AAWG Rotorburst Recommendation Document

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Acronyms

AAWG	Airworthiness Assurance Working Group
AC	Advisory Circular
AIA	Aerospace Industries Association
ARAC	Aviation Rulemaking Advisory Committee
CFR	Code of Federal Regulations
CS	Certification Specifications
EASA	European Aviation Safety Agency
FAA	Federal Aviation Administration
FAR	Federal Aviation Regulation
LDC	Large Damage Capability
NAA	National Aviation Authorities
OEM	Original Equipment Manufacturer
PS	Policy Statement
SDC	Structural Damage Capability
TAMCSWG	Transport Airplane Metallic and Composite Structures Working Group
UEDDAM	Uncontained Engine Debris Damage Assessment Model

References

FAA Policy Statement PS-ANM100-1993-00041, "Compliance with 25.571(e) Discrete Source Damage (Uncontained Engine Failure) dated September 1, 1993	
FAA Advisory Circular AC 20-128A, "Design Considerations for Minimizing Hazards Caused by Uncontained Turbine Engine and Auxiliary Power Unit Rotor Failures", dated March 25, 1997	
FAA Advisory Circular AC 25.571-1D, "Damage Tolerance and Fatigue Evaluation of Structure", dated January 13, 2011	
"AIA Project Report on High Bypass Ratio Turbine Engine Uncontained Rotor Events and Small Fragment Threat Characterization 1969-2006" Volume 1, dated January 2010	

1. Executive Summary

The FAA formally tasked the Aviation Rulemaking Advisory Committee (ARAC); Transport Airplane Metallic and Composite Structures Working Group (TAMCSWG) to provide recommendations on § 25.571 and associated regulatory guidance material. As part of this effort, the TAMCSWG assigned the Airworthiness Assurance Working Group (AAWG) to evaluate § 25.571(e) and associated guidance material (AC 25.571-1D, AC 20-128A and FAA Policy Statement PS-ANM100-1993-0041) as they pertain to uncontained engine failures. This report documents the findings, conclusions, and recommendations of the Working Group for this Task.

The AAWG met a total of six times (including a face-to-face meeting in March 2016) to accomplish the work set forth in the Tasking Statement. The AAWG reviewed the regulations and guidance material with respect to uncontained engine failures and reached the following four conclusions:

1. The Original Equipment Manufacturers (OEM) essentially use an identical approach in showing compliance to the Part 25 requirements for uncontained engine failure. For compliance to § 25.571(e), OEMs have included structural risk within the airplane level risk assessment.

2. As supported by service experience, the existing method of compliance for showing compliance to Part 25 uncontained engine failure requirements provides an adequate level of safety and will continue to provide the same level of safety in the future.

3. The existing engine failure model per AC 20-128A is adequate for structural evaluation and there is no basis for having different requirements for structure. The established method, which includes the existing engine failure model combined with assumptions in the structural evaluation, provides a conservative approach that results in an adequate level of safety for airplane structure.

4. Although the method of compliance that is used by the AAWG member OEMs has been well established and understood to be consistent with available guidance, it does not agree with the current FAA interpretation of the guidance materials. The guidance materials, including the FAA Policy Statement, require clarification with respect to risk assessment requirements.

Considering the conclusions reached by the AAWG, the AAWG recommends that the ARAC, TAMCSWG consider enacting the following four recommendations to clarify the structural requirements for § 25.571(e) and § 25.903(d) as they pertain to uncontained engine failures:

1. Revise AC 25.571-1D to clarify that structural risk is included within the airplane level risk calculations as performed per AC 20-128A. In addition, clarify that the applicant may consider phase of flight aspects and allow for averaging all rotors on all engines of a given airplane when calculating the structural risk component within the airplane level risk calculation.

2. Revise AC 20-128A to strengthen the definition of structural design considerations and to further emphasize that risk from structural damage should be included in the calculation of the airplane level hazard ratios.

3. Keep regulations § 25.571(e) and § 25.903(d) unchanged, recognizing that there will continue to be a lack of harmonization between the various NAA regulations.

4. While the regulations may not be harmonized, the AAWG recommends harmonization with respect to guidance material. The Working Group therefore recommends that the other National Airworthiness Authorities (NAA) revise their guidance material in accordance with the proposed changes to FAA AC 25.571-1D and AC 20-128A.

2. Introduction and Background

The provisions for considering discrete source damage in Title 14, Code of Federal Regulations (14 CFR) 25.571(e) require the successful completion of the flight after likely damage occurs as a result of fan blade impact, uncontained engine failure, or uncontained high energy rotating machinery failure. Advisory Circular (AC) 25.571-1D provides guidance on flight loading conditions that need to be considered after the likely damage required by § 25.571(e), and AC 20-128A contains an engine burst model criteria for minimizing the hazards in accordance with § 25.903.

However, neither AC provides clear guidance on the extent of damage an applicant should consider "likely" by § 25.571(e). Consequently, an assessment conducted using both ACs does not guarantee compliance with § 25.571(e). FAA Policy Statement PS-ANM100-1993-00041 does provide applicants guidance on applying AC 20-128A to show compliance with § 25.571(e), but some applicants have misinterpreted the allowance of this statement when determining the extent of damage considered "likely" by § 25.571(e).

The applicable regulation, § 25.571(e) - *Damage-tolerance (discrete source) evaluation* specifies:
"The airplane must be capable of successfully completing a flight during which **likely structural damage** occurs as a result of – …
(1) (bird strike)
(2) Uncontained fan blade impact;
(3) Uncontained engine failure; or
(4) Uncontained high energy rotating machinery failure

Section 25.571(e), Amendment 25-45, was not intended to allow the use of probabilistic methods in showing compliance. However, the inclusion of the term "likely structural damage" in the rule suggests that some level of probability is permitted in determining potential structural damage scenarios resulting from a rotor burst and therefore necessitates additional clarification.

Policy Statement PS-ANM100-1993-00041 (refer Appendix A) attempts to provide such clarification by stating "The intent of § 25.571(e) is to ensure survival of the airplane with any likely damage resulting from an engine failure. It was not intended, for this evaluation, that the crown skins and belly skins would be exempt from rotor strikes. However, if the combined probability of all structural damage, including crown and belly skin damage, resulting from failure of any engine rotor has no greater chance than 1 in 20 of producing catastrophic results, the design meets the airworthiness requirements of this regulation."

The Policy Statement goes on to say "AC 20-128 provides the engine burst criteria to use in showing compliance with § 25.903(d)(1) requirements to minimize the hazard to the airplane in the event of an engine rotor failure. The total level of risk from all damage cases should be assessed. In recent certification programs the FAA has accepted the risk levels provided in ACJ 25.903(d)(1)."

The industry has understood the Policy Statement to be consistent with their common approach to show compliance to the uncontained engine failure requirements of § 25.571(e). The common approach combines structural risk with other airplane level risks in the analysis performed to show compliance to § 25.903(d)(1) using the failure model and risk methodologies, including phase of flight, contained in AC 20-128A. The analysis results demonstrate that the overall averaged risk of catastrophic damage from a 1/3 disk segment is within the 1:20 target prescribed by AC 20-128A, which is identical to the risk target given in ACJ 903(d)(1) and the Policy Statement.

This addresses the requirement of the Policy Statement that "all structural damage" is evaluated, since all potential damage scenarios from the engine failure model in AC 20-128A are evaluated. It also addresses the Policy Statement requirement that the damage could come from "any engine rotor", since damage from each rotor is evaluated and each rotor has an equal probability of failing. Furthermore, the industry considers this as meeting the § 25.571(e) requirement that "The airplane must be capable of successfully completing a flight during which likely structural damage occurs . . ." , since all structural damage scenarios are evaluated against the strength and stability requirements in AC 25.571-1 and since uncontained engine failure events in some phases of flight will not be structurally catastrophic. The industry also maintains that this approach demonstrates compliance to § 25.903(d)(1) "Design precautions must be taken to minimize the hazards to the airplane in the event of an engine rotor failure . . ." since the design must have sufficient robustness and redundancy to meet the risk target in AC 20-128AC.

Subsequent discussions with the FAA revealed that the Policy Statement was meant to clarify that the probability of catastrophic structural failure resulting from failure of ***any single engine rotor*** be less than 1:20. The FAA has stated that to show compliance with § 25.571(e) the applicant would need to address the loads that would reasonably be expected to occur during any phase of flight, as addressed in the Policy Statement. The FAA also stated that the requirements of § 25.571(e) and § 25.903(d) are substantively different. Section 25.571(e) requires a sufficient level of structural capability to return from any flight during which an engine failure occurs. Section 25.903(d) intends to minimize catastrophic events resulting from engine failures that are not practical to mitigate by arrangement of critical systems, flight controls and redundancy. Therefore, methods of compliance that are appropriate for § 25.903(d) will not necessarily be applicable to § 25.571(e). The FAA has requested the TAMCSWG to weigh in on this interpretation, who in turn assigned this task to the AAWG.

This report summarizes the current industry practices for addressing rotorburst requirements and makes recommendations on how to clarify the relevant guidance material. The outcome will allow for OEMs, operators and NAAs to have a common understanding of the requirements of § 25.571(e) as it pertains to uncontained engine failures.

3. AAWG Tasking

The TAMCSWG has been tasked to provide recommendations on § 25.571 and associated regulatory guidance material. The TAMCSWG has assigned the evaluation of Policy Statement PS-ANM100-1993-00041 to the AAWG. As part of its evaluation and recommendation, the FAA requests the AAWG perform the following:

1. Review historical rotor burst events, and damage that occurred.
2. Assess trends in rotor burst events.
3. How do applicants show compliance with § 25.571? Do you only use the average risk criteria in AC 20-128A, or do you do something additional for compliance with § 25.571? Do you apply the 1/20 criterion to each stage and for every flight segment?
4. Assess whether damage scenario assumptions in AC 20-128A are realistic and whether applicants should use more realistic damage scenarios.
    a. Is assuming infinite energy of fragments appropriate for the purpose of structural analysis?
    b. Would more realistic assumptions result in improved damage tolerance capability?
    c. Should we use the same analytical assumptions for all types of disks or should we use different assumptions for different types of disks?
    d. How is paragraph 10.e. (Specific Risk) of the AC applied in your company?
        i. Do you include a reduction in probability for structures assuming rotor burst occurring during takeoff before V1 is not catastrophic (refer to AC 20-128A paragraph 6.8.1)?
5. Assess whether current practice provides an adequate level of safety.
6. Study the uncontained engine debris damage assessment model (UEDDAM) and determine whether it provides a better assessment of rotor burst damage.
7. Assess the relationship between rotor burst damage and large damage capability and the need to have a minimum residual strength capability for both (including accounting for aeroelastic stability, including flutter and divergence).
8. Assess current practices for minimization of a catastrophic event for structures due to rotor burst, e.g., the practicality of having redundant structure, alternate materials, additional means.

Section 5 of this report contains AAWG findings for each of the above assigned tasks. Section 6 of this report contains AAWG conclusions.

4. Research Information

4.1 AIA Project Report on Engine Uncontained Rotor Events

The *Aerospace Industries Association (AIA) Project Report on High Bypass Ratio Turbine Engine Rotor Events and Small Fragment Threat Characterization* report from January 2010 (refer Appendix B) provides a comprehensive single rotorburst database for high bypass turbofans to help gain an understanding of rotor uncontainment threats. The AIA Working Group collected data on disk uncontainment events and their airplane level consequences for the time period 1969 thru 2006. During this time period, there have been a total of 58 nacelle uncontained disk events. 46 of these events were from 1st generation engines and 12 were from 2nd generation engines. At the time of publication, there had been no events from 3rd generation engines.

4.2 Updated information and more recent events

An estimated 100 million additional engine flight cycles have been accrued for 3rd generation engines since 2006. During this time, there have been two known uncontained engine failure events on aircraft equipped with 3rd generation engines. The first involved an Airbus A380 equipped with Rolls-Royce Trent 900 engines and occurred on November 4, 2010. The event occurred four minutes after take-off, the airplane was able to safely land without injury to the passengers or crew. Shrapnel from the exploding engine punctured part of the wing and damaged the fuel system, though overall structural integrity was maintained.

The second event involved a Boeing B777 and occurred on September 8, 2015. The engine failure occurred during take-off and resulted in a fire, which prompted abortion of the take-off and evacuation of all passengers and crew. The aircraft had suffered an uncontained engine failure in the left GE90 engine. Other than damage resulting from the subsequent fire, there was no damage to primary structure due to the uncontained engine failure.

5. Assignments and Findings

5.1 Review and assessment of historical trends

Based on review of the information referenced in Section 4 of this report, the trends show a low incidence of disk uncontainment events, especially for airplanes equipped with 2nd and 3rd generation engines. Per the original AIA report, no 3rd generation events occurred through 2007. If one conservatively assumed one 3rd generation event and accounted for cumulative cycles accrued through 2007, the historical rate of a 3rd generation event through 2007 would have been 2.5 E-8/cycle. We now know that two events (the A380 and B777 events) have occurred since 2007. To update the AIA report rate, we can now assume two events and account for cycles accrued through 2014. When this is done, the historical rate of a 3rd generation event is slightly reduced to 1.4 E-8/cycle. To date, there has never been a catastrophic structural failure resulting from uncontained engine failure for airplanes equipped with 2nd or 3rd generation engines. The AAWG has concluded that the risks of disk uncontainment events exist, but that historical data has shown airplane designs safely accommodate this level of risk.

The operators were further tasked to review and assess events and trends beyond what is contained in the AIA report. They reached consensus that insufficient data has been gathered over the years concerning airframe damage due to uncontained engine failures. They noted that additional guidance should be given to regulatory agencies to request this information when doing investigations and normal reporting. The operators acknowledge that reliability of 3rd generation engines has improved over that for older engines, but did request that OEMs follow up on review of their designs, especially considering the recent A380 and B777 events.

5.2 Applicant showings of compliance with § 25.571(e)

During the March 2016 AAWG meeting in Everett WA, the OEM members each gave a presentation summarizing the method of showing compliance with § 25.571(e) for uncontained engine failure. These presentations are included in Appendices C thru F of this report. The presentations demonstrate that all of the AAWG-member OEMs have essentially a common approach in showing compliance. Structural risk is combined with other airplane level risks and the overall averaged risk of catastrophic damage from a 1/3 disk segment is shown to be 1:20 or less. The overall risk from each single engine disk is similarly determined and is shown to be less than or equal to twice the averaged risk. The 1/3 disk fragment definition and the risk targets are per AC 20-128A. The evaluation of structural damage is performed per the criteria in AC 25.571-1D Paragraph 9(c). The OEMs also account for Phase of Flight, as described in AC 20-128A Appendix A Paragraph 6.8. As a result, structural damage is not considered to be catastrophic for ground conditions. Note that the threat under consideration is the 1/3 disk fragment. Per AC 20-128A Paragraph 10.c.(5) no risk analysis is performed for the fan blade fragment, small fragments, and APU rotor stages which are qualified as contained. Structural evaluation is not performed for these threats.

5.3 Damage scenario assumptions per AC 20-128A

5.3.1 Appropriateness of infinite energy assumption

The AAWG-member OEMs have all consistently assumed infinite energy for the 1/3 disk uncontained fragments. The OEMs maintain this is an appropriate way to address the fragment energy. It is a conservative assumption that is consistent with AC 20-128A and greatly simplifies the analysis. They also recognize that this is a common practice that is acceptable per the AC, and is generally recognized as conservative. One operator however suggested that actual fragments may not travel linearly, as is assumed by an infinite energy model, but may be deflected on impact with structural members.

5.3.2 Consideration of more realistic assumptions and benefits

The OEMs acknowledge that accounting for a realistic energy level would make it easier for an applicant to meet the risk targets in AC 20-128A. This would not result in enhanced structural capability and may not result in higher safety, since a more realistic energy model would produce less predicted damage from an uncontained engine failure event. On the other hand, a finite energy model may show it is practical to shield systems, which could decrease the residual risk. The FAA stated that, for certain cases, a more realistic energy and trajectory model may show shielding through additional structure is a practical way to shield systems or critical structure to minimize the effects of rotor fragments. However, the OEMs stated this approach would considerably increase the cost and effort to perform and validate the analysis. The operators stated that using a less conservative approach, compared to assuming infinite energy could lead to lighter more efficient designs since it would be easier to meet the risk targets in AC 20-128A. Some operators also noted that the industry (FAA and operators) should do a better job of collecting rotorburst related data such as the fragment definitions and failure modes.

5.3.3 Consideration of different types of disks and benefits

The OEMs determined that there is not a practical way to address different disk types considering that the current assumptions of infinite energy and equal probability of failure for any stage are conservative. Changes to these assumptions would require substantially more analysis and validation effort, with an unknown net impact to the level of safety, as explained in Section 5.3.2. The operators noted that service history could be used to modify assumptions, but did not recommend making any changes to the failure model unless it could be clearly shown to lead to a safety benefit. One operator noted that multiple engine types available on an airframe all must be assessed due to differences in the engine configuration (spin direction, disk location, disk size, etc.) and that current guidance does not address engine mounting location, or disk material. Some AAWG members also noted the lack of guidance for engine types other than turbo fan (e.g., turbo prop and unducted fan types). One operator also suggested that a probability approach, similar to what is used for compliance to § 25.1309 could be used for rotor failures.

5.3.4 Use of specific risk

The OEMs have addressed specific risk as described above in Section 5.2. Structural risk for any given disk is combined with other airplane level risks for that disk and the combined risk of catastrophic damage is shown to be less than or equal to twice the risk from averaging all the disks. All the AAWG-member OEMs have considered phase of flight in the risk assessment which results in ground events being assigned a risk of 0.0 for structural damage.

5.4 Assessment of current OEM practices provide an adequate level of safety

The OEMs have consistently used a similar means of compliance as described in Section 5.2. By evaluating all structural damage scenarios resulting from the engine failure model given in AC 20-128A and including the resulting structural risk into the airplane level risk assessment per § 25.903(d)(1), the applicant has shown that likely damage due to an uncontained engine failure event has been addressed. Furthermore, this demonstrates that the design meets the airworthiness requirements of § 25.571(e), and that the risk has been sufficiently minimized. There have not been any catastrophic events related to uncontained engine failure that would indicate that this approach does not provide an adequate level of safety. On the contrary, uncontained engine events seen in service on airplanes designed to the criteria described in Section 5.2 have shown that the structure has adequate residual strenth with regard to damage from engine fragments. This robustness is anticipated based on the conservatism used in the analysis, such as infinite energy of fragments, and “get-home” load capability per AC 25.571-1D.

5.5 Assessment of UEDDAM

Boeing and Airbus have both done limited studies with UEDDAM between 2004 and 2006. Based on those studies, the AAWG member OEMs do not recommend incorporating UEDDAM as a tool for showing compliance with the requirements associated with uncontained engine failure per 25.571(e). Some of the significant concerns include the following:

1. The time and effort required to define the airplane configuration;
2. The run time of the program;
3. The reliance on a Monte Carlo simulation; and
4. The difficulty in validating some of the energy and penetration analysis methods.

The position of the OEMs is that the current methods and analysis used for compliance are sufficient and provide an adequate level of safety. In more recent discussions, the FAA has elaborated on the benefits of UEDDAM which include:

1. More realistic assumptions for energy levels;
2. Accounting for multiple small fragment scenarios as seen in a recent service event; and
3. The ability to highlight vulnerable areas.

The FAA also noted numerous improvements have been made to UEDDAM since it was last reviewed by Airbus and Boeing and that a current copy has been provided to those OEMs who have asked for one. The AAWG decided to not perform any further evaluation of UEDDAM since the existing engine failure model and analysis methodology provide an adequate level of safety with acceptable cost and effort as described in Section 5.4 Individual OEMs can perform further studies at their own discretion.

5.6 Assessment of relationship between rotorburst and Structural Damage Capability

The OEMs did not identify any Large Damage Capability (LDC) or Structural Damage Capability (SDC) criteria that were applied to designs to explicitly address uncontained engine failure. Rather, existing design criteria and regulatory requirements inherently provide damage capability for uncontained engine failure. This is validated when the airplane is shown to meet the risk targets given in AC 20-128A for uncontained engine failure. When evaluating structural damage from an uncontained engine failure event, the criteria in AC 25.571-1D Paragraph 9(c) are applied to determine whether the damage is catastrophic. The AC requires that the structure maintain a minimum strength level when damaged (70% limit flight maneuver loads and 40% limit gust velocity), and be free from flutter up to V_D/M_D, to be considered survivable. When these criteria are used to categorize the structural damage risk that is included in the airplane level analysis, and the airplane is shown to meet the AC 20-128A risk targets, then the structure has also been shown to have adequate residual strength capability. It should be further noted that although, as of the writing of this report, SDC criteria are still being developed under a separate AAWG effort, the AAWG has not determined that a link between SDC and rotorburst is required.

The operators also generally agreed that existing design practices are adequately conservative to account for damage caused by uncontained engine failure, but noted that deflection of the engine fragment should be considered in the evaluation.

5.7 Current practices for minimization

The OEMs agree that there are no standard minimization strategies for structural design. Generally, OEMs adequately minimize the risk by employing existing design practices (proper material selection, redundancy, crack stoppers, etc.) that are otherwise utilized to show compliance with regulatory requirements including damage tolerance and static strength. The OEMs use the quantitative risk assessment, as described above in Sections 5.2 and 5.6, to show that these design practices inherently minimize the risk to an acceptable level and no design changes are required to specifically address uncontained engine failure. Other strategies the OEMs have used to ensure the airplane meets the quantitative risk targets of AC 20-128A include locating critical structure features, such as engine mounts or the pressurized compartment, outside the burst zone.

Similar to their position stated in Section 5.6 above, operators generally agreed that existing minimization practices are adequately conservative to account for damage caused by uncontained engine failure, but noted that deflection of the engine fragment should be considered in the evaluation.

6. Conclusions/Issues with Findings

1. The OEMs have had essentially an identical approach in showing compliance to the Part 25 requirements for uncontained engine failure. This approach has been in place since the introduction of Amendment 45 to § 25.571 in 1978. Specifically, for compliance to §25.571(e), OEMs have included structural risk within the airplane level risk assessment performed per AC 20-128A to support compliance to §25.903(d)(1).

2. The existing method of compliance for showing compliance to Part 25 uncontained engine failure requirements provides an adequate level of safety and would continue to provide the same level of safety in the future. This conclusion is supported by service experience. Uncontained engine failure events, including recent events on third generation engines on the A380 and B777, have not resulted in structural damage that jeopardized continued safe flight and landing. As discussed in Section 5.1 the rates of uncontained engine failure continue to drop. Furthermore the compliance approach maintains the level of safety, even as engines grow and evolve, since the performance based engine failure model in AC 20-128A is tied to the size and locations of the engine disks. Not only must the airplane level risk be kept within AC20-128A established limits, the specific risk target for each individual disk must be met, ensuring that no individual disk will contribute a disproportionate amount of risk. Additionally, projects involving new engine installations on existing airframes may maintain or increase the level of risk mitigation/minimization. These are considered major projects and a new airplane level risk evaluation is required for each new engine installation.

3. The existing engine failure model per AC 20-128A is adequate for structural evaluation and there is no basis for having different requirements for structure. This model has been used consistently among the OEMs with satisfactory results, as has been previously explained. The airplane level risk evaluation requires a common threat model, therefore it would be counterproductive to make any changes to the model for structural evaluation only. Several issues with the failure model however were discussed within the working group. These include addressing deflected trajectories, accounting for multiple fragments, accounting for finite energy, considering effects of various blade/disk types and material systems, utilizing UEDDAM, and using risk targets per § 25.1309. However, as previously discussed, the working group concluded that the established method, which includes the existing engine failure model combined with assumptions in the structural evaluation, is a conservative approach that results in an adequate level of safety for airplane structure. Changes to the engine failure model, which would affect aspects of the airplane beyond just structures, would more appropriately be addressed by a propulsion focused working group rather than a structures working group.

4. Although the method of compliance that is used by the AAWG member OEMs is well established and understood to be consistent with available guidance, it is inconsistent with the current FAA interpretation of the guidance materials (as described in Section 2). One significant example is the FAA understanding that the 1:20 requirement applies to each engine disk. The OEMs have consistently understood the requirement to be that the 1:20 target is an airplane level risk, that includes structural risk, which is an averaged over all engine stages. This indicates that the guidance materials, including the Policy Statement, are not currently clear enough to be used effectively.

7. Recommendations

Considering the regulatory objectives pertaining to uncontained engine failures and their impact on structural integrity, the AAWG recommends an update to current guidance materials to clearly reflect the common method of compliance that the applicants have utilized. This includes clarifying that structural risk should be included in the airplane level risk evaluation and clarifying that minimization of structural risk is accomplished, and the requirements of § 25.571(e) are met, when the airplane level risk meets the quantitative risk targets in AC 20-128A. To this end, the AAWG recommends that the TAMCSWG make the following recommendations to the FAA:

A. Revise AC 25.571-1D as proposed in Appendix G. Such updates include the following:
   1. Cross reference to AC 20-128A, to clarify that structural risk is included within the airplane level risk calculations
   2. Clarification that the applicant may consider phase of flight aspects as described in AC 20-128A when calculating the structural risk component within the airplane level risk calculation
   3. Clarification that the applicant may allow for averaging all rotors on all engines of a given airplane in the mean risk calculation as allowed in AC 20-128A

B. Revise AC 20-128A as proposed in Appendix H. Such updates include the following:
   1. Strengthening structural design considerations as follows: “Good design practices, which may include proper material selection, redundancy and crack/damage stoppers, as well as existing structural regulatory requirements, should limit subsequent damage and provide designs with stringer, frame and rib sizing and spacing that result in a highly robust configuration that inherently minimizes the risk from uncontained engine fragments.”
   2. Clarify that use of this AC in the compliance for § 25.903(d)(1) does not preclude the requirement to comply with § 25.365(e)(1) and (g)
   3. State that risk from structural damage should be included in the calculation of the hazard ratios for both the mean risk calculation and the single disk risk calculation.
   4. Revise Appendix, paragraph 2.2(f) to clarify that structural risk is included in the overall risk assessment, as opposed to being a standalone calculation
   5. Include a cross reference to AC 25.571-1D
   6. Remove statement in Appendix, paragraph 7.2, Table 1 that implies single fragment requirements do not apply to structures. Re-emphasize that structural damage is included in the overall risk level assessments contained in Table 1

   The FAA does not concur on the OEM assessment that risk is inherently minimized in designs and that the risk is shown to be adequately minimized when the airplane level risk targets of AC 20-128A are met. The FAA has stated that further minimization may be required and that examples of these types of minimization strategies should be provided to applicants in advisory material, such as shielding of systems or critical structure by improving the damage tolerance characteristics of certain structure.

C. Keep the regulations § 25.571(e) and § 25.903(d) unchanged. There was general consensus to allow the regulations (notably the FARs and the EASA CS) to remain non-harmonized. Keeping a specific structural requirement in 25.571(e) makes clear the intention that a structural evaluation is required for uncontained engine failure. Removing the references to uncontained engine failure, in order to harmonize with CS 25.571, may incorrectly be interpreted by an applicant as meaning no structural evaluation is required. Those OEMs who were in favor of harmonization agreed on the consensus position, provided the following:
   1. There is no need for additional structural compliance demonstration for § 25.571(e) beyond what is provided for § 25.903(d)
   2. FAA Policy Statement PS-ANM100-1993-00041 will be rescinded
   3. Averaging of risk and phase of flight considerations will be allowed
   4. Minimization practices should be maintained at current practical levels

   Two operators (British Airways and Federal Express) voted for harmonization because maintenance compliance can be more complicated with non-harmonized regulations. However, they did indicate they can support the majority position.

   Lastly, another operator (Delta) proposed that in lieu of using the existing approach for risk assessment in the event of uncontained engine failure, that compliance should be based on the Systems-based approach as required by § 25.1309 (i.e. less than 1E-9 likelihood of catastrophic failure).

D. Although there is general concurrence to allow the regulations to remain non-harmonized, the AAWG recommends that NAA guidance material should be harmonized to the greatest extent possible. It is therefore recommended that advisory material such as the EASA equivalents to AC 20-128 and AC 25.571 be revised in a similar manner to that proposed above in paragraphs A and B.

E. The operators recommend that the industry as a whole (NAAs, operators and OEMs) could be more diligent with respect to gathering data whenever an uncontained engine failure event occurs. Of particular interest would be size of fragments and noting level of damage. Such data could be used to supplement the data provided by the AIA report, which appears to have not been updated since 2007.

Appendix A – FAA Policy Statement PS-ANM100-1993-00041

Appendix B – AIA Project Report on Uncontained Rotor Events

Appendix C – Airbus Rotorburst Structure Assessment

Appendix D – Boeing Structural Compliance for Uncontained Engine Failure

Appendix E – Bombardier Rotorburst Compliance

Appendix F – Embraer Rotorburst Philosophy and Practices

Appendix G – AAWG proposed change to AC 25.571-1D

Appendix H – AAWG proposed change to AC 20-128A