Background – High Bypass Ratio Turbofan Uncontained Disk Data

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Introduction

The material presented here has been developed by the Continued Airworthiness Assessment Methodologies (CAAM) Committee. The CAAM Committee is a Working Group of industry experts under the auspices of the Aerospace Industries Association (AIA) Propulsion Committee. The charter of the CAAM Committee includes updating the database of safety-significant propulsion system historical malfunctions. The approach taken by the Committee for this update has been to create a database to be available online as opposed to the historical approach of publishing a report covering events over a fixed period of time (i.e. the CAAM 1, 2, and 3 reports). Further guidance on the application of these datasets and how best to interpret the data for the purpose of numerical safety assessments is being developed and will be provided in a separate document.

Engines & Installations Covered

The engines that are contained in this dataset are in Table 1 along with a definition of the engine generations used. The aircraft contained in this dataset are in Table 2.

Generation	Description	Examples
Gen 1	First generation high bypass turbofan. Those designed in the late 1960s/1970s.	Includes the JT9D, JT15D series, RB211-22B and early RB211-524 models, TFE731-2/3, CF6-6, CF6-50 & CF34-3.
Gen 2	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.	Includes the AE3007, CFE738, CF34-8, TFE731-4 and later TFE models, 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, PW305A/B, PW306A/B, PW530A, PW535A, PW545A/B, and PW4000-94.
Gen 3	Third generation high bypass turbofan. Those designed to incorporate the lessons learned from the second generation.	Includes the GE90-94”/ 115”, CFM56-7, CF34-10, PW306C/D/D1, PW307A/D, PW308 A/C, PW535B, PW545C, PW4000 100”/112” fan, PW6000, Trent500, Trent700, Trent800, BR710, and BR715.
Gen 4	Fourth generation high bypass turbofan. Those designed to incorporate the Lessons Learned from the third generation.	Includes GEnx, GP7000, AS907, Trent 900, Trent 1000, PW800 series, and BR725.
Gen 5	Fifth generation high bypass turbofan. Those designed to incorporate the Lessons Learned from the fourth generation.	Includes LEAP, GE9X, Passport, Trent XWB, TEN, Trent7000, Pearl 15, and PW1000G series.

Table 1 - Engines contained in Dataset

Airbus A220	Bombardier Global 7500/8000	Embraer ERJ
Airbus A300	Bombardier CRJ900	Fairchild Dornier 328 JET
Airbus A310	Cessna Citation Bravo	Fokker 70
Airbus A320	Cessna Citation Encore+	Fokker 100
Airbus A330	Cessna Citation Excel	Gulfstream G100 (Astra SPX)/G150
Airbus A340	Cessna Citation Latitude	Gulfstream G200
Airbus A350	Cessna Citation I/III/VI/VII/X/Longitude	Gulfstream G280
Airbus A380	Cessna Citation Sovereign/Sovereign+	Gulfstream IV/G350/G450
BAHS125	Cessna Citation Ultra	Gulfstream V/G550/G650
Boeing 717	Cessna Citation Ultra Encore	Gulfstream G500/G600
Boeing 737	Cessna Citation XLS/XLS+	Gulfstream VI/G650
Boeing 747	COMAC ARJ21	Hawker 800/800XP/850XP/900XP
Boeing 757	Dassault Falcon 10/20/50/100	Hawker 1000/4000
Boeing 767	Dassault Falcon 900/2000	IAI Westwind 1124
Boeing 777	Dassault Falcon 6X	Learjet 23/24/25
Boeing 787	Dassault Falcon 7X/8X	Learjet M31/35/36/40/45/55/60
Bombardier Challenger 300/350	Dassault Falcon 2000EX/DX/LX/S/LXS	L1011
Bombardier Challenger 600	DC10	Lockheed L1329
*Bombardier Challenger 800	DHC-5	MD11
*Bombardier CRJ100/200	Embraer E-Jet E2 family	MD90
*Bombardier CRJ700 series	Embraer Legacy 450/500/600 Embraer Praetor 600	North American Sabreliner 65/65A
Bombardier Global Express		

*Aircraft type certificate transferred post CAAM 3 time period to the MHIRJ Aviation Group

Table 2 - Airplanes contained in Dataset

Dataset Boundaries

The datasets will be collected and updated over time. This release of data provides the events for "Uncontained Disk". The data includes all known applicable high bypass (defined as a bypass ratio of 2.0 or more) turbo fan engine events from 1969 through to 2021. The consequences of each event have been assessed using the hazard level definitions in Appendix 1 of the CAAM 3 report[3].

Any disk failures which where contained within the powerplant have not been included since they are, by definition, not nacelle uncontained. Some previous datasets, such as AIA Rotor Burst report[4] included these as Level 0 consequences. Events where the nature of the uncontainment is axial rather than radial are not included in the dataset. Axial Uncontained events will be considered in a subsequent separate dataset.

Narrative and Data Presentation

Unlike the previous CAAM reports[1,2,3], a narrative has been included for all events, not just the higher severity (Level 3, 4 & 5) events. This is to aid in the production of numerical analyses by providing further insight for the analyst to consider.

It should be noted that on Level 3, 4 & 5 events the effects that have contributed to the higher severity grading are noted in the event narrative. For the lower severity events, the narrative may contain additional information to highlight specific details that the author felt was important although not all events contain this level of detail.

Difference in details, wording, nomenclature, etc. amongst the narratives is due to different authors and levels of event reporting. As examples, similar but subtly different wording/nomenclatures such as “disk failure”, “disk fracture”, “disk separation”, “disk liberation”, “disk missing”, and “disk departure” were used by different authors to convey similar concepts. The Committee felt that the effort required to standardize the work amongst the different authors would delay publication of the data while not resulting in a material difference relative to the grading of the events or the intended usage of the data itself.

A table showing the count of the number of events of a given severity, similar to the tables provided in previous CAAM reports, is included with the dataset.

Comparison to Prior Datasets

A comparison between this dataset and the events in the AIA Rotor Burst report[4] has been made. The data cannot directly be compared since the AIA Rotor Burst includes contained disk events (Level 0), has a different definition of high bypass ratio and differences with respect to some of the participating Original Equipment Manufacturers (OEMs) in CAAM. The current dataset also includes an expanded reporting period. Differences in grading are explained by AIA Rotor Burst focussing on the grading based on the containment aspects and also revisions in the hazard level definitions since the Rotor Burst assessment was done. Despite these differences, comparing a subset of the data with the AIA Rotor Burst data shows that for the uncontained disks there is good agreement between the data. A summary of the differences are provided in Table 3.

AIA Event	Current data	Discussion
1976 2nd event	C1976_0002	Event in AIA as IPT but is actually HPT.
1980 1st event	N/A	Event is a duplicated event in AIA and therefore not included.
1981 1st event	N/A	Event is a Fan Axial Uncontained so not in this CAAM release.
1981 3rd event	N/A	Event is a Fan Axial Uncontained so not in this CAAM release.
1985 5th event	N/A	This event is a spacer failure event so not in this CAAM release.
N/A	C1991_0001	Additional event not in AIA Rotor Burst Data
1992 1st event	C1992_0001	Level 3 in CAAM, Level 2 in AIA
1999 1st event	N/A	This event is a seal failure event so not in this CAAM release.
2000 1st event	C2000_0001	Level 3 in CAAM, Level 2 in AIA
2000 3rd event	N/A	Unknown possibly a manufacturer not currently part of CAAM.
2002 1st event	C2002_0002	Level 3 in CAAM, Level 2 in AIA
2002 2nd event	C2002_0003	Level 3 in CAAM, Level 2 in AIA

Table 3 – Comparison to AIA Rotor Burst Data

A comparison has also been carried out with respect to the previous CAAM reports[1,2,3]. Direct correlation of the lower level (less than level 3 consequences) events is not possible due to the lack of detailed information in the CAAM reports. In aggregate, the CAAM reports had a total of 61 events (in the current dataset there are 24 more events due to the expanded reporting period). A summary of the evet counts from the current dataset and CAAM reporting periods is given in Table 4. These differences may be due to different definitions of uncontained used between the datasets (e.g. Level 0 and axial uncontainments included in previous CAAM reports) and difference in the OEMs in the previous CAAM reports. Comparison of the Level 3, 4 & 5 events from all three CAAM reports is

included in Table 5. Comparison of lower level events is not possible as there is insufficient information on the events in the CAAM reports.

	CAAM Datasets		Current Dataset	
	All events	Level 3, 4 or 5	All events	Level 3, 4 or 5
1982-1991 (CAAM1)	18	9	16	6
1992-2000 (CAAM2)	27	8	23	10
2001-2012 (CAAM3)	16	6	13	7

Table 4 – Comparison of Event Count against Previous CAAM Reports

CAAM Event	Current data	Discussion
CAAM1 L3 Fan Event	N/A	Unknown possibly a manufacturer not currently part of CAAM.
CAAM1 L3 Fan Event	C1990_0002	Review of the 'substantial damage' resulted in this event being classified as a Level 2 by CAAM definitions.
CAAM 1 L3 LPT Event	N/A	Unknown possibly a manufacturer not currently part of CAAM.
N/A	C1994_0002	Level 3 LPT event in current dataset but not original dataset or was originally classified as Level 2 or lower.
N/A	C2000_0006	Level 3 HPT event in current dataset but not original dataset or was originally classified as Level 2 or lower.
CAAM 3 L3 LPT Event	N/A	This is an axial uncontained event so not in this CAAM release.
N/A	C2002_0003	Level 3 HPT event in current dataset but not original dataset or was originally classified as Level 2 or lower.
N/A	C2007_0001	Level 3 Fan event in current dataset but not original dataset or was originally classified as Level 2 or lower.

Table 5 – Comparison to Level 3, 4 & 5 in Previous CAAM Reports

Therefore, the new CAAM data for disk uncontainment events are consistent and updated from the previous AIA Rotor Burst & CAAM datasets and should be used in lieu of this prior work.

References

[1] 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; October 25, 1999
[2] 2nd 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; January 31, 2005
[3] 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; March 30, 2017
[4] AIA Project Report on High Bypass Ratio Turbine Engine Uncontained Rotor Events and Small Fragment Threat Characterization 1969-2006 Volume 1; January 2010
[5] Advisory Circular 39-8 Continued Airworthiness Assessments of Powerplant and Auxiliary Power Unit Installations of Transport Category Airplanes; U.S. Federal Aviation Administration; September 08, 2003