Certification Memorandum

Parts Detached from Aeroplanes

EASA Proposed CM No.: CM–21.A-A-001 Issue 01 issued 20 April 2018

Regulatory requirement(s): 21.A.3B (b), AMC&GM 21.A.3B (b)

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Log of issues

Issue	Issue date	Change description
01	21.04.2018	First Issue

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1. Introduction

1.1. Purpose and scope

The purpose of this Certification Memorandum is to provide specific guidelines, limited to large aeroplanes, for evaluating whether an unsafe condition exists in case of Parts Departed from Aeroplanes events, hereafter referred to as 'PDA', which can be applied by European large aeroplane(s) DA holders.

This CM attempts to clarify how Part 21 AMC providing the definition of unsafe conditions should be interpreted when a case of PDA occurs.

Additionally, this CM provides harmonization with the FAA on draft policy PS-ANM-25-23 "Risk to Persons on the Ground from Objects Falling off Transport Category Airplanes" published by the FAA for comments in 2017.

1.2. References

It is intended that the following reference materials be used in conjunction with this Certification Memorandum:

Reference	Title	Issue	Date
[1]	Federal Aviation Administration, "Transport Airplane Risk Assessment - Life Risk," PS-ANM-25-05 TARAM Handbook	-	[2011]
[2]	2nd CAAM Report - Technical Report on Propulsion System and APU-Related Aircraft Safety Hazards Appendix 4: Hazards to Persons Being Overflown – A Joint Effort of FAA and AIA	-	[2005]
[3]	Equivalent Safety Analysis using Casualty Expectation Approach, Frank M. Grimsley, AIAA 2004-6428	-	[2004]
[4]	The Economic Cost of FOD to Airlines, Iain McCreary, Produced for www.FODNews.com by Insight SRI Ltd.	-	[2008]

1.3. Abbreviations

AIAA	Aerospace Industries Association
AMC	Acceptable Means of Compliance
CAAM	Continued Airworthiness Assessment Methodologies
CAT	Catastrophic
CM	Certification Memorandum
CS	Certification Specification

DA	Design Approval
EASA	European Aviation Safety Agency
FAA	Federal Aviation Administration
FH	Flight Hours
FOD	Foreign Object Damage
HAZ	Hazardous
PDA	Parts Departed from Aeroplanes
PSE	Principal Structural Elements

1.4. Definitions

PDA	In the context of this certification memorandum, parts detached from the aeroplane with no or low initial relative speed to the aeroplane.

2. Background

EASA is required to issue airworthiness directives to correct any unsafe condition that is likely to exist in other aircraft in accordance with Part 21.A.3B (b).

In the framework of Continued Airworthiness, PDA represent recurrent events whose consequences may lead to unsafe conditions.
The objective of the CM is to provide criteria to help applicants determine whether a PDA is an unsafe condition or not.
As per AMC 21.A.3B(b) an unsafe condition exists if there is factual evidence […] that:

(a) *An event may occur that would result in fatalities, usually with the loss of the aeroplane(s), or reduce the capability of the aircraft or the ability of the crew to cope with adverse operating conditions to the extent that there would be:*

(i) A large reduction in safety margins or functional capabilities, or
(ii) Physical distress or excessive workload such that the flight crew cannot be relied upon to perform their tasks accurately or completely, or
(iii) Serious or fatal injury to one or more occupants

unless it is shown that the probability of such an event is within the limit defined by the applicable certification specifications, or

(b) *There is an unacceptable risk of serious or fatal injury to persons other than occupants, or* […]

PDA can be very different in nature and location: doors, access panels, fairings, engine cowlings, fasteners, etc., therefore determining if an unsafe condition exists is not always straightforward. There are three main categories of potential consequences following PDA events that can be foreseen:

1. Damage and reduced functionality of the aeroplane (wing, fuselage, horizontal or vertical stabilizer structures, engine ingestion, control and other systems) potentially causing injuries to its occupants
2. Injuries to people on the ground

3. Damage to other aeroplane(s)s (e.g. PDA encountered on runways) potentially causing injuries to its occupants

As quoted above, the risk to the aeroplane and its occupants is covered by AMC 21.A.3B(b), paragraph (a) and further guidance is provided in GM 21.A.3B(b). The risk of injuring people on the ground or in other aeroplane(s) is addressed by AMC 21.A.3B(b), paragraph (b) for which an unsafe condition exists when there is an 'unacceptable risk' of serious or fatal injury to third parties. However, the word 'unacceptable' does not bound specific scenarios and is open to interpretation with no further guidance provided in the AMC or GM to Part 21.

3. EASA Certification Policy

3.1. Objective

The objective of this CM is to provide guidance, limited to large aeroplanes, for evaluating whether an unsafe condition exists in case of PDA events that can be applied by European large aeroplane(s) DA holders.

The three main potential effects of a PDA identified in section 2 have been analysed in terms of severity and occurrence following a 'CS 25.1309-like' approach. They will be described in section 3.2 to 3.4 and a conclusion is provided in section 4.

It is important to emphasize that, in the context of this document, PDA events are considered as an unintentional loss of parts within the framework of Continued Airworthiness. Although no unsafe condition for the aeroplane exists in some cases of PDA, in general, it is not acceptable to allow failures that result in loss of a part as design criteria for mitigating certain failure cases in Initial Airworthiness, for which this CM does not apply. Loss of parts should be prevented as much as possible.

This CM is covering the cases of parts detached from the aeroplane with no or low initial relative speed to the aeroplane. Cases, such as high energy rotating parts departing from the engine, or inadvertent ejection of ELT, DFDR/CVR, are therefore not subject of this CM.

3.2. SCENARIO 1: Damage to the aeroplane itself

In case of PDA an unsafe condition can be generated by direct effect of the detached part, i.e. the loss of the function that this part provides, and side effect, i.e. impact on other zones of the aeroplane.
Concerning the direct effects of the PDA, an assessment must show that the aeroplane (performance, strength, stability, control, etc.) and its occupants are not adversely affected up to the point of experiencing an unsafe condition due to the loss of the part following the guidance of GM 21.A.3B(b).

Similarly, concerning the side effects, the same guidance can be used once the probable damage due to the part impact on the aeroplane structures and systems has been assessed. As a general principle, it is not an unsafe condition if, regardless of the trajectory followed by the detached parts, the effect on structural integrity or system functionality is negligible. If the likelihood of compromising the structural integrity of all potentially impacted parts can be demonstrated to be extremely improbable, (i.e. less than 1E-9/FH), the unsafe condition may be discarded. Structural integrity after impact would include aspects such as deformation, residual strength and aero-elastic stability (including vibration and buffeting).

PDA may prevent the safe completion of the flight. The typical scenario is any PSE or essential system being hit by the departed part, with the consequent prevention of its intended function and impairment of the aeroplane safe flight and landing, with potential injuries on occupants and/or flight crew. As per AMC 25.1309, any failure condition, which would result in multiple fatalities, usually with the loss of the aeroplane, are classified as catastrophic (CAT). The safety objective associated with a CAT event is satisfied if the

probability of occurrence per FH is less than 1E-9. There are other cases for which the severity of the event can be different. These should be analysed on a case-by-case basis. The probability of a PDA impacting the aeroplane(s) depends on the trajectory that the released part will follow and the potential damage that a PDA impacting the aeroplane can cause depends on the force with which it may impact the aeroplane. The trajectories cannot be easily predicted, whereas the impact energy may be conservatively estimated.
For this potential risk, engineering judgement represents the most reasonable approach to be adopted. The location of the part in the aeroplane, its weight, size, shape and the configuration of the aeroplane are important parameters in order to identify the existence or not of an unsafe condition. Based on service experience typical PDA includes servicing doors or panels, lights, fairings, etc.

The combination of part trajectory and impact energy should therefore be considered when assessing side effects of PDA. The following aspects may be taken into account:

A. Trajectory of the detached part. Although predicting the exact trajectories of detached parts is not generally possible. However, some acceptable assumptions are that:

   - Relatively light parts not behaving as lifting surfaces may follow the streamlines along the aeroplane
   - Parts behaving as lifting surfaces (like panels) will not follow the streamlines along the aeroplane
   - Non-lifting high-mass lost parts may not present a risk of hitting the aeroplane if the trajectory is mainly determined by gravity, or if the starting location on the aeroplane is such that the detached part is unlikely to damage the aeroplane
   - The results of statistical analysis of existing in-service data may be acceptable

B. Damage to impacted area. The potential damage depends on the energy of the detached part, the impact angle, geometrical and material properties of detached part. The following steps may be accepted:

   - An estimation of the impact energy based on an estimation of the maximum relative impact speed and mass of the detached part
   - Estimation of impact angle and worst orientation of part
   - Estimation of the worst possible extent of the damage
   - Statistical analysis or in-service data used to substantiate the likelihood of a certain level of damage

In general the maximum energy of impact of a detached part can be conservatively estimated by considering the maximum estimated relative speed of the part and its mass.

If this combined estimation does not show that the effect on structural integrity or system functionality is acceptable, then engineering judgement should be applied for taking into consideration shape and size, mass distribution of the part, potential impacted zone and trajectory.

In any case the results of a search into historical data back to 1990, available at the Agency, show that all occurrences involving PDA have always been completed with uneventful landings and without serious or fatal injuries for the occupants

Note: Some approval holders may wish to use existing bird strike compliance demonstrations as part of their assessment. As the impact dynamics for a bird versus a part impacting an aircraft are generally different in terms of density, body shape and consistency, a simple comparison of the energy level involved in the PDA

event with the one defined in the bird strike requirements is not considered as a sufficient substantiation for assuring the impact will not prevent continued safe flight and landing.

3.3. SCENARIO 2: People on ground

PDA could produce serious or fatal injuries to people on the ground. The typical number of people hit by a part detached from an aeroplane can be assumed to be a small number. In the context of this CM, serious or fatal injures of few people on ground is considered being a Hazardous repercussion, even if people on ground are not 'taking the risk' of travelling on the aeroplane. Having an occurrence probability less frequent than 1E-7/FH would therefore make this risk acceptable. This numerical threshold is in line with the EASA AMC 25.1309 safety objective associated to Hazardous failure condition, which is including the possibility of "serious or fatal injuries to a relatively small number of people".

Several methods can be adopted in order to quantify the likelihood of causing fatal injury to the people on ground associated to PDA, however for all of them the variables to be adopted are generally the same:

- The density of population, with reasonable correction factors related to time exposure and shielded arrangements.
- The size and weight of the concerned aeroplane(s) part.

The likelihood / probability of causing fatal injury is expressed as the combination of:

- Likelihood of a PDA event
- Likelihood of a person being struck by the PDA
- Likelihood that, if struck by the PDA, there will be fatal consequences;

The probability of a person fatally injured once struck by PDA is set to 1, as a conservative assumption.

The probability of a person being struck by PDA, considered as large debris, is strictly connected to time exposure calculated using density population and factors such as exposed area per person during day and night [2].

The aforementioned evaluation could be less conservative by considering the theory of the lethal area [3] using size/weight criteria.

Following the different methods, the result is that the probability of debris fatally hitting people is in the order of magnitude of 1E-3 and, therefore, in order to meet a target of 1E-7 occurrences-per-FH the probability of losing a part per FH would need to be less than 1E-4.

Data retrieved from several large aeroplane manufacturers have been analysed. These data show a rate of loss of parts in the range of 1E-6/FH, resulting in an overall risk to people on the ground substantially lower than the proposed objective. The analysed data comprise different types of large aeroplane (long range, regional and business jets) which represent more than the 90% of the European certified flying fleet. These data show a level of homogeneity suggesting that the results obtained can be representative of any fleet.

To help establish the policy, the estimated probability per hour of an individual on the ground being hit by a part falling from any aeroplane has been investigated. This latter probability appears to be significantly lower than, for example, the probability of death for an individual on commercial aeroplanes, which is between 1E-7 and 1E-8 per hour [1]. This very low probability value is confirmed once again by field data that show no case of people on the ground having been fatally injured by PDA.

The conclusion is that the likelihood of fatally injuring people on the ground due to a PDA event is conservatively estimated to be close to the objective set in CS 25.1309 for system failures with catastrophic effect, i.e. 1E-9/FH and can therefore be considered acceptable. Furthermore, this is supported by the absence of historical events of people fatally injured as a consequence of PDA, a situation that should be

maintained. As a result, no unsafe condition is identified for people on the ground provided the general rate of PDA events does not exceed current levels.

An extrapolation of the parameters used in the assessment together with the conservatism of some assumptions confirms that this estimate will be valid in the mid and long-term.

A reassessment by the DA holder of a specific PDA case is expected when parts being lost with a probability per FH an order of magnitude above the rates currently observed in the field.

3.4. SCENARIO 3: Damage to other aeroplanes/parts on the runway

A PDA, if lost on the runway, on a taxiway or in the airport area may represent a threat to other aeroplanes (Foreign Object Damage - FOD). Statistics state that typically the mostly potential damaged areas are aeroplane engines and wheels. In most cases there is only economic impact on maintenance costs with no significant impact on safety [2].
Nevertheless, depending on the damage that can be caused to another aeroplane, the severity may go up to CAT and therefore the safety objective as low as 1E-9 occurrences per FH. As mentioned in Scenario #2, EASA has retrieved information on the parts lost from some European manufacturers, obtaining a rate of detached part in the range of 1E-6/FH. Furthermore, considering the exposure time of the take-off and landing runs, the probability per FH to lose a part on the runway might be estimated about two orders of magnitude below, between 1E-8 and 1E-7, except for parts which are exclusively operated during the take-off or landing runs, for example thrust reverser system. For these kind of parts the probability of loss cannot be reduced by any exposure time.
Anyhow, for this scenario the likelihood that a PDA lost on runway will hit the aeroplane, i.e. the equivalent of the 1E-3/FH probability in Scenario #2, cannot be determined. For this reason, a quantitative approach for this scenario will not be addressed even though the above numerical considerations suggest that the safety target could be met.
For this scenario the field experience is the most valuable data on which to base a risk assessment.

In the recent history of European commercial air transport with aeroplane certified under FAR/JAR/CS25 there have been events caused by parts on the runway. There is only one record of an accident with fatal injuries in which PDA was involved, although in this case it cannot be concluded that PDA was the unique contributor of the accident.

Moreover, requirement CS 25.734 was introduced at Amendment 14 to reduce the risk to an agreed and acceptable level in cases of damaging effects on systems or structures due to wheel or tyre failures that are caused by a FOD.

As a consequence it can be concluded that the risk that PDA causes an accident of another aeroplane is generally considered negligible.

A reassessment by the DA holder of a specific PDA case is expected when parts are being lost with a probability per FH an order of magnitude above the rates currently observed in the field or when the part is specifically determined to be most likely to be lost on runways.

4. Conclusion

In case of PDA events, given the usual observed rates of parts loss per FH, the risk of damages to third parties does not need specific assessment. The DA holder should reassess any PDA scenario, in which the assumptions made that support this conclusion may be invalidated. In addition, the DA holders are expected to present yearly to EASA that the rate of PDA remains in the range of 1E-6/FH per aeroplane type.

As a consequence, the main scenario that a DA holder is expected to address is the possibility of the existence of an unsafe condition as per AMC 21.A.3B(b), paragraph (a), i.e. the possibility that a part detached from an aeroplane in service creates an unsafe condition for the aeroplane itself. For this, the guidelines provided in the Section 3.2 of this text and GM 21.A.3B(b) are expected to be followed.

5. Remarks

1. This EASA Proposed Certification Memorandum will be closed for public consultation on the **4th of June 2018**. Comments received after the indicated closing date for consultation might not be taken into account.
2. Comments or suggestions regarding this EASA Proposed Certification Memorandum should be referred to the Certification Policy and Safety Information Department, Certification Directorate, EASA. E-mail CM@easa.europa.eu.
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