONTACT

FIGURE 48. FATAL HUMAN INGESTION / PROPELLER CONTACT - 2001 THROUGH 2012

ENGINE TYPE	TURBOPROP				JET/LOW BYPASS				ALL HIGH BYPASS			
HAZARD LEVEL	ALL	3	4	5	ALL	3	4	5	ALL	3	4	5
NUMBER EVENTS	2	0	2	0	0	0	0	0	4	0	4	0

ENGINE TYPE	1st Generation HBTF				2nd Generation HBTF				3rd/4th Generation HBTF			
HAZARD LEVEL	ALL	3	4	5	ALL	3	4	5	ALL	3	4	5
NUMBER EVENTS	0	0	0	0	2	0	2	0	2	0	2	0

- Turboprop rate of occurrence is 2 events in 3.79×10^{7} airplane flights, for a rate of 5.28×10^{-8}.
- Turbofan high bypass rate of occurrence is 4 events in 31.4×10^{7} airplane flights, for a rate of 1.27×10^{-8}.

Event summaries – Fatal Human Ingestion / Propeller Contact – Hazard Level 4 or 5.

Engine Type	Event Summary
Turboprop	Ramp agent attempted to remove chocks from path of taxiing aircraft and was fatally struck by the #2 engine propeller. (Hazard Level 4.d.) Twin.
	While on the stand, a mechanic tried to position chocks under wheels and was hit by the #1 engine propeller. Investigation revealed a cell phone was being used by the mechanic at the time of the accident. (Hazard Level 4.d.) Twin.
Low Bypass	No events.
High Bypass	Dispatch engineer ingested during maintenance ground run. (Hazard Level 4.d.) 2nd generation. Twin.
	Oil leak and maintenance ground run. Mechanic stepped into inlet hazard zone while engine at 70% power. (Ground run above idle against explicit airport rules). (Hazard Level 4.d.) 3rd generation. Twin.
	Maintenance technician ingested by engine during ground run. (Hazard Level 4.d.) 2nd generation. Twin.
	During taxi, airplane encountered mechanic on runway; ingestion. (Hazard Level 4.d.) 3rd generation. Twin.

Event summaries – Fatal Human Ingestion / Propeller Contact – Hazard Level 3.

Turboprop	No events.
Low Bypass	No events.
High Bypass	No events.

Figure 49 is a sample of In Flight Shut Down (IFSD) events for the 2012 calendar year, broken out by Hazard Level category for both turbofan and turboprop aircraft. The tables show the comparison of events above and below 1500 feet above ground level.

FIGURE 49. IFSD SNAPSHOT BY CAAM HAZARD LEVEL 2012 DATA ONLY

TURBOFAN

CAAM Level		Description
0	302	Above 1500 feet
1	31	Below 1500 feet
2	0	
3	0	
4	0	
5	0	
Unknown	1	
Total	334	

TURBOPROP

CAAM Level		Description
0a	42	Above 1500 feet
0b	0	
0c	4	
0d	2	
1	14	Below 1500 feet
2	10	
3	0	
4	0	
5	0	
Unknown	0	
Total	72	

Figure 50 is a sample of Rejected Take Off (RTO) events for the 2012 calendar year, broken out by Hazard Level category for both turbofan and turboprop aircraft.

FIGURE 50. RTO SNAPSHOT BY CAAM HAZARD LEVEL
2012 DATA ONLY

TURBOFAN

CAAM Level	Total Events
0.d.	352
1.g.	
2.g.	6
Unknown	2
Total	360

TURBOPROP

CAAM Level	Total Events
0.d.	38
1.g.	
2.g.	3
Unknown	0
Total	41

APU EVENTS

The team did not find APU events which were categorized as hazard level 3 or higher. Lower level APU events are not included in the report.

TURBOPROP EVENTS

FIGURE 51. PROPELLER SYSTEM-RELATED AIRCRAFT HAZARD MATRIX 2001 THROUGH 2012

HAZARD LEVEL	ALL	3	4	5
PROPELLER SYSTEM MALFUNCTION	**NUMBER EVENTS**			
PROPELLER SEPARATION/DEBRIS RELEASE	9	2	0	0
AUTOFEATHER/PITCH LOCK	104	4	0	0
PSMRR	*	4	5	3
CREW ERROR	*	2	1	2
TOTAL EVENTS	*	12†	6	5

* LOWER-LEVEL EVENTS NOT REPORTED.
† DUPLICATE CLASSIFICATION OF SOME EVENTS.

FIGURE 52. HAZARD RATIOS FOR PROPELLER

PROPELLER SYSTEM EVENT	PROPELLER SEPARATION/ DEBRIS RELEASE	AUTOFEATHER/ PITCH LOCK	PSMRR	CREW ERROR
LVL.5/ALL	0/9 = *	0/104 = *	**	**
LVL.4+5/ALL	0/9 = *	0/104 = *	**	**
LVL.3+4+5/ALL	2/9 = .22	4/104 = .04	**	**

* HAZARD RATIO NOT CALCULATED
** PREPARATION OF HAZARD RATIO NOT POSSIBLE GIVEN THE UNKNOWN INCIDENCE OF LOWER-LEVEL EVENTS.

Event summaries – Turboprop - Hazard level 4 or 5.

Malfunction	**Event Summary**
Propeller Separation/ Debris Release	No events.
Autofeather/Pitch Lock	No events.
PSMRR	PSMRR Hazard Level 4/5 turboprop event summaries are contained in the PSMRR section on pages 90-91.
Crew Error	Crew Error Hazard Level 4/5 turboprop event summaries are contained in the Crew Error section on page 95.

Event summaries – Turboprop - Hazard level 3.

Malfunction	**Event Summary**
Propeller Separation / Debris Release	During landing rollout, while engines were in reverse and brakes applied, aircraft nose wheel impacted deer crossing the runway. Deer was thrown into the left engine propeller, which detached from the engine on impact, puncturing the fuselage. (Hazard Level 3.a.) Twin.
	No reverse on right engine; runway departure into 4-ft. ditch at 70 kts., gear collapse and FOD to props. One failed at hub, pieces penetrated fuselage (8" tear). No injuries (hazard level 3.a., 3.f.)
Autofeather/Pitch Lock	After landing, aircraft departed runway due to propeller pitch lock. Nose landing gear snapped, aircraft turned and skidded on grass. (Hazard Level 3.a.) Twin.
	Right propeller pitch locked due to inadequate oil pressure. Full reverse selected on landing. Runway departure, significant aircraft damage, minor injuries (Hazard Level 3.a, 3.f.) Twin.
	Runway excursion on landing due to asymmetric thrust due to pitch lock. Aircraft veered to the right and ran over a ditch, collapsing the nose landing gear. (Hazard Level 3.a.) Twin.

Just after touchdown in rainy conditions, propeller pitch lock caused aircraft to exit runway, moving through an escape area where it hit obstacles, suffering heavy damage to nose landing gear and both main landing gears, as well as other associated damage. (Hazard Level 3.a.) Twin.

During final approach flight crew observed the right hand engine propeller speed remained at 70%. Crew elected to proceed with landing. During landing roll, aircraft veered off the runway and suffered nose landing gear damage. (Hazard Level 3.a.) Twin.

PSMRR PSMRR Hazard Level 3 turboprop event summaries are contained in the PSMRR section on page 93.

Crew Error Crew Error Hazard Level 3 turboprop event summaries are contained in the Crew Error section on page 96.

FIGURE 53. AIRCRAFT HAZARD EVENT COUNT MATRIX - SUMMARY REVENUE SERVICE 2001 THROUGH 2012

ENGINE TYPE	TURBOPROP				JET/LOW BYPASS				HIGH BYPASS				ALL			
HAZARD LEVEL	**ALL**	**3**	**4**	**5**	**ALL**	**3**	**4**	**5**	**ALL**	**3**	**4**	**5**	**ALL**	**3**	**4**	**5**
MALFUNCTION TYPE	**EVENT COUNTS**															
UNCONTAINED SUBTOTAL	1	0	0	0	12	1	0	0	93	7	3	0	106	8	3	0
Blade	*0*	*0*	*0*	*0*	*10*	*0*	*0*	*0*	*58*	*1*	*1*	*0*	*68*	*1*	*1*	*0*
Disk, Spool, etc.	*0*	*0*	*0*	*0*	*2*	*1*	*0*	*0*	*16*	*5*	*1*	*0*	*18*	*6*	*1*	*0*
Other	*1*	*0*	*0*	*0*	*0*	*0*	*0*	*0*	*19*	*1*	*1*	*0*	*20*	*1*	*1*	*0*
CASE RUPTURE	0	0	0	0	0	0	0	0	2	0	0	0	2	0	0	0
CASE BURNTHROUGH	4	0	0	0	3	0	0	0	21	0	0	0	28	0	0	0
UNDER-COWL FIRE	93	0	0	0	18	0	0	0	83	7	0	0	194	7	0	0
STRUT / PYLON FIRE	-	-	-	-	-	-	-	-	5‡	3	1	0	5‡	3	1	0
FUEL LEAK	**	0	0	0	10	1	0	0	318	6	7	0	328	7	7	0
ENGINE SEPARATION	0	0	0	0	2	0	1	0	1	0	0	0	3	0	1	0
COWL SEPARATION	6‡	0	0	0	17	0	0	0	96	2	0	0	119	2	0	0
PSMRR	**	2	4	3	**	0	0	4	**	4	2	1	**	6	6	8
CREW ERROR	**	2	1	2	**	1	0	0	**	3	3	3	**	6	4	5
REVERSER/BETA INFLIGHT DEPLOY	**	0	0	2	0	0	0	0	6	0	0	0	**	0	0	2
FUEL TANK RUPTURE	0	0	0	0	0	0	0	0	1	0	1	0	1	0	1	0
TAILPIPE FIRE	29‡	0	0	0	54	0	0	0	386	21	0	0	469	21	0	0
MULTI-ENG – NON-FUEL SUBTOTAL	11	2	4	1	13	2	1	3	105	5	13	2	129	9	18	5
Environmental – Non-Bird	*1*	*0*	*0*	*0*	*5*	*1*	*0*	*0*	*24*	*0*	*3*	*1*	*30*	*1*	*3*	*1*
Environmental – Birds	*0*	*0*	*0*	*0*	*0*	*0*	*0*	*0*	*29*	*0*	*4*	*0*	*29*	*0*	*4*	*0*
Maintenance	*1*	*0*	*0*	*1*	*2*	*1*	*1*	*0*	*2*	*0*	*1*	*0*	*5*	*1*	*2*	*1*
Other/Unknown	*9*	*2*	*4*	*0*	*6*	*0*	*0*	*3*	*50*	*5*	*5*	*1*	*65*	*7*	*9*	*4*

FIGURE 53. Continued

ENGINE TYPE	TURBOPROP				JET/LOW BYPASS				HIGH BYPASS				ALL			
HAZARD LEVEL	ALL	3	4	5	ALL	3	4	5	ALL	3	4	5	ALL	3	4	5
MALFUNCTION TYPE	EVENT COUNTS (continued)															
MULTI-ENG - FUEL SUBTOTAL	3	0	2	1	1	0	1	0	20	2	7	0	25	2	9	1
Fuel Contamination	*0*	*0*	*0*	*0*	*0*	*0*	*0*	*0*	*7*	*0*	*0*	*0*	*7*	*0*	*0*	*0*
Fuel Mismanagement	*1*	*0*	*1*	*0*	*0*	*0*	*0*	*0*	*6*	*2*	*0*	*0*	*7*	*2*	*1*	*0*
Fuel Exhaustion	*2*	*0*	*1*	*1*	*1*	*0*	*1*	*0*	*7*	*0*	*7*	*0*	*10*	*0*	*9*	*1*
HUMAN FATAL CONTACT/INGESTION	2	0	2	0	0	0	0	0	4	0	4	0	6	0	6	0
PROPELLER SYSTEM SUBTOTAL	**	10	5	5	-	-	-	-	-	-	-	-	**	12	6	5
Blade Separation/Debris	*9‡*	*2*	*0*	*0*									*9*	*2*	*0*	*0*
Autofeather/Pitch Lock	*104‡*	*4*	*0*	*0*									*104*	*1*	*0*	*0*
Propeller PSMRR	**	*2*	*4*	*3*									*	*4*	*5*	*3*
Propeller Crew Error	**	*2*	*1*	*2*									*	*2*	*1*	*2*
GRAND TOTAL	**	**16**	**16**	**14**	**144**	**5**	**3**	**6**	**1007**	**61**	**41**	**6**	**1379**	**84**	**56**	**26**

** Total event count unknown
‡ SUSPECTED UNDER-REPORTING.

FIGURE 54. AIRCRAFT HAZARD RATIO MATRIX - SUMMARY
REVENUE SERVICE 2001 THROUGH 2012

ENGINE TYPE	TURBOPROP			JET/LOW BYPASS			HIGH BYPASS		
HAZARD RATIO	(3+4+5)/ ALL	(4+5)/ ALL	5/ ALL	(3+4+5)/ ALL	(4+5)/ ALL	5/ ALL	(3+4+5)/ ALL	(4+5)/ ALL	5/ ALL
MALFUNCTION	HAZARD RATIOS								
UNCONTAINED				0.083					
Blade	-	-	-	-	-	-	0.034	0.017	-
Disk, spool, etc.	-	-	-	0.500	-	-	0.375	0.063	-
Other	-	-	-	-	-	-	0.105	0.053	-
CASE RUPTURE	-	-	-	-	-	-	-	-	-
CASE BURNTHROUGH	-	-	-	-	-	-	-	-	-
UNDER-COWL FIRE	-	-	-	0.020	-	-	0.084	0.023	-
PYLON/STRUT FIRE	-	-	-				0.800	0.200	
FUEL LEAK	-	-	-	0.100	-	-	0.041	0.022	-
ENGINE SEPARATION	-	-	-	0.500	0.500	-	-	-	-
COWL SEPARATION	-	-	-	-	-	-	0.021	-	-
REVERSER/BETA – INFLIGHT DEPLOY	-*	-*	-*	-	-	-	-	-	-
FUEL TANK RUPTURE	-	-	-	-	-	-	1.00	1.00	-
TAILPIPE FIRE	-	-	-	-	-	-	0.054	-	-
MULTI-ENG – NON-FUEL SUBTOTAL									
Environmental – Non-Bird	-	-	-	0.200	-	-	0.167	0.167	0.042
Environmental – Birds	-	-	-	-	-	-	0.138	0.138	-
Maintenance	1.00	1.00	1.00	1.00	0.500	-	0.500	0.500	-
Other/Unknown	0.667	0.444	-	0.500	0.500	0.500	0.220	0.120	0.020

FIGURE 54. Continued

ENGINE TYPE	TURBOPROP			JET/LOW BYPASS			HIGH BYPASS		
HAZARD RATIO	(3+4+5)/ ALL	(4+5)/ ALL	5/ ALL	(3+4+5)/ ALL	(4+5)/ ALL	5/ ALL	(3+4+5)/ ALL	(4+5)/ ALL	5/ ALL
MALFUNCTION	HAZARD RATIOS								
MULTI-ENG – FUEL SUBTOTAL									-
Fuel Contamination	-	-	-	-	-	-	-	-	-
Fuel Mismanagement	1.00‡	1.00‡	-	-	-	-	0.333	-	-
Fuel Exhaustion	1.00	1.00	.050	1.00	1.00	-	1.00	1.00	-
HUMAN FATAL CONTACT/INGESTION	*	*	*	*	*	*	*	*	*
PROPELLER SYSTEM SUBTOTAL									
Blade Separation/Debris	*	*	*	†	†	†	†	†	†
Autofeather/Pitch Lock	*	*	*	†	†	†	†	†	†
Propeller PSMRR	*	*	*	†	†	†	†	†	†
Propeller Crew Error	*	*	*	†	†	†	†	†	†

* HAZARD RATIOS NOT CALCULATED DUE TO NON-REPORTING OF BASE EVENTS.
† NOT APPLICABLE.
‡ HAZARD RATIOS CONSERVATIVE DUE TO SUSPECTED UNDER-REPORTING.

FIGURE 55. AIRCRAFT EVENT RATES MATRIX - SUMMARY
2001 THROUGH 2012

RATES GIVEN PER 100 MILLION AIRPLANE DEPARTURES

ENGINE TYPE	TURBOPROP				JET/LOW BYPASS				HIGH BYPASS			
HAZARD LEVEL	ALL	3+4+5	4+5	5	ALL	3+4+5	4+5	5	ALL	3+4+5	4+5	5
MALFUNCTION TYPE	**EVENT RATES****											
UNCONTAINED SUBTOTAL	3	-	-	-	54	4	-	-	30	3	1	-
Blade	-	-	-	-	45	-	-	-	18	1	1	-
Disk, Spool, etc.	-	-	-	-	9	4	-	-	5	2	1	-
Other	3	-	-	-	-	-	-	-	6	1	1	-
CASE RUPTURE	-	-	-	-	-	-	-	-	1	-	-	-
CASE BURNTHROUGH	11	-	-	-	13	-	-	-	7	-	-	-
UNDER-COWL FIRE	250	-	-	-	80	-	-	-	26	2	-	-
STRUT / PYLON FIRE	-	-	-	-	-	-	-	-	-	2	1	-
FUEL LEAK	-	-	-	-	45	4	-	-	101	4	2	-
ENGINE SEPARATION	-	-	-	-	9	4	4	-	1	-	-	-
COWL SEPARATION	16	-	-	-	76	-	-	-	31	1	-	-
PSMRR	*	24	19	8	*	18	18	18	*	2	1	1
CREW ERROR	*	13	8	5	*	4	-	-	*	3	2	1
REVERSER/BETA – INFLIGHT DEPLOY	-	5	5	5	-	-	-	-	2	-	-	-
FUEL TANK RUPTURE	-	-	-	-	-	-	-	-	1	1	1	-
TAILPIPE FIRE	78	-	-	-	241	-	-	-	123	7	-	-
MULTI-ENG – NON-FUEL SUBTOTAL	30	19	13	3	58	27	18	13	33	6	5	1
Environmental – Non-Bird	3	-	-	-	22	4	-	-	8	1	1	1
Environmental – Birds	-	-	-	-	-	-	-	-	9	1	1	-
Maintenance	3	3	3	3	9	9	4	-	1	1	1	-
Other/Unknown	24	16	11	-	27	13	13	13	16	4	2	1

FIGURE 55. Continued

ENGINE TYPE	TURBOPROP				JET/LOW BYPASS				HIGH BYPASS			
HAZARD LEVEL	ALL	3+4+5	4+5	5	ALL	3+4+5	4+5	5	ALL	3+4+5	4+5	5
MALFUNCTION TYPE	**EVENT RATES****											
MULTI-ENG - FUEL SUBTOTAL	8	8	8	3	4	4	4	-	6	3	2	-
Fuel Contamination	-	-	-	-	-	-	-	-	2	-	-	-
Fuel Mismanagement	3	3	3	-	-	-	-	-	2	1	-	-
Fuel Exhaustion	5	5	5	3	4	4	4	-	2	2	2	-
HUMAN FATAL CONTACT/INGESTION	5	5	5	-					1	1	1	
PROPELLER SYSTEM SUBTOTAL	*	62	30	13								
Blade Separation/Debris	24	52	-	-								
Autofeather/Pitch Lock	280	11	-	-								
Propeller PSMRR	*	32	22	8								
Propeller Crew Error	*	13	8	5								

* Rates not calculated due to under-reporting/non-reporting of base or level 3 events.

** Rates have been rounded to the nearest integer, except where the calculated rate was greater than zero but less than 0.5 per 100 million departures. In these cases, the rate has been rounded up to a value of one per 100 million, since rounding down to zero would indicate a false zero rate.

NOTE: Totals have removed the effect of duplicate events.

FIGURE 56. AIRCRAFT EVENT RATES MATRIX – COMPARISON OF FIRST, SECOND, AND THIRD/FOURTH GENERATION HBPR REVENUE SERVICE 2001 THROUGH 2012 SELECTED EVENT TYPES

RATES GIVEN PER 100 MILLION AIRPLANE DEPARTURES

ENGINE TYPE	FIRST GENERATION HBPR				SECOND GENERATION HBPR				THIRD/FOURTH GENERATION HBPR			
HAZARD LEVEL	ALL	3+4+5	4+5	5	ALL	3+4+5	4+5	5	ALL	3+4+5	4+5	5
MALFUNCTION TYPE	EVENT RATES**											
UNCONTAINED	601	88	-	-	19	2	1	-	17	6	-	-
Blade	283	18	-	-	14	1	1	-	11	-	-	-
Disk, spool, etc.	212	53	-	-	1	1	1	-	6	6	-	-
Other	106	18	-	-	4	1	1	-	-	-	-	-
MULTI-ENGINE	584	212	159	18	25	4	4	-	106	22	11	-
Environmental – Non-Bird	124	0	0	-	6	1	1	-	6	-	-	-
Environmental – Birds	88	18	18	-	6	1	1	-	45	6	6	-
Maintenance	-	-	-	-	1	1	1	-	-	-	-	-
Other/Unknown	230	142	88	18	11	1	1	-	34	6	-	-
Fuel Contamination	53	-	-	-	1	-	-	-	11	-	-	-
Fuel Mismanagement	35	-	-	-	1	1	-	-	6	6	-	-
Fuel Exhaustion	53	53	53	-	1	1	1	-	6	6	6	-

** Rates have been rounded to the nearest integer, except where the calculated rate was greater than zero but less than 0.5 per 100 million departures. In these cases, the rate has been rounded up to a value of one per 100 million, since rounding down to zero would indicate a false zero rate.

FIGURE 57. AIRCRAFT EVENT RATES MATRIX - SUMMARY
COMPARISON AMONG CAAM3 (C3), CAAM2 (C2), and CAAM1 (C1) (FORMAT SHOWN: C3 *C2 (C1)*)
SELECTED EVENT TYPES
INCLUDING SIMILAR EVENTS COLLECTED FOR ALL THREE CAAM EXERCISES
REVENUE SERVICE 2001 THROUGH 2012

RATES GIVEN PER 100 MILLION AIRPLANE DEPARTURES

ENGINE TYPE	TURBOPROP			JET/LOW BYPASS			HIGH BYPASS		
HAZARD LEVEL	ALL	3+4+5	4+5	ALL	3+4+5	4+5	ALL	3+4+5	4+5
MALFUNCTION TYPE	EVENT RATES**								
UNCONTAINED SUBTOTAL	3 36 (64)	- 4 (6)	- 4 (3)	13 59 (120)	4 15 (25)	- 6 (4)	30 129 (349)	3 10 (33)	1 1 (8)
Blade	- 4 (22)	- - (1)	- - (1)	45 47 (86)	- 4 (11)	- 2 (-)	18 97 (277)	1 2 (3)	1 - (-)
Disk, Spool, etc.	- 24 (38)	- 4 (5)	- 4 (5)	9 13 (26)	4 11 (12)	- 4 (4)	5 26 (46)	2 7 (23)	1 1 (8)
Other	3 8 (37)	- - (-)	- - (-)	- - (7)	- - (-)	- - (-)	6 6 (25)	1 1 (8)	1 - (-)
CASE RUPTURE	- - (15)	- - (-)	- - (-)	- 13 (26)	- - (5)	- - (3)	1 7 (25)	- - (5)	- - (-)
CASE BURNTHROUGH	11 12 (77)	- 4 (1)	- - (-)	13 7 (7)	- - (-)	- - (-)	7 27 (113)	- 1 (-)	- - (-)
UNDER-COWL FIRE	250 79 (22)	- 16 (4)	- - (1)	89 24 (22)	4 - (1)	- - (-)	26 85 (226)	2 3 (8)	- - (-)
ENGINE SEPARATION	- * (*)	-	-	9 13 (2.5)	4 9 (*)	- 6 (*)	1 3 (5)	- 3 (5)	- 1 (5)
COWL SEPARATION	16 * (*)	- * (*)	- * (*)	76 59 (34)	- 2 (-)	- - (-)	31 115 (200)	1 1 (3)	- - (-)
PSMRR	*	24 47 (23)	19 43 (18)	*	18 18 (9)	18 11 (6)	*	2 7 (-)	1 5 (5)
CREW ERROR	*	13 4 (6)	8 4 (6)	*	4 7 (1)	- 4 (-)	*	3 * (8)	2 - (3)
MULTI-ENG SUBTOTAL	30 71 (*)	19 48 (28)	13 36 (22)	58 55 (43)	27 42 (16)	13 15 (6)	33 88 (264)	6 20 (63)	7 6 (10)
GRAND TOTAL (all causes including those not listed here)	*	51 241 (74)	39 111 (53)	*	63 93 (61)	40 42 (21)	*	34 53 (167)	15 16 (33)

* RATES NOT CALCULATED DUE TO UNDER-REPORTING/NON-REPORTING OF BASE OR LEVEL 3 EVENTS.
** Rates have been rounded to the nearest integer, except where the calculated rate was greater than zero but less than 0.5 per 100 million departures. In these cases, the rate has been rounded up to a value of one per 100 million, since rounding down to zero would indicate a false zero rate.

NOTES:
GRAND TOTAL INCLUDES ALL LEVEL 3 AND 4 EVENTS, INCLUDING THOSE NOT COLLECTED IN CAAM1 OR CAAM2.
GRAND TOTAL REMOVES THE EFFECT OF DUPLICATE EVENTS.
BASE-LEVEL AND LEVEL 3 EVENTS SHOULD BE COMPARED WITH CAUTION, SINCE THE EXTENT OF REPORTING AND LEVEL 3 DEFINITIONS VARIED AMONG THE THREE CAAM STUDIES.

Data Comparison to previous CAAM data

Uncontained Blade: The total number of uncontained blade failure events has declined significantly from 195 events in the CAAM1 period to 120 events in the CAAM 2 period to 60 events in the CAAM3 period. The rate of blade event occurrence for all aircraft in the study (measured per 100 million departures) has decreased from 385 in the CAAM1 period to 148 in the CAAM2 period to 27 in the CAAM3 period. The total number of hazard level 3+ blade uncontainments has followed the same trend, decreasing from 11 to 4 to 2 events over the three time periods. The hazard level 3+ event rates have also decreased, from 15 to 10 to 1 per 100 million departures.

Uncontained Disk: The total number of uncontained disk failures shows a downward trend, decreasing from 69 to 38 to 13 events over the three study periods. The rate of disk event occurrence for all aircraft in the study (measured per 100 million departures) has decreased from 110 to 63 to 8 over the three time periods. The total number of hazard level 3+ disk uncontainments has decreased from 23 to 12 to 6 over the three study periods, and the hazard level 3+ disk event rates have decreased from 40 to 22 to 6 per 100 million departures.

High bypass turbofan (HBTF) engines continue to exhibit a low hazard ratio for HBTF blades (.034), similar to CAAM1 and CAAM2. Second generation HBTF blade rates are significantly lower than first generation HBTF blade rates (18 per 100 million departures for 2nd generation versus 566 per 100 million departures for 1st generation). Third/fourth generation HBTF blade rates are similar (17 per 100 million departures) to second generation event rates.

Case Rupture: The number of case rupture events on the high bypass fleet has decreased significantly from CAAM1 to CAAM2 to CAAM3 (25 vs. 7 vs.1). The rates for case rupture events have also shown significant improvement over the three study periods, from 66 to 20 to 1 per 100 million departures. There were no hazard level 3 or higher events in CAAM2 or CAAM3 versus 5 in CAAM1.

Case Burnthrough: Case burnthrough rates for the jet/low bypass and high bypass fleets in CAAM3 also showed a decrease across the three study periods, from 120 to 34 to 11 per 100 million departures. There were no hazard level 3 case burnthrough events in the CAAM3 time period. The trend in turboprop aircraft events did not show the same trend between the CAAM2 and CAAM3 study periods, as the number of events was relatively flat (3 vs. 4) and the rates were similar (12 vs. 11 per 100 million departures).

Undercowl Fire: For undercowl fire, the numbers of events and the hazard ratios in CAAM2 were very similar to those observed in the first CAAM study, even though the definition of "uncontrolled fire" was made more restrictive for the second study. The rates show some improvement for the high bypass turbofan fleet, and some deterioration for the turboprop fleet. Further refinement of the definitions was accomplished for CAAM3. As a result, direct comparisons between CAAM2 and CAAM3 are not possible.

Tailpipe Fires: Tailpipe fires are shown in CAAM3 to be a relatively large contributor to the total number of hazard level 3+ events. The definition of tailpipe fire was refined and expanded for CAAM3 such that a significantly larger number of events were categorized as Hazardous (hazard level 3). It should be also noted that no tailpipe fire events progressed beyond hazard level 3. Because of the expanded definitions for tailpipe fires in CAAM3, direct comparisons to the data in previous CAAM studies are not possible.

Overheat: The CAAM2 data showed, as in the first CAAM report, that the likelihood of a propulsion system high pressure air leak or compartment overheat leading to a serious event at the airplane level is controlled to a very low level. This data was not collected for the CAAM3 time period.

Cowl Separation: It was noted in CAAM2 that the number of cowl separation events had increased since the first study, primarily in the high bypass turbofan fleet. This was partially attributed to the expansion of the event definition to include ground events as well as flight events, which would be expected to drive the number up. The hazard ratio remained low. The number of cowl separation events in CAAM3 decreased slightly for the high bypass turbofan fleet, as the comparison shows 95 events in CAAM 3 versus 117 events in CAAM2. Because the fleet utilization for CAAM3 is significantly greater than in CAAM2, the overall high bypass fleet event rates are lower in CAAM3, decreasing from 115 to 30 per 100 million departures.

Cowl separation events for the low bypass jet fleet continued to increase from CAAM2 to CAAM3. This is likely due to the changes in definition, and is probably further influenced by the economics of the low bypass jet fleet. The rates for the low bypass fleet increased for the CAAM3 study, from 59 to 98 per 100 million departures.

Engine Separation: In CAAM2 the number of engine separation events, number of serious events and low bypass fleet event rate all increased since the first CAAM report. It should be noted that the first report intent was only to document in-flight events, while the scope was broadened to intentionally include on-ground events for CAAM2. CAAM3 provides data showing improvement over CAAM2 hazard ratios.

PSMRR (was PSM+ICR): The number of PSMRR events is still relatively constant compared with the first two CAAM studies. Interventions were introduced in the late 1990s to address this issue; however, these interventions should be reviewed with respect to their effectiveness. CAAM3 data indicates that safety improvement in the category of PSMRR is insignificant. The CAAM team again recommends that follow-on work be continued to improve the effectiveness of these interventions and take further action as needed.

Crew Error: There was some reduction in the number and severity of crew error events in CAAM2 compared to the first CAAM report. This continues in CAAM3.

Reverser: There was an increase in the number of reverser severe events in CAAM2 compared to the first CAAM report, but it should be recognized that the first report did not include turboprop in-flight beta malfunction, which accounted for most of the level 4 and 5 events. In CAAM3, the number of reverser inflight deploy events was significantly less. Only one severe event associated specifically with thrust reversers was documented in CAAM3.

Multi-Engine Power Loss: The definition for a level 3 multi-engine power loss event was expanded for the CAAM2 update, to include events in which engine power was completely lost for a sufficient time that the airplane lost 5000 feet of altitude. In the first study, many of these events would have been classified as less serious than level 3. There was also more data collected from the turboprop fleet than for the first report, and the power losses were grouped differently. CAAM3 utilized a yet more precise definition, resulting in differences in rates that are not directly comparable. In addition, CAAM3 chose to differentiate multi-engine power loss events due to bird ingestion due to the focus on bird ingestion events.

Caution should be used in comparing numbers of base events and level 3 events among the three CAAM reports. However, notwithstanding changes to the definitions, the high bypass turbofan fleet had fewer multiple engine power loss events for all causes than in the first two reports.

APU: APU events were not collected for CAAM3.

Appendix 4

Pareto Charts for Hazard Level 3, 4, and 5 Events

NOTE: The event counts that appear in the tables of Appendix 4 remove the effects of "double-counting". Hence the numbers that appear below may not match the event counts in the specific malfunction sections above where events have been categorized with a Primary and a Secondary malfunction category. Please refer to Note 2, page 9 of this document for further clarification.

FIGURE 58. PARETO OF ALL HAZARD LEVEL 3, 4 AND 5 EVENTS (HIGH BYPASS TURBOFAN AIRCRAFT)
REVENUE SERVICE 2001 THROUGH 2012

MALFUNCTIONS		NUMBER EVENTS
TAILPIPE FIRE		21
MULTI-ENGINE POWERLOSS – NON-FUEL		18
Other	9	
Environmental - Non-Bird	4	
Birds	4	
Maintenance	1	
FUEL LEAK		11
UNCONTAINED - ALL		10
Disk	6	
Blades / Stators	2	
Other / Unknown	2	
CREW ERROR		8
PSMRR		6
STRUT / PYLON FIRE		4
MULTI-ENGINE POWERLOSS – FUEL		4
Fuel exhaustion	3	
Fuel mismanagement	1	
OTHER - HUMAN INGESTION		4
UNDER-COWL FIRE		3
FUEL TANK RUPTURE/EXPLOSION		1
COWL SEPARATION		1
CASE BURNTHROUGH		0
CASE RUPTURE		0
ENGINE SEPARATION		0
REVERSER/BETA – INFLIGHT DEPLOY		0
SUBTOTAL TURBOFANS		91
Turbofan A/C flights 2001-2012		313,534,579

FIGURE 59. PARETO OF ALL HAZARD LEVEL 4 AND 5 EVENTS (HIGH BYPASS TURBOFAN AIRCRAFT)

REVENUE SERVICE 2001 THROUGH 2012

(Mirrored in Figure 1.)

MALFUNCTIONS	NUMBER EVENTS		RATE PER A/C FLIGHT
MULTI-ENGINE POWERLOSS – NON-FUEL		15	4.78E-08
Other	*6*		
Environmental - Non-Bird	*4*		
Environmental - Birds	*4*		
Maintenance	*1*		
FUEL LEAK		6	1.91E-08
CREW ERROR		5	1.59E-08
MULTI-ENGINE POWERLOSS – FUEL		4	1.28E-08
Fuel exhaustion	*3*		
Fuel mismanagement	*1*		
OTHER - HUMAN INGESTION		4	1.28E-08
PSMRR		3	9.57E-09
UNCONTAINED - ALL		3	9.57E-09
Disk	*1*		
Blades / Stators	*1*		
Other/Unknown	*1*		
FUEL TANK RUPTURE/EXPLOSION		1	3.19E-09
STRUT / PYLON FIRE		1	3.19E-09
CASE BURNTHROUGH		0	
CASE RUPTURE		0	
COWL SEPARATION		0	
ENGINE SEPARATION		0	
REVERSER/BETA – INFLIGHT DEPLOY		0	
TAILPIPE FIRE		0	
UNDER-COWL FIRE		0	
TOTAL - HIGH BYPASS TURBOFANS		42	1.34E-07
All High Bypass Turbofan A/C flights 2001-2012:		313,534,579	

FIGURE 60. PARETO OF ALL HAZARD LEVEL 3, 4, AND 5 EVENTS (ALL TURBOFAN AIRCRAFT - HIGH BYPASS AND LOW BYPASS)
REVENUE SERVICE 2001 THROUGH 2012

MALFUNCTIONS	NUMBER of EVENTS		RATE PER A/C FLIGHT
TAILPIPE FIRE		21	6.25E-08
MULTI-ENGINE POWERLOSS – NON-FUEL		20	5.95E-08
Other	*11*		
Environmental - Non-Bird	*4*		
Environmental - Birds	*4*		
Maintenance	*1*		
FUEL LEAK		11	3.27E-08
UNCONTAINED - ALL		11	3.27E-08
Disk	*7*		
Blades / Stators	*2*		
Other / Unknown	*2*		
PSMRR		10	2.98E-08
CREW ERROR		9	2.68E-08
MULTI-ENGINE POWERLOSS – FUEL		5	1.49E-08
Fuel exhaustion	*4*		
Fuel mismanagement	*1*		
STRUT / PYLON FIRE		4	1.19E-08
OTHER - HUMAN INGESTION		4	1.19E-08
UNDER-COWL FIRE		3	8.93E-09
FUEL TANK RUPTURE/EXPLOSION		1	2.98E-09
COWL SEPARATION		1	2.98E-09
CASE BURNTHROUGH		0	
CASE RUPTURE		0	
ENGINE SEPARATION		0	
REVERSER/BETA – INFLIGHT DEPLOY		0	
SUBTOTAL TURBOFANS		100	2.98E-07
Turbofan A/C flights 2001-2012		335,896,903	

FIGURE 61. PARETO OF ALL HAZARD LEVEL 4 AND 5 EVENTS (ALL TURBOFAN AIRCRAFT – HIGH BYPASS AND LOW BYPASS)

REVENUE SERVICE 2001 THROUGH 2012

(Mirrored in Figure 2.)

MALFUNCTIONS	NUMBER of EVENTS		RATE PER A/C FLIGHT
MULTI-ENGINE POWERLOSS – NON-FUEL		17	5.06E-08
Other	*8*		
Environmental - Non-Bird	*4*		
Environmental - Birds	*4*		
Maintenance	*1*		
PSMRR		7	2.08E-08
FUEL LEAK		7	2.08E-08
CREW ERROR		6	1.79E-08
MULTI-ENGINE POWERLOSS – FUEL		5	1.49E-08
Fuel exhaustion	*4*		
Fuel mismanagement	*1*		
OTHER - HUMAN INGESTION		4	1.19E-08
UNCONTAINED - ALL		3	8.93E-09
Disk	*1*		
Blades / Stators	*1*		
Other / Unknown	*1*		
FUEL TANK RUPTURE/EXPLOSION		1	2.98E-09
STRUT / PYLON FIRE		1	2.98E-09
CASE BURNTHROUGH		0	
CASE RUPTURE		0	
COWL SEPARATION		0	
ENGINE SEPARATION		0	
REVERSER/BETA – INFLIGHT DEPLOY		0	
TAILPIPE FIRE		0	
UNDER-COWL FIRE		0	
SUBTOTAL TURBOFANS		51	1.52E-07
Turbofan A/C flights 2001-2012		335,896,903	

FIGURE 62. PARETO OF ALL HAZARD LEVEL 3, 4, AND 5 EVENTS (TURBOPROP AIRCRAFT)

REVENUE SERVICE 2001 THROUGH 2012

MALFUNCTIONS	NUMBER EVENTS		RATE PER A/C FLIGHT
PSMRR		9	2.42E-07
MULTI POWER LOSS - NON-FUEL		7	1.89E-07
Environmental	*0*		
Other	*6*		
Maintenance	*1*		
CREW ERROR		5	1.35E-07
AUTOFEATHER/PITCH LOCK		4	1.08E-07
HUMAN FATAL INGESTION / PROPELLER CONTACT		2	5.39E-08
MULTI POWER LOSS - FUEL		2	5.39E-08
Fuel exhaustion	*2*		
Mismanagement	*2*		
PROPELLER MALFUNCTION		1	2.69E-08
PROPELLER SEPARATION/DEBRIS		1	2.69E-08
ENGINE FIRE		0	
FUEL LEAK		0	
REVERSER BETA - INFLIGHT DEPLOY		0	
SUBTOTAL TURBOPROPS		31	8.35E-07
Turboprop A/C flights 2001-2012		37,130,431	

FIGURE 63. PARETO OF ALL HAZARD LEVEL 4 AND 5 EVENTS (TURBOPROP AIRCRAFT)

REVENUE SERVICE 2001 THROUGH 2012

(Mirrored in Figure 3.)

MALFUNCTIONS		NUMBER EVENTS	RATE PER A/C FLIGHT
PSMRR		7	1.89E-07
MULTI POWER LOSS - NON-FUEL		5	1.35E-07
Environmental	*1*		
Other	*4*		
Maintenance	*0*		
CREW ERROR		3	8.08E-08
MULTI POWER LOSS - FUEL		3	8.08E-08
Fuel exhaustion	*2*		
Fuel mismanagement	*1*		
HUMAN FATAL CONTACT		2	5.39E-08
PROPELLER MALFUNCTION		1	2.69E-08
AUTOFEATHER/PITCH LOCK		0	
ENGINE FIRE		0	
FUEL LEAK		0	
PROPELLER SEPARATION/DEBRIS		0	
REVERSER/BETA - INFLIGHT DEPLOY		0	
TAILPIPE FIRE		0	
TOTAL TURBOPROPS		21	5.66E-07
Turboprop A/C flights 2001-2012		37,130,431	

FIGURE 64. PARETO OF ALL HAZARD LEVEL 3, 4, AND 5 EVENTS (TURBOFAN AND TURBOPROP AIRCRAFT)

REVENUE SERVICE 2001 THROUGH 2012

MALFUNCTIONS	NUMBER of EVENTS		RATE PER A/C FLIGHT
TAILPIPE FIRE		21	6.25E-08
MULTI-ENGINE POWERLOSS – NON-FUEL		20	5.95E-08
Other	*11*		
Environmental - Non-Bird	*4*		
Environmental - Birds	*4*		
Maintenance	*1*		
FUEL LEAK		11	3.27E-08
UNCONTAINED - ALL		11	3.27E-08
Disk	*7*		
Blades / Stators	*2*		
Other / Unknown	*2*		
PSMRR		10	2.98E-08
CREW ERROR		9	2.68E-08
MULTI-ENGINE POWERLOSS – FUEL		5	1.49E-08
Fuel exhaustion	*5*		
STRUT / PYLON FIRE		4	1.19E-08
FATAL HUMAN INGESTION / PROPELLER CONTACT		4	1.19E-08
UNDER-COWL FIRE		3	8.93E-09
FUEL TANK RUPTURE/EXPLOSION		1	2.98E-09
COWL SEPARATION		1	2.98E-09
CASE BURNTHROUGH		0	
CASE RUPTURE		0	
ENGINE SEPARATION		0	
REVERSER/BETA – INFLIGHT DEPLOY		0	
SUBTOTAL TURBOFANS		100	2.98E-07
Turbofan A/C flights 2001-2012		**335,896,903**	
PSMRR		9	2.42E-07
MULTI POWER LOSS - NON-FUEL		7	1.89E-07
Environmental	*0*		
Other	*6*		
Maintenance	*1*		
CREW ERROR		5	1.35E-07
AUTOFEATHER/PITCH LOCK		4	1.08E-07
HUMAN FATAL INGESTION / PROPELLER CONTACT		2	5.39E-08
MULTI POWER LOSS - FUEL		2	5.39E-08
Fuel exhaustion	*2*		
Mismanagement	*2*		
PROPELLER MALFUNCTION		1	2.69E-08
PROPELLER SEPARATION/DEBRIS		1	2.69E-08
ENGINE FIRE		0	
FUEL LEAK		0	
REVERSER BETA - INFLIGHT DEPLOY		0	
SUBTOTAL TURBOPROPS		31	8.35E-07
Turboprop A/C flights 2001-2012		**37,130,431**	

FIGURE 65. PARETO OF ALL HAZARD LEVEL 4 AND 5 EVENTS (TURBOFAN AND TURBOPROP COMBINED)

REVENUE SERVICE 2001 THROUGH 2012

MALFUNCTIONS		NUMBER of EVENTS	RATE PER A/C FLIGHT
MULTI-ENGINE POWERLOSS – NON-FUEL		17	5.06E-08
Other	8		
Environmental - Non-Bird	4		
Environmental - Birds	4		
Maintenance	1		
PSMRR		7	2.08E-08
FUEL LEAK		6	1.79E-08
CREW ERROR		5	1.49E-08
MULTI-ENGINE POWERLOSS – FUEL		5	1.49E-08
Fuel exhaustion	5		
FATAL HUMAN INGESTION / PROPELLER CONTACT		4	1.19E-08
UNCONTAINED - ALL		3	8.93E-09
Disk	1		
Blades / Stators	1		
Other / Unknown	1		
FUEL TANK RUPTURE/EXPLOSION		1	2.98E-09
STRUT / PYLON FIRE		1	2.98E-09
CASE BURNTHROUGH		0	
CASE RUPTURE		0	
COWL SEPARATION		0	
ENGINE SEPARATION		0	
REVERSER/BETA – INFLIGHT DEPLOY		0	
TAILPIPE FIRE		0	
UNDER-COWL FIRE		0	
SUBTOTAL TURBOFANS		49	1.46E-07
Turbofan A/C flights 2001-2012		**335,896,903**	
PSMRR		7	1.89E-07
MULTI POWER LOSS - NON-FUEL		5	1.35E-07
Environmental	0		
Other	6		
Maintenance	1		
CREW ERROR		3	8.08E-08
FATAL HUMAN INGESTION / PROPELLER CONTACT		2	5.39E-08
MULTI POWER LOSS - FUEL		2	5.39E-08
Fuel exhaustion	2		
Mismanagement	2		
PROPELLER MALFUNCTION		1	2.69E-08
AUTOFEATHER/PITCH LOCK		0	
ENGINE FIRE		0	
FUEL LEAK		0	
PROPELLER SEPARATION/DEBRIS		0	
REVERSER BETA - INFLIGHT DEPLOY		0	
SUBTOTAL TURBOPROPS		20	5.39E-07
Turboprop A/C flights 2001-2012		**37,130,431**	

Appendix 5
Fleet Included in the Data-Collection Process

TURBOJETS/ TURBOFANS

A300
A310
A320
A330
A340
A380
Aerospatiale Corvette
BAe125
BAe146
Beech 400 Beechjet
Boeing 707
Boeing 717
Boeing 727
Boeing 737
Boeing 747
Boeing 757
Boeing 767
Boeing 777
Boeing 787
Canadair 600/601 Challenger
Canadair RJ
Cessna Citation
Concorde
Dassault Falcon
DC10
DC8
DC9
Embraer ERJ 135
Embraer ERJ 145
Fokker 100
Fokker 70
Fokker F28
Gulfstream GII, III, IV
Hawker Siddeley BAe 125
L1011
Learjet
MD11
MD80
MD90
Caravelle
BAC111
Trident

TURBOPROPS

ATR 72
ATR 42
BAe ATP
BAe Jetstream 41
BE99
CASA/IPTN C-212
CASA C295
CASA/IPTN CN-235
Convair 580
DHC 6
DHC-7
DHC-8
Dornier Do328
Embraer EMB-120
FH227
Fokker 50
Fokker F27
Grumman Gulfstream I
Hawker Siddeley HS748
Lockheed 100
Lockheed 188 Electra
Saab 2000
Saab SF340
Shorts 330
Shorts 360
Swearingen SA 226
Swearingen SA 227
Vickers Viscount

Appendix 6

Thrust Excursions (High Bypass Fleet)

CAAM3 did not collect the thrust excursions data or loss of thrust control events as these types of events are reviewed quarterly with the New England Region FAA as part of the failure, malfunction and defect reporting process. This review process monitors and trends the occurrence rates to ensure that the FAR Part 33 requirements for uncontrollable high thrust are maintained below 1E-7 probability. Please refer to the CAAM2 documentation for previous discussion.