Background – High Bypass Ratio Turbofan Fire Zone Fire Data

Note: in previous CAAM work this category was referred to as "Under-Cowl Fires", a detailed rationale for nomenclature change is provided below.

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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 is to create an online database 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 interpretation of the data for the purpose of numerical safety assessments will be provided in a separate document.

Relationship to Prior Data

Fire Zone Fires were addressed in all three previous CAAM reports. While there is not a 1:1 correlation between the historically published data and the present data, for Generation 2 and later High Bypass Ratio engines the currently posted dataset supersedes that which can be found in the previously published reports:

CAAM 1 report (Reference [1]) Fire – Under-Cowl, Figures 14 & 15
CAAM 2 report (Reference [2]) Under-Cowl Fire, Figures 24 & 25 and Appendix 7
CAAM 3 report (Reference [3]) Under-Cowl Fire, Figures 28 & 29

The Fire Zone Fire category, as with most all CAAM topics, has evolved over time. Familiarization with the prior work will help add context to currently published work and aid the analyst in understanding progression of the topic.

Definitions

<u>Fire Zone Fire</u>

As noted previously, the "Fire Zone Fire" nomenclature replaces what has historically been referred to as "Under-Cowl Fire". The Committee made this change to recognize that in some installations it is possible to have a fire in an area under a cowl, but not in a fire zone with the recognition that the specifics of where a fire occurs can influence the hazard it presents. To provide a more accurate description of what the dataset contains, the Committee decided to adopt the "Fire Zone Fire" nomenclature and to define it as:

> *Fire Zone Fire: A fire that initiates in a fire zone - the cavity between the outer surfaces of the engine cases and inner surfaces of the nacelle where both flammable fluid carrying lines and/or components coexist with ignition sources. Flammable fluids generally consist of fuel, oil, and hydraulic fluid while ignition sources are predominately hot surfaces but can include*

electrical arcing or hot air leaks. Fire zones include design features intended to mitigate fires including sealed boundaries/fire walls, detection, suppression, engine isolation (i.e. shutting off flammable fluid flow into the zone), ventilation, drainage, and hardware capable of withstanding fire for certain defined periods of time (i.e. fireproof and fire-resistant components). Fires that initiate outside of a fire zone will be captured in other dedicated categories such as pool fires (currently a proposed category) and tailpipe fires.

As a rule for evaluating an event, <u>if at least two of the following three</u> conditions exist it can be considered as a Fire Zone Fire event:

1. Flight deck fire warning or visible flames in and/or exiting the fire zone
2. The presence of soot deposits within the Fire Zone
3. Thermal distress (such as melted wiring, heat distressed clamp cushions, melted fire loop grommets, etc.) within the Fire Zone

<u>Event Level Classification</u>

Consistent with previous CAAM work, event severity classification is based on the actual event outcome and observations/findings as opposed to "what could have been". The CAAM 3 report (Reference [3]) is the basis for event severity classification, with the following specific modifications:

Level 2 – Significant Consequences:

Level 2 Fire Zone Fires previously have included severity Level 2.c. "Controlled fires (i.e. inside fire zones)". The revised definition of a Level 2.c. Fire Zone Fire is:

A fire initiating in a fire zone without Level 3 consequences. Fires that escape from the fire zone (for example by burning through the nacelle, burning through a fire wall, or escaping vents) must meet the criteria of Level 3 damage before being classified as such.

Level 3 – Serious Consequences:

Level 3 Fire Zone Fires previously have included severity Level 3.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." The revised definition of a Level 3.b. Fire Zone Fire is:

A fire initiating in a fire zone that subsequently escapes and impinges flames onto the wing, empennage, or fuselage, or acts as an ignition source for flammable material anticipated to be present outside[1] the fire zone. With respect to phrase "impinges flames onto…", to avoid introducing judgement or speculation, there should be positive indications of impingement including thermal damage to the impinged upon surface that requires repair or replacement.

[1] With respect to flammable material anticipated to be outside the fire zone, the word "anticipated" was consciously added in previous CAAM reports to specifically exclude events resulting in grass fires from being classified as Level 3. Addition of the word "anticipated" was intended to include such things as composite material or airplane fuel or hydraulic system elements outside of the engine fire zone, which are ignited as the result of a Fire Zone Fire. For example, a Fire Zone Fire which escapes the engine fire zone and ignites composite material within the Thrust Reverser Transcowl would be considered Level 3.b. per this part of the definition.

While soot deposits that can be cleaned/wiped away are specifically excluded as an indication of impingement, bubbled/blistered paint is included as the threshold for "requiring repair".

With respect to Fire Zone Fires, for all other event severity grading not addressed by the above discussion refer to the CAAM 3 report (Reference [3]).

Discontinued Terminology

In various forums, Fire Zone Fires (previously referred to as Under-Cowl Fires) have been described as "controlled", "uncontrolled", or "uncontained" which has led to confusion regarding event severity grading. As an example, these terms can be found in Airworthiness Regulations and Regulatory Guidance material. Consistent with the spirit of grading events based on their actual consequences and effects, the Committee has decided to discontinue use of these specific terms within the confines of the CAAM effort. This decision is intended to avoid confusion/conflict with any Regulatory use of these terms and to avoid the potential for different groups of individuals to have differing definitions for these terms. The Committee determines that discontinued use of these terms in no way detracts from event descriptions or severity grading in the context of the CAAM effort.

Narrative and Data Presentation

This dataset provides the event summary and grading for the Fire Zone Fire category and is intended to be updated over time. This data includes all known applicable Generation 2 High Bypass Ratio turbofan engine events through 2023. It was recognized by the Committee that events, especially lower level, from the 1970's and even the 1980's may be difficult to find reliable information on. As a result, the decision was made to limit the scope of the data collection to Generation 2 and later engines and exclude the Generation 1 engines that were included in previous CAAM reports.

Specifically excluded from the Fire Zone Fire data published here:

1. Fires that initiate after a fire zone has been breached (including, but not limited to, nacelle uncontainments) where the integrity of the fire zone is compromised before the fire initiates. Secondary damage associated with the initiating events may affect event progression since the effectiveness of the fire detection and suppression systems may have been compromised. Engine and nacelle contained events (where the fire zone remains intact) that result in flammable fluid leakage and ignition may be considered for inclusion. The consequences of fires from nacelle uncontained events are captured in the relevant uncontained data categories.
2. Case burnthrough events (such as combustor case, sump fires, internal gearbox fires, and compressor rapid oxidation events) where there is no subsequent ignition of flammable fluid within the fire zone. While case burnthroughs may result in a subsequent Fire Zone Fire which could be considered for inclusion within the scope of this data, a case burnthrough in and of itself, with no further progression, is not a Fire Zone Fire for the purposes of this data collection. Case burnthroughs will be considered for their own dedicated category of event data.
3. Electrical arcing events with no subsequent ignition of flammable fluids are specifically excluded from this category for the purposes of maintaining uniformity of the dataset.
4. Duct ruptures and hot air leaks that do not involve subsequent ignition of flammable fluids are likewise excluded.
5. Fire events involving material foreign to the engine (for example burning a rag that was inadvertently left in a fire zone) are specifically excluded.

Unlike the previous CAAM reports (References [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.

Included when available and believed to be potentially useful in providing further insight, are details such as the fuel source, leak rate, flight crew actions (if available), and indication/fire duration.

For Level 3 and higher events, the effects that contributed to the higher severity grading are noted in the event narrative. For the Level 2 and lower 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. 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.

Engines & Installations

The engines that are contained in this dataset are in Table 1 along with a definition of the engine generations used. The aircraft applicable to these engines that are contained in this dataset are in Table 2. Note that some of the listed aircraft have multiple possible engine configurations and that the list is included for reference only. Some aircraft may also have engine configuration options not captured by this dataset.

Generation	Description	Examples
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, Trent 1000 TEN, Trent7000, Pearl 15, and PW1000G series.

Table 1 - Engines contained in Dataset

Airbus A220	Bombardier Global 7500	Embraer E-Jet E2 family
Airbus A300	*Bombardier CRJ900	Embraer Legacy 450/500/550/600 Embraer Praetor 600
Airbus A310	Cessna Citation Bravo	Embraer ERJ
Airbus A320	Cessna Citation Encore+	Fairchild Dornier 328 JET
Airbus A330	Cessna Citation Excel	Fokker 70
Airbus A340	Cessna Citation Latitude	Fokker 100
Airbus A350	Cessna Citation I/ VII/X/Longitude	Gulfstream G100 (Astra SPX)/G150
Airbus A380	Cessna Citation Sovereign/Sovereign+	Gulfstream G200
BAe 125 Series 800/1000	Cessna Citation Ultra	Gulfstream G280
Boeing 717	Cessna Citation Ultra Encore	Gulfstream IV/G350/G450
Boeing 737	Cessna Citation XLS/XLS+	Gulfstream V/G550/G650
Boeing 747	COMAC ARJ21	Gulfstream G500/G600
Boeing 757	Dassault Falcon 20/50EX	Gulfstream VI/G650
Boeing 767	Dassault Falcon 900/2000	Hawker 800/800XP/850XP/900XP
Boeing 777	Dassault Falcon 6X	Hawker 1000/4000
Boeing 787	Dassault Falcon 7X/8X	Learjet 40/45/60/70/75
Bombardier Challenger 300/350/3500	Dassault Falcon 2000EX/DX/LX/S/LXS	MD11
*Bombardier CRJ700 series	DC8	MD90
Bombardier Global Express	DHC-5	

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

Table 2 - Aircraft applicable to the Engines in Table 1

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