Guidance Material for use with CAAM Uncontained Disk Data

Cautionary Note: This document is intended to provide the CAAM Committee's assessment and interpretation of the uncontained disk data set. The insights provided in this guidance are based on the collective experience of the CAAM Committee members. It should be noted that any given issue may have nuances that makes this material more or less applicable to that situation. This material is general in nature and should only be utilized in conjunction with a thorough assessment of the specific situation to which it is being applied. While this material was developed by practitioners with a wealth of experience, it is always possible that a given assessment is not valid for a specific issue being analyzed based on factors that can't currently be foreseen or contemplated. For these reasons care should be taken in the use of this material and the data it accompanies.

The following assessments are contained in this document:

I. Disk fragmentation: bore-rim fracture vs. rim segment release

The uncontained disk data set contains different disk fracture types. The data has been broadly categorized as “disk”, where essentially the entire part is released, and “rim”, where only a portion of the part is separated. Data in the “disk” categorization includes bore-rim type fractures and tri-hub bursts as examples. This type of fragmentation can result in multiple large fragments exiting the powerplant in multiple trajectories. “Rim” fractures include instances where an entire disk rim peels through the disk web or a rim segment (e.g. “shark bite”) separates in the disk web but the bore remains intact. This type of fragmentation can result in smaller fragments and potentially fewer significant fragment trajectories than a “disk” type fracture. Specifically excluded from the uncontained disk category are disk lug fractures where a disk post (or multiple) and the associated blades are released. These types of events are captured under the blade uncontainment category.

Figure 1 is an assessment of the data separating the “disk” from the “rim” categorized fractures. Based on this cutting of the data it is assessed that there have been a meaningful number of both disk and rim type fractures to make a comparison. It is observed that within the disk data there have been six (6) CAAM Level 4 or higher events while there have been none in the rim data. Furthermore, the Level 3+ Hazard Ratio (HR) for the disk events is 4x higher than the that for the rim events. Given the likelihood that the “disk” categorized events resulted in larger fragments and multiple large fragment trajectories, these results are consistent with the perception that the “disk” events would be more hazardous.

	disk	rim
total	36	25
level 4or5	6	0
level 3 4 or 5	27	4
L4 HR	0.2	-
L3+4 HR	0.8	0.2

Figure 1

<u>Conclusion:</u> When using this data to develop Hazard Ratios, it is advised that disk fragmentation may be part of the consideration in selecting what is the most appropriate data for a specific issue.

II. Engine module effects

The traditional approach to developing a hazard ratio for an uncontained disk has been to limit the data utilized to the module being assessed. The one caveat to this is that intermediate spool data has tended to be grouped with high spool data, specifically High Pressure Compressor (HPC) data has been combined with Intermediate Pressure Compressor (IPC) data and High Pressure Turbine (HPT) data has been combined with Intermediate Pressure Turbine (IPT) data.

Assessment of the current data supports this continued approach with differences in hazard ratios demonstrated between engine modules.

As observed in Figure 2, when looking at all fragments, Fan and HPT/IPT disks have exhibited higher hazard ratios than HPC/IPC or LPT disks, most notably when looking at Level 4 consequences. The differences become even more pronounced when the assessment is done by removing the rim fragment data (i.e. looking only at "disk" fractures) as seen in Figure 3.

all fragments	Fan	HPC/IPC	HPT/IPT	LPT
total	10	24	27	26
level 4or5	3		3	
level 3 4 or 5	6	6	11	10
L4 HR	0.3	0.0	0.1	0.0
L3+4 HR	0.6	0.3	0.4	0.4

Figure 2

large disk fragr	Fan	HPC/IPC	HPT/IPT	LPT
total	10	18	15	21
level 4or5	3		3	
level 3 4 or 5	6	5	9	9
L4 HR	0.3	0.0	0.2	0.0
L3+4 HR	0.6	0.3	0.6	0.4

Figure 3

Conclusion: The traditional approach of segregating data by engine module for developing a hazard ratio is supported by assessment of the data.

III. Installation effects

The uncontained disk data set contains a mix of different types of installations. Included in these are twin wing mounted engines, aft fuselage mounted engines, tail engine installations (such as on a three engine airplane), and quad installations with both wing inboard and wing outboard engines. Because these different architectures place the engines in different proximity and location to different critical points on the airplane, it was desired to determine if the resulting hazard ratios could be influenced by installation. The analyses below were based on available data which may be limited. Conclusions may change if more data becomes available. Note that for all assessments in this section the uncontained disks from all modules were combined.

Figure 4 presents a comparison of aft mounted installations (engines mounted to the aft fuselage or in the tail) to wing mounted installations (includes both inboard and outboard locations on quad jets). Inspection of these results does not indicate a significant difference in hazard ratios for aft versus wing mount installations.

	aft	wing
total	31	58
level 4or5	3	3
level 3 4 or 5	9	24
L4 HR	0.1	0.1
L3+4 HR	0.3	0.4

Figure 4

Figure 5 presents a hazard ratio comparison for inboard versus outboard engines on quad engine configuration airplanes. Inspection of these results does not indicate a significant difference in hazard ratios for inboard versus outboard engines on quad airplanes.

In review of the event narratives, it was noted that inboard engines are more likely to affect outboard engines than vice versa. This is likely due to the stagger of the engines on swept wing airplanes. While this may be an explanation for the inboard engines demonstrating different hazard ratios than outboard engines, the differences are small and there is not enough data to make this a true differentiator. Further study is required before segregating the data in this manner.

	Quad ibd	Quad obd
total	12	12
level 4or5	0	0
level 3 4 or 5	5	3
L4 HR	-	-
L3+4 HR	0.4	0.3

Figure 5

Figure 6 builds upon the assessment of the data in Figure 5 by including wing mounted engines on twin jets and tri jets. The assessment of this data indicates that the twin/tri wing installations have numerically higher hazard ratios when compared to quad inboard and, separately, outboard engines with the difference more pronounced with the outboard installations. Evaluation of these numerical differences should include a consideration of the limited number of data points used for the calculations. Further study is also recommended relative to determining a physics-based explanation for any observed differences before segregating the data in this manner.

	Quad ibd	Quad obd		twin or tri
total	12	12		34
level 4or5	0	0		3
level 3 4 or 5	5	3		16
L4 HR	-	-		0.1
L3+4 HR	0.4	0.3		0.5

Figure 6

It should be noted that hazard ratios in all of the above assessments were of the same order of magnitude ranging between 0.3-0.5 for Level 3+ ratios and ~0.1 for the Level 4 ratio when the ratio can be calculated (i.e. when there were Level 4 or 5 events in the data).

Conclusion: Twin/tri jet wing configurations were the only installations identified that may have an influence on hazard ratio. The data used to make this assessment is limited and the different hazard ratios calculated as part of this assessment were all of the same order of magnitude and within a limited range. Further justification is recommended before segregating the data in this manner for hazard ratio development.

IV. Air versus ground events

Figure 7 is a comparison of hazard ratios developed by segregating the data based on the event occurring on the ground versus in the air. The assessment in this section combined the uncontained disks from all modules. There is nearly an order of magnitude difference noted for the Level 4 hazard ratio, with on ground events being more likely to have higher level consequences. This result is due, in part, to on-ground events presenting conditions more likely for a pool fire to develop. The utility of this information may be limited for issues that are considered on a flight cycle basis, given that each flight cycle involves both air and ground portions. This information does, however, provide insight into factors that influence event outcome.

	air	ground
total	55	30
level 4or5	2	4
level 3 4 or 5	20	13
L4 HR	0.04	0.13
L3+4 HR	0.4	0.4

Figure 7

<u>Conclusion:</u> On-ground events have demonstrated a higher probability for more adverse outcomes versus those events that have occurred in air.

Revision History

15 September 2022 – Initial Release

Xx October 2022 – Revision 1

Corrected typographical error in Cautionary Note on 1st page

Formatting change to section I.

Added section II. Engine module effects

Added section III. Installation effects

Added section IV. Air versus ground events