Notification of a Proposal to issue a Certification Memorandum

PARTS DETACHED FROM ROTORCRAFT

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Regulatory requirement(s): 21.A.3B(b), AMC1 & GM1 21.A.3B(b)

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Log of issues

Issue	Issue date	Change description
CM-21.A-A-002	03/09/2021	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 small and large rotorcraft for evaluating whether an unsafe condition exists in events involving Parts Departed from Rotorcraft, hereafter referred to as 'PDR'. These guidelines can be applied by organisations required to report in accordance with 21.A.2B(b), including European DOA and TC/STC holders.
This CM attempts to clarify how the AMC1 & GM1 21.A.3B(b), that provides the definition of unsafe conditions, should be interpreted when a case of PDR occurs.

1.2. References

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

Reference	Title	Code	Issue	Date
[1]	Certification Memorandum PARTS DETACHED FROM AEROPLANES	CM–21.A-A-001	Issue 1	29/11/2018

1.3. Abbreviations

AMC	Acceptable Means of Compliance
CAT	Catastrophic
CM	Certification Memorandum
CS	Certification Specification
DA	Design Approval
DFDR	Digital Flight Data Recorder
EASA	European Aviation Safety Agency
GM	Guidance Material
HAZ	Hazardous
PDR	Part Detached from Rotorcraft
MAJ	Major
NHEC	Non-Human External Cargo
STC	Supplemental Type Certificate
TC	Type Certificate

TR	Tail Rotor
MR	Main Rotor
FH	Flight Hours
ICAO	International Civil Aviation Organization

1.4. Definitions

Continued Safe Flight and Landing	*This phrase means that the aircraft is capable of continued controlled flight and landing, possibly using emergency procedures, without requiring exceptional pilot skill or strength. On landing, some aircraft damage may occur because of a Failure Condition. (from AC 27-1B/ AC 29- 2C MG19 change 7)*

2. Background

EASA shall issue Airworthiness Directives to correct any unsafe condition that is likely to exist, in accordance with Part 21.A.3B(b).

In the framework of Continued Airworthiness, PDR represent events which may lead to unsafe conditions.

The objective of this CM is to provide the criteria to determine if the identification of a rotorcraft failure, malfunction, defect, or other occurrence which has resulted or may result in a PDR event constitutes an unsafe condition for the affected rotorcraft.

PDR can be very different in their nature and location. For example, doors, access panels, fairings, engine cowlings, fasteners, lights, external installation, external loads etc. may be involved. Therefore, determining whether an unsafe condition exists is not always straightforward.

Three main categories of potential consequences following PDR events can be foreseen:

1. SCENARIO 1: Damage to and/or reduced functionality of the rotorcraft (MR and TR controls and blades, fuselage, horizontal or vertical stabiliser structures, engine ingestion, fixed flight control and other systems) possibly causing injuries to its occupants.
2. SCENARIO 2: Injuries to people on the ground[1]. This scenario will be further divided into:
    a. SCENARIO 2A: Injuries to people on the ground caused by general PDR;
    b. SCENARIO 2B: Injuries to people on the ground caused by loss of NHEC.

[1] Basic Regulation (EU) 2018/1139, Article 4 – Section 2:

> *"The measures taken under this Regulation shall correspond and be proportionate to the nature and risk of each particular activity to which they relate. In preparing and enacting such measures, the Commission, the Agency and the Member States shall take into account, as appropriate for the activity concerned: […]*
> *(b) to what extent third parties or property on the ground could be endangered by the activity;"*

Damage to property is addressed by scenario 2.

3. SCENARIO 3: Damage to other aircraft (e.g. PDR encountered on runways) potentially causing injuries to their occupants.

Considering the operational environment of the rotorcraft, and the low risk of damage to other aircraft, this CM will mainly focus on Scenarios 1 and 2.

As per AMC1 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 aircraft(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* […] "

The meaning of 'unacceptable' in this context is not further clarified in AMC or GM to Part 21.

In addition, GM1 21.A.3B (b) at paragraph 2.1.2.2 *Structural or mechanical systems* specifies that:

> *"An unsafe condition exists if the deficiency may lead to a structural or mechanical failure which […] could result in the loss of a structural piece that could damage vital parts of the aircraft, cause serious or fatal injuries to persons other than occupants. […]"*

This definition of unsafe condition is applicable to PDR events and covers all three scenarios defined above.

To summarise, an unsafe condition can be defined either by the effect on the rotorcraft and its occupants, as per §(a) in AMC1 21.A.3B(b) and paragraph 2.1.2.2 in GM1 21.A.3B(b), or by the effect on people on ground or on other rotorcraft, as per §(b) in AMC1 21.A.3B(b) and §2.1.2.2 in GM1 21.A.3B(b).

3. EASA Certification Policy

3.1. Objective

The objective of this CM is to provide guidance, limited to CS-27/CS-29 rotorcraft, for evaluating whether each potential PDR event that has been identified for a CS-27/CS-29 rotorcraft type (including different models) constitutes an unsafe condition.

The potential consequences of PDR events (as identified in Section 2) have been analysed to determine their severity and, when appropriate, a target probability of occurrence following a 'CS 2X.1309-like' approach. These assessments are presented in Sections 3.2 to 3.4, and the conclusion is provided in Section 4.

This CM should be only used to assess PDR events in the framework of Continued Airworthiness. Although some PDR scenarios mentioned in this CM could be acceptable based on the observed rate of parts loss per FH, in general the loss of parts should be prevented and minimised as far as possible.

This CM covers the cases of:

- parts that become detached from rotorcraft with no or low initial speed relative to the rotorcraft.
- uncommanded release of external load rated as NHEC (with reference to CS 27/29.865)

Loose equipment that is not properly restrained, departing from the cabin/cargo compartment during flights with doors open or for in-flight opening of cargo doors, are not covered by this CM. For these events, the investigation should focus on operational aspects and functional deficiencies of the mechanical system as necessary.

3.2. SCENARIO 1: Damage to the rotorcraft

In the case of a PDR, an unsafe condition can be driven by the direct effect of the detached part (i.e. the loss of the function that the detached part had provided), or by the indirect effect on the rotorcraft (i.e. due to damage resulting from an impact on other zones of the rotorcraft).

Concerning the direct effects, an assessment should show whether the rotorcraft functions are compromised by the missing part or adversely affected up to the point of experiencing an unsafe condition, implementing the guidance of GM1 21.A.3B(b)[2].

Similarly, concerning the indirect effects, an assessment should establish whether the effects of the potential impact of the part on the rotorcraft does not potentially cause an unsafe condition, implementing the guidance of GM1 21.A.3B(b).

In order to properly classify the event (as potentially unsafe or not) both direct and indirect effects need to be considered.

This CM only gives information on how to assess the classification of indirect effects of a PDR event.

Direct effect shall be assessed separately.

Typical parts detached from rotorcraft include:

- Cowlings
- Doors/ service doors
- Service panels

[2] Note: If the PDR is a PSE or a control/thrust/lift surface, the failure is likely to be catastrophic and there is no need to go through a probabilistic analysis: It is UNSAFE by definition and must be addressed as soon as possible.

It is important to observe that the loss of a nut or fastener can have severe consequences on the functionality which are not addressed in this CM. For further guidance see EASA CM-S-003.

- Windows
- Fairings
- External lights/Antenna
- Protection device (i.e rotor boot)
- Others small parts (i.e. nuts/bolts)
- External loads (a special case): NHEC External load systems are often a combination of a fixed installation approved through a Major Change/STC and other means that are used to restrain the cargo and are subject to operational approval. For this special case a set of ad-hoc considerations are given in Section 3.4.

Occurrences involving PDR have shown that MR and TR (and other control surfaces) are often exposed to impact damage (e.g. detached door, open/detached cowling), so that PDR events need to be assessed for damage to the rotorcraft.

3.2.1. Severity

The applicable certification specifications and associated acceptable means of compliance (AMC) for Initial Airworthiness defines the severity of failure conditions based on their effect on the aircraft and its occupants:

- For Structure:
  - AC 27/29.573 Catastrophic Failure. An event that could prevent continued safe flight and landing.
  - AC27/29 MG-8 CATASTROPHIC FAILURE. Any structural failure, which results in death, severe injury, or loss of the aircraft
- For Systems:
  - AC 27/29.1309
    - "CATASTROPHIC. Any failure condition that would result in multiple fatalities, usually with the loss of the aircraft, is classified as catastrophic (CAT)"
    - "HAZARDOUS. Any failure condition that would result in serious or fatal injury to a relatively small number of the occupants other than flight crew, is classified as Hazardous (HAZ)"
  - AMC 27/29.865

    "A failure of the external load system (including QRS, hook, complex PCDS where applicable, and attachments to the rotorcraft) should be shown to be extremely improbable (i.e. 1 × 10-9 failures per flight) for all failure modes that could cause a catastrophic failure, serious injury or a fatality anywhere in the total airborne system. Uncontrolled high-speed descent of the hoist cable would fall into this category."

To summarise, a Catastrophic Structural Failure, may be any failure that:

- could prevent continued safe flight and landing; or
- results in death, severe injury, or loss of the aircraft.

The assessment of the potential damage is a key aspect, especially when the classification is somewhere between CATASTROPHIC and HAZARDOUS. The following additional guidance is provided:

- When the damage could prevent continued safe flight and landing (e.g. loss of control) it shall be classified as CATASTROPHIC because in this case all occupants are exposed to the highest risk.

- When the adverse effects on the structural strength, performance or flight characteristics of the aircraft are such that an emergency landing is possible[3] without exceptional piloting skill, it can be classified as HAZARDOUS because in this case the occupants have the possibility to survive.

The definitions above suggest evaluating the worst possible damage to the aircraft and the effects to its occupants after the PDR event.

The damage that can be caused to the rotorcraft is a function of the relative kinetic energy of the detached part versus the impacted part, the shape/density of the detached part and the characteristics of the impacted part, i.e. its function and carried load (e.g. airframe structure, control surface, rotors, doors etc). The estimation of the damage on the aircraft is a complex engineering problem. However, in most of the cases, engineering assessment should be sufficient to classify the event.

Conventional analysis is sufficient in most cases, detailed dynamic modelling may not be required.

The following steps may be followed:

- Estimate the impact energy based on the mass and the maximum relative impact speed of the detached part;
- Estimate the possible trajectories, impact angles combined with the worst orientation of the part[4];
- Estimate the worst possible extent of the damage;
- Use statistical analysis or in-service data, when statistically relevant, 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 relative speed of the part and its mass. The relative speed of the part is dependent on the drag coefficient of the PDR during its travel from the departure point to the impact point.

[3] Different classifications may be applicable to Category A and B rotorcraft, following the considerations of applicable regulatory material:

- AC 29-2C: 29.1309 “Additionally, for a category A rotorcraft, an autorotation is not considered continued safe flight and landing.”
- AC 29.571 “The FAA/AUTHORITY has determined that for Category A rotorcraft the phrase, “continued safe flight” means that the rotorcraft retains the capability to return and land safely at the point of departure or continue and land safely at the original intended destination or a suitable alternate site.”
- Point (18) in Annex I to Regulation (EU) No. 965/2012 (Air Ops): “‘Category B with respect to helicopters’ means a single-engined or multi-engined helicopter that does not meet category A standards. Category B helicopters have no guaranteed capability to continue safe flight in the event of an engine failure, and **unscheduled landing** is assumed”

[4] Recirculation during in ground effect should be taken into account as detached parts could impact the rotors.

3.2.2. Probability

There is no direct link between the certification specifications for structural integrity and design and the probability of a PDR event, except for the external load requirement CS 27/29.865. Indeed, the initial airworthiness certification of a structural/mechanical part has no probabilistic aspects that could be useful in this context[5]. However, the probability of occurrence of a PDR event that causes damage to the aircraft or its systems and that could result in a HAZARDOUS or CATASTROPHIC failure condition should be identified in the Continued Airworthiness.

This Section proposes a methodology to determine this probability, which will be used in the next Section for the classification of unsafe conditions.

It is proposed to determine the probability of each relevant PDR case as a combined probability:

P (case X) = P (PDR event leading to case X) * P (damage by PDR in case X)

Where:

- X is an identified case in which a PDR event could result in damage to the rotorcraft or its systems.
- P (PDR event leading to case X) is the probability of occurrence of the PDR event leading to case X. It should not be restricted to the detachment of a specific part but rather consider all parts installed under the same conditions (i.e. type/number of fittings, means of installation, location) which are susceptible of creating the PDR event that leads to case X. If a non-compliance to the certification basis is at the origin of the PDR, the probability of PDR event should be set to 1.
- P (damage by PDR in case X) is the probability that the PDR actually causes a damage to the rotorcraft or its systems. It is associated, amongst others, with the impacted area or system (i.e. MR/TR, FCS, etc.), the physical characteristics of the detached part (e.g. size, mass, shape, etc.) and its trajectory.

Predicting the exact trajectories of detached parts is not generally possible, however some acceptable assumptions are that:

- relatively light parts which do not behave as lifting surfaces may follow trajectories similar to the streamlines along the rotorcraft;
- parts which behave as lifting surfaces (like panels or undercarriage doors) will not follow the streamlines along the rotorcraft;
- for operation near the ground lightweight parts that behave as lifting surfaces may be directed into the main rotor because of air flow recirculation;

[5] The probabilistic aspects linked to assessment of fatigue failures in requirements 27/29.571 and 573 are not useful to classify a PDR event as potentially unsafe or not. The fatigue failures addressed in these requirements are only associated with PSE, and therefore always associated with UNSAFE conditions.

- non-lifting high-mass lost parts may not present a risk of hitting the rotorcraft if the trajectory is mainly determined by gravity, or if the starting location on the rotorcraft is such that the detached part is unlikely to impact the rotorcraft;
- the results of a statistical analysis of existing in-service data, when statistically relevant, may be acceptable.

A proper assessment of the trajectory of a detached part involves the identification of a range of possible trajectories in different flight conditions. Each of these may be associated to a certain probability of causing a damage to the aircraft and possibly other cascading failures. Both CATASTOPHIC and HAZARDOUS scenarios should be considered further in the analysis; the most probable and the worst scenario, also when these do not coincide, should at least be captured.

If the estimated trajectory is away from a critical area, the relevant probability could be set to “0” and the case should no longer be considered.

Note: Some approval holders may wish to use existing bird strike compliance demonstrations (CS 29.631) as part of their assessment. As the impact dynamics for a bird versus a part impacting a rotorcraft are generally different in terms of their densities, shapes and consistencies, a simple comparison of the energy level involved in the PDR event with the one defined in the bird strike requirements is not considered sufficient to ensure that the impact will not prevent a continued safe flight and landing.

3.2.3. Classification

The commonly accepted safety objectives for CATASTROPHIC and HAZARDOUS events are as follows:

- The safety objective associated with a CATASTROPHIC event is satisfied if the probability of occurrence per FH is less than 10^{-9}.
- The safety objective associated with a HAZARDOUS event is satisfied if the probability of occurrence per FH is less than 10^{-7}.

These targets are used to define safety objectives for the effects on rotorcraft/occupants and can be used for the classification of a PDR event as explained further in this CM. Examples are provided in the annexes of this CM, based on known data from in-service experience with mature products that have cumulated a large number of FH.

There are cases where the observed in-service probability is not directly applicable for classification. If a failure occurs as a result of a non-compliance with the Certification Basis, the probability of a PDR event is automatically set to 1. The combined probability in this case can be used to discuss the corrective action plan.

In a general case, a comparison between actual and target probabilities may be used to classify the event and to define the appropriate corrective action, especially when a design deficiency is identified.

To summarise, the following should be presented as result of the assessment of a case X:

- Description of the Case X
- Potential Severity under the worst conditions

- P (PDR event leading to case X)
- P (damage by PDR in case X)
- P (Case X)
- Classification as UNSAFE / SAFE
- Corrective action plan

3.3. SCENARIO 2A: People on the ground – general PDR case

A PDR could produce serious or fatal injuries to people on the ground. However, service experience suggests that the number of people potentially hit by a part detached from a rotorcraft can be assumed to be limited.

Several methods exist to quantify the likelihood of causing fatal injuries to people on the ground associated with a PDR event, and for all of them the criteria to be considered are generally the same:

- the density of population, with reasonable correction factors related to time exposure and shielding (e.g. by buildings, if the level of protection is sufficient);
- the size/shape and mass of the rotorcraft part(s) detached.
- the type of operation (e.g. associated with people around the rotorcraft operation site, on the ground)

The probability of causing a fatal injury is then expressed as the combination of:

- The probability of occurrence of the PDR event;
- The probability of a person being hit by that PDR;
- The probability that, if hit by the PDR, there are fatal consequences.

Rotorcraft are operated more often than large aeroplanes above congested areas and their type of operations requires the assistance of people on the ground. In this context, for the analysis of Scenario 2 PDR events, the definitions of CATASTROPIC and HAZARDOUS events given in the CS 27/29.1309 and associated AMC are not considered applicable by extrapolation, although the associated safety objectives remain valid. In other words, the acceptable probability in Part 21.3B (b) of an event leading to a fatal injury of a single person on the ground is set to extremely improbable. This approach is consistent with Article 4(2)of the Basic Regulation[6] that requires considering:

> *"[…](b) to what extent third parties or property on the ground could be endangered by the activity,*

[6] Regulation (EU) 2018/1139 of the European Parliament and of the Council of 4 July 2018 on common rules in the field of civil aviation and establishing a European Union Aviation Safety Agency, and amending Regulations (EC) No 2111/2005, (EC) No 1008/2008, (EU) No 996/2010, (EU) No 376/2014 and Directives 2014/30/EU and 2014/53/EU of the European Parliament and of the Council, and repealing Regulations (EC) No 552/2004 and (EC) No 216/2008 of the European Parliament and of the Council and Council Regulation (EEC) No 3922/91 (OJ L 212, 22.8.2018, p.1).

[…] (f) the extent to which the persons affected by the risks involved in the operation are able to assess and exercise control over those risks; […]"

3.3.1. Severity

The certification specifications for initial airworthiness do not give specific guidance on this type of event because failure conditions are focussed on the effect on the aircraft and its occupants. Indeed, using the definition of the CS 27/29.1309 for CATASTROPHIC and HAZARDOUS failure conditions would lead to underestimate the safety issue because a single PDR event is unlikely to result in injuring more than one person on the ground.

It is therefore proposed to determine the severity of a PDR on the basis of the level of injury that it could potentially cause. This means that when there is a risk to fatally injure a single person on the ground, the PDR event should be considered potentially CATASTROPHIC. In order to be proportionate, two additional levels of injury should be associated to events with the potential of being HAZARDOUS and MAJOR.

This concept is not completely new: the concept of a single fatality/serious injury triggering the highest severity is already applied in the context of Human External Cargo certification, as per AMC No 2 to CS 27/29.865:

"A failure of the external load system (including QRS, hook, complex PCDS where applicable, and attachments to the rotorcraft) should be shown to be extremely improbable (i.e. 1×10^{-9} failures per flight) for all failure modes that could cause a catastrophic failure, serious injury or a fatality anywhere in the total airborne system. Uncontrolled high-speed descent of the hoist cable would fall into this category. "

The reference value of the kinetic energy of the PDR at impact that potentially causes a fatal injury is set at 100 J, which corresponds to a probability of 50% of the impact to a human resulting in a fatal injury.

Accordingly, the severity of a PDR is defined based on impact energy as follows:

- A PDR event for which the kinetic energy at impact is >= 100 J (brain trauma causing death) is potentially **CATASTROPHIC**
- A PDR event for which the kinetic energy is >= 20 J and <100 J is potentially **HAZARDOUS**
- A PDR event for which the kinetic energy is < 20 J is potentially **MAJOR**

This severity classification has a certain level of conservatism, as some kind of shield (e.g. construction, vegetation) could indeed protect people on ground from the PDR especially in case of low energy impacts.

3.3.2. Probability

To complete the classification, the combined probability should be determined:

P (case X) = P (PDR event leading to case X) * P (people on ground hurt by PDR in case X)

Where:

- X is an identified case in which a PDR event could result in people hurt on the ground
- P (PDR event leading to case X) is the probability of occurrence of the PDR event leading to case X. It should not be restricted to the detachment of a specific part but rather consider all parts installed under the same conditions (i.e. type/number of fittings, means of installation, location) which are susceptible of creating the PDR event that leads to case X. If a non-compliance to the certification basis is the origin of the PDR, the probability of PDR event should be set to 1.
- P (people on ground hurt by PDR in case X) is the probability that the PDR striking and injuring people on the ground. It is a function of the area of impact on ground, the population density in the area and the likelihood of being unprotected by natural shield.

Note:

The probability that a PDR striking people on the ground is considered to be LOW (usually from 10^{-5} to 10^{-8} depending on the area) based on in-service experience.

A quick way to determine this probability is to consider the number of people in a square metre (density of population), and assume that the falling object hits a target area of 10% of the unit surface and that the likelihood of being protected against such threat is 90%:

People/m²	***Probability of being hit***	***Probability of being unprotected***	***Probability of being hit with damage***
10^{-3}(1000/km²)	*10^{-4}*	*10^{-1}*	*10^{-5}*
10^{-4}(100/km²)	*10^{-5}*	*10^{-1}*	*10^{-6}*
10^{-5}(10/km²)	*10^{-6}*	*10^{-1}*	*10^{-7}*
10^{-6}(1/km²)	*10^{-7}*	*10^{-1}*	*10^{-8}*

Conservatively, and in the absence of further analysis, the Applicant should select a probability of injuring people on the ground of $1*10^{-5}$.

This consideration does not apply to the external load operations where the external load has a considerable size and task specialists are working directly below the external load not protected by any natural/built shield. In this case, the probability to strike people on the ground is very HIGH. This case will be assessed separately in section3.4.

3.3.3. Classification

Having determined the severity and the combined probability, we can now compare with the safety objectives from CS 27/29.1309:

- For CATASTROPHIC events the target probability is less than 10^{-9}
- For HAZARDOUS events the target probability is less than 10^{-7}
- For MAJOR events the target probability is less than 10^{-5}

Using the suggested value of 10^{-5} for the probability to injure people on the ground, it looks easy to meet the target combined probability for CATASTROPHIC and HAZARDOUS. However, when the PDR event is caused by a design deficiency, the occurrence level should be set to 1 and consequently the event should be classified potentially as being UNSAFE if the detached part meets the energetic criteria >20J.

For a PDR event that is potentially CATASTROPHIC (energy >=100 J), when the root cause is not a design deficiency, an occurrence level of 10^{-4} or lower may allow the event to be classified as being not UNSAFE[7].

For a PDR event that is potentially HAZARDOUS (100 J>energy >20 J), when the root cause is not a design deficiency, an occurrence level of 10^{-2} or lower may allow the event to be classified as being not UNSAFE.

Particular attention is necessary in assessing the occurrence level with respect to the population of affected parts and the counting of FH. The occurrence level should be assessed considering the in-service experience, when statistically relevant, of the specific part design not of a specific P/N.

If parts start frequently detaching soon after introducing a change in their installation, the probability rate may become high enough to require prompt corrective actions.

A reassessment by the DOA holder or TC/STC holder of a specific PDR case for a potential unsafe condition is expected when the loss of a specific part has a probability rate per FH that is significantly higher than the average probability rate, which is between 10^{-6}/FH and 10^{-4}/FH, as currently observed in the field.

3.4. SCENARIO 2B: People on the ground – loss of NHEC

This section addresses the specific rotorcraft scenario in which people on the ground are potentially hit by a detached external load (NHEC).

An external load system normally includes:

-an **upper system** (part of the rotorcraft) to restrain and operate the whole external load (e.g. cargo hook system)

-an **lower system** to restrain the cargo at a certain distance from the upper system (e.g. long line with hook/s and net as necessary)

-the **cargo**

The detached external load may include the retaining means (lower system) and the actual load (cargo), but no actual part of the rotorcraft (upper system).

The loss of external load can occur due to a failure of the upper system **or** the lower system and its probability is therefore the sum of both:

[7] A not UNSAFE classification does not constitute relief for the DA Holder in assessing and acting upon the safety issue associated to the event. A recurrent maintenance error can qualify as a design deficiency and the DA Holder is expected investigate this aspect. A production deficiency, when identified, shall also be corrected.

P (loss of NHEC) = P (upper system failure) + P (lower system failure)

Usually, in the airworthiness certification of the upper system, the occurrence of an inadvertent release is substantiated to be Remote (for old products, value driven by the effect on occupants), up to Extremely Remote (EASA expectation for newly certified products, giving more consideration to third parties on ground). The terms “Remote” and “Extremely Remote” are used in the meaning of AC 27/29.1309.

For the lower system, it is usually not possible to estimate a failure rate because a quantitative safety assessment is not available. A conservative value should then be used:

$$P\ (\text{lower system failure}) \geq 10^{-3} \text{ per FH}$$ [8]

In this case, the P (lower system failure) prevails, bringing the P (loss of NHEC) to the same order of magnitude.

The associated effect of people on the ground being struck by a detached cargo can be considered to be fatal due simply to the size of external load. In general, the probability to injure people on the ground is a function of the area of impact on ground, the population density in the area and the likelihood of being protected by a natural/built shelter.

In-service experience shows that external load operations are also performed over highly populated areas. Therefore, the DOA holder or TC/STC holder responsible for the upper or lower system, cannot lower the probability of the detached cargo hurting people on the ground, based on the assumption that operations are only conducted over sparsely populated areas.

Additionally, a failure of the upper system is likely to trigger an occurrence level higher than the target certification reliability because the number of flight hours logged in actual external load operation is not so high.

Finally, considering the associated risk, when the unwanted release of external load occurs due to a malfunction or failure, the event should be classified as being potentially UNSAFE.

In conclusion, the methodology proposed shows that the unwanted release of external load occurring due to a malfunction or failure should be classified as being potentially UNSAFE and reported to the Agency by the approval holder. Corrective actions will have to be agreed on a case by case basis.

In case the loss of NHEC is due to a failure of the lower system for which no design approval is applicable, the Operator should always notify the Competent Authority. In parallel the DOA holder or TC/STC holder shall notify the event to the Agency for information. Such information is essential to gather all possible lessons from the field.

Although not exhaustive, some operational considerations intended to minimize the residual risk have been derived from reviewing accident investigations and are shared here below:

[8] This is a reference value and is not intended to set a target requirement for lower system design. Incorrect set up of cargo may lead to loss of load also without a system failure. Such scenario is not considered here but shall be duly considered by the Operator.

- Rotorcraft performance should be verified upfront and complied with;
- Wind limitations associated with external cargo operations and all other RFM procedures should be complied with;
- Task specialists should be informed by the Operator of the risk associated to working below a rotorcraft carrying external load. The concept of combined failure probabilities for P (loss of NHEC) should be explained;
- The means to restrain/secure the cargo should be suitable and operated in accordance with the applicable procedures;
- The load master should verify the correct configuration before giving the authorization for take-off;
- All the task specialists should clear the area below the rotorcraft as soon as practicable;
- The rotorcraft with external load shall be operated in a safe corridor.

Refer to EASA SIB 2021-02 on external loads for further guidance.

3.5. SCENARIO 3: Damage to other aircraft/parts on the runway

The operational conditions and the performance of rotorcraft make Scenario 3 significantly less frequent compared to aeroplanes. So far, no specific events have been reported in this category. However, DOA and TC/STC Holders should pay particular attention to prevent occurrences of PDR when the parts are prone to be lost during the taxying, take-off or landing phases and are of a nature that could cause tyre or engine damage to other aircraft.

4. Conclusion

The main scenario to be addressed by DOA and TC/STC Holders is the possibility of an unsafe condition as per AMC1 21.A.3B(b), paragraph (a), i.e. the possibility that a PDR event creates an unsafe condition for the rotorcraft itself. For this possibility, the guidelines provided in Section 3.2 of this Certification Memorandum and GM1 21.A.3B(b) are expected to be followed.

Regarding people on the ground, as per AMC1 21.A.3B(b), paragraph (b), the DOA and TC/STC Holder should assess the risk of serious or fatal injury. An approach based on kinetic energy is proposed for the definition of severity of the PDR event. For this scenario, the guidelines provided in Section 3.3 and 3.4 of this Certification Memorandum and GM1 21.A.3B(b) are expected to be followed. A workflow is proposed in Annex 2 with further guidance on the steps that could be followed.

The scenario of damage to other aircraft/parts on the runway can be reasonably excluded from the analysis, as it is a very unlikely event for rotorcraft, more pertinent to large aeroplanes while using the runway of an airport/aerodrome. However, DOA and TC/STC Holders should pay particular attention to prevent occurrences of PDR when the parts are prone to be lost during the taxying, take-off or landing phases.

4.1. Who this Certification Memorandum affects

This Certification Memorandum affects organisations required to report in accordance with 21.A.2B(b), including European DOA and TC/STC holders when assessing Continued Airworthiness events involving Parts Detached from Rotorcraft.

5. Remarks

1. This EASA Proposed Certification Memorandum will be closed for public consultation on the **15th of October 2021**. Comments received after the indicated closing date for consultation might not be taken into account.
2. For any question concerning the technical content of this EASA Proposed Certification Memorandum, please contact:

NAME, First Name: PILIERO, Pietro
Function: Project Certification Manager VTOL
Phone: +49 (0)221 89990 4227
E-mail: pietro.piliero@easa.europa.eu

NAME, First Name: PINSARD, Laurent
Function: Senior Expert Structures – General Aviation and & VTOL
Phone: +49 (0)221 89990 4029
E-mail: laurent.pinsard@easa.europa.eu

6. ANNEX 1-Examples of classification

Scenario	Severity (potential)	P (PDR event)	P (damage)	Combined probability	UNSAFE	Corrective action
SCENARIO 1 Loss of large rotorcraft part(s) impacting the rotorcraft and leading to the impossibility to continue safe flight and landing (i.e. loss of control). It should be classified as CATASTROPHIC as in this case all occupants are exposed to the highest risk.	CAT	STEP 1: Select candidate (e.g. Door). STEP 2: Determine probability	It should be quantified (e.g. it can be justified with trajectory analysis)	P(PDR event) * P(damage)	EASA's involvement is necessary in all cases.	If there is a *production/ design deficiency,* a corrective action should be developed in all cases. EASA's decision on AD will follow as necessary.
		If it is assumed that the observed probability for this event is EXTREMELY REMOTE	Assuming it is 10^{-2}	EXTREMELY IMPROBABLE	NO	
			Assuming it is 10^{-1}	EXTREMELY REMOTE	YES	
		If there is a non-compliance with the certification basis of structure and mechanical parts the probability is set to 1	As resulting from analysis	Most likely it will not be EXTREMELY IMPROBABLE	YES	
SCENARIO 2A Loss of rotorcraft part (*) impacting people on the ground leading to severe injury or death. (*) here we consider a PDR event for which the kinetic energy is >= 100 J (brain trauma causing	CAT	STEP 1: Select candidates: Doors/cowlings/fairings/external lights and antennas/cameras/other parts with high density. STEP 2: Determine probability	For a PDR, the probability to cause a fatal injury to people on the ground is considered to be LOW (usually from 10^{-5} to 10^{-8} depending on the area) based on in-service experience	P(PDR event) * P(damage)	EASA's involvement is necessary in all cases	If there is a *production/ design deficiency,* a corrective action should be developed in all cases. EASA's decision on AD will follow as necessary.
		If it is assumed that the observed probability is REMOTE	Assumed 10^{-5}	EXTREMELY IMPROBABLE	NO	

Scenario	Severity (potential)	P (PDR event)	P (damage)	Combined probability	UNSAFE	Corrective action
death of people on ground)		If there is a non-compliance with the CS for structure and mechanical parts the probability is set to 1		REMOTE	YES	
SCENARIO 1 Loss of rotorcraft part impacting the rotorcraft and with such adverse effects on the structural strength, performance or flight characteristics of the rotorcraft that an emergency landing is always possible. In this case the occupants have the possibility to survive.	HAZ	STEP 1: Select candidates Doors/cowlings/fairings/external lights and antennas/other small parts with high density. A long line cable rebound scenario should also be considered as a special case. STEP 2: Determine probability	It should be quantified (e.g. it can be justified with trajectory analysis)	P(PDR event) * P(damage)	Scenario cannot be excluded by observed occurrence as cowlings/doors can cause SUBSTANTIAL DAMAGE. In all cases EASA's involvement is applicable.	If there is a *production/ design deficiency* a corrective action should be developed in all cases. EASA's decision on AD will follow as necessary.
		If it is assumed that the observed probability is REMOTE	Assuming it is 10^{-2}	EXTREMELY REMOTE	NO	
			Assuming it is 10^{-1}	REMOTE	YES	
		If there is a non-compliance with the CS for structure and mechanical parts the probability is set to 1	As resulting from analysis	Most likely it will not be EXTREMELY REMOTE	YES	
SCENARIO 2A Loss of rotorcraft part (*) impacting people on the ground leading to injury.	HAZ	STEP 1: Select candidates medium and small parts are candidates STEP 2: Determine probability	The probability of causing a serious injury to people on the ground is considered, based on in service experience, LOW (usually from 10^{-5} to 10^{-8} depending on the area)	P(PDR) * P(damage)	In all cases EASA's involvement is applicable.	If there is a *production/ design deficiency* a corrective action should be developed in all

Scenario	Severity (potential)	P (PDR event)	P (damage)	Combined probability	UNSAFE	Corrective action
A PDR event for which the kinetic energy is <100 J and >= 20 J is potentially HAZARDOUS		If it is assumed that the observed probability is REMOTE	Assumed to be 10^{-5}	EXTREMELY IMPROBABLE	NO	cases. Agency decision on AD will follow as necessary.
		If we assume that the observed probability is REASONABLY PROBABLE		REMOTE	YES	
SCENARIO 1 Loss of a rotorcraft part impacting the rotorcraft and with such adverse effects on performance or flight characteristics of the aircraft that increased pilot workload is expected.	MAJ	STEP 1: Select candidates (medium and small parts) STEP 2: Determine probability	It should be quantified (e.g. it can be justified with trajectory analysis)	P(PDR event) * P(damage)	Looking at their consequences, these occurrences can be considered not UNSAFE.	If there is a *production/ design deficiency* a corrective action should be developed in all cases. The resolution has to be handled under the DOA approved procedures
		If we assume that the observed probability is REASONABLY PROBABLE	Assuming it is 10^{-2}	REMOTE	NO	

The special case of External Load:

Severity (potential)	P (PDR event)	P (level of injury)	Combined probability	UNSAFE
SCENARIO 1 CATASTROPHIC For damage to people airborne (occupants and HEC)	For structural failure of HEC installation/component. A single Structural Failure of any part of the system retaining the load→P=1	1	N/A as not pertinent to structure	YES (malfunction/defect to be addressed asap)
	For HEC system failures. When such a failure occurs, it is unlikely to be able to demonstrate a probability of EXTREMELY IMPROBABLE (as per a/c system design requirements)		Not EXTREMELY IMPROBABLE	YES
	For HEC system failures. If it is assumed that the observed probability is EXTREMELY REMOTE for legacy systems design requirements		EXTREMELY REMOTE	YES
SCENARIO 2B CATASTROPHIC For damage to people impacted by NHEC	For structural failures. A single Structural Failure of any part of the NHEC system retaining the load →P=1	Estimated [*$5*10^{-2}$*] For people involved in the task	N/A	YES
	For NHEC system failures. External loads (loss of NHEC load, system failure) Up to 10^{-5} for a/c internal system +TBD for external restraint system (**)	Estimated [*$5*10^{-2}$*] For people involved in the task	Unknown	YES

(**) NHEC External load systems are often a combination of an internal system holding a Major Change/STC approval and an external system to restrain the cargo that is not always certified and possibly subject to operational approval. The TC Holder may not have enough data to estimate the failure rate of the external system for cargo restraint and may limit the analysis to its area of competence/responsibility.

EXTREMELY (EXT) IMPROBABLE (IMP): having an Average Probability Per Flight Hour of the order of 1x 10^{-9} or less.

EXTREMELY REMOTE: having an Average Probability Per Flight Hour of the order of 1x 10^{-7} or less, but greater than of the order of 1 x 10^{-9}.

REMOTE: having an Average Probability Per Flight Hour of the order of 1x 10^{-5} or less, but greater than of the order of 1 x 10^{-7}.

REASONABLY PROBABLE (also referred as PROBABLE): having an Average Probability Per Flight Hour of the order of 1x 10^{-3} or less, but greater than of the order of 1 x 10^{-5}.

FREQUENT: having an Average Probability Per Flight Hour greater than of the order $1x10^{-3}$.

7. ANNEX 2-Work flow

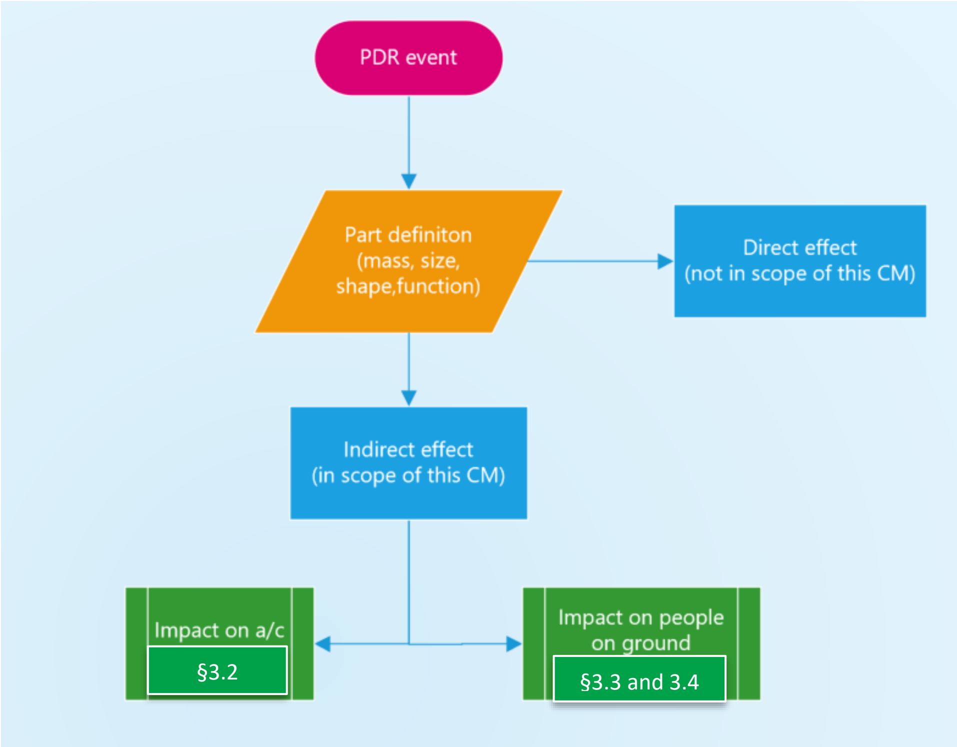

Figure 1-WF Step 1

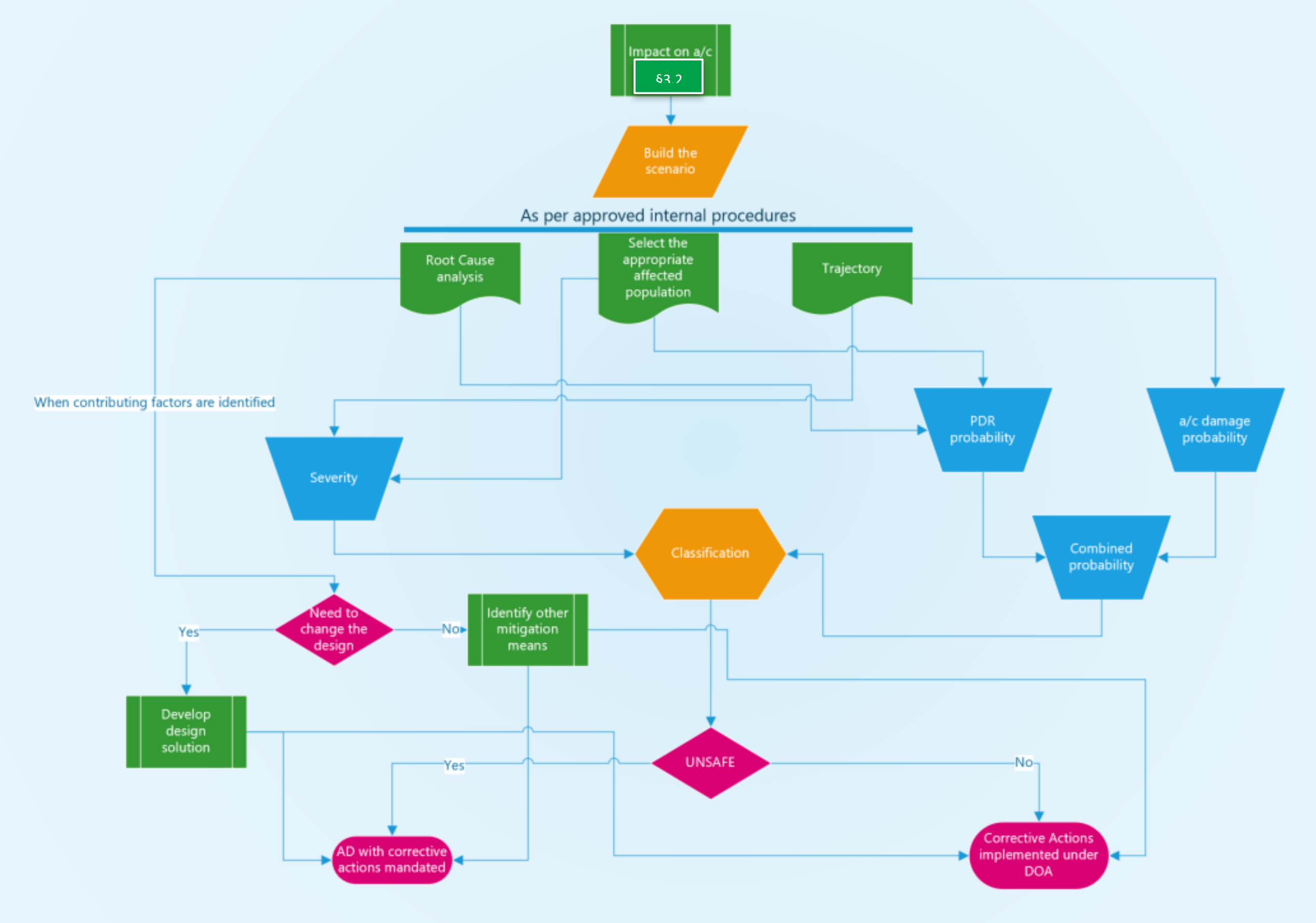

Figure 2-WF step 2a

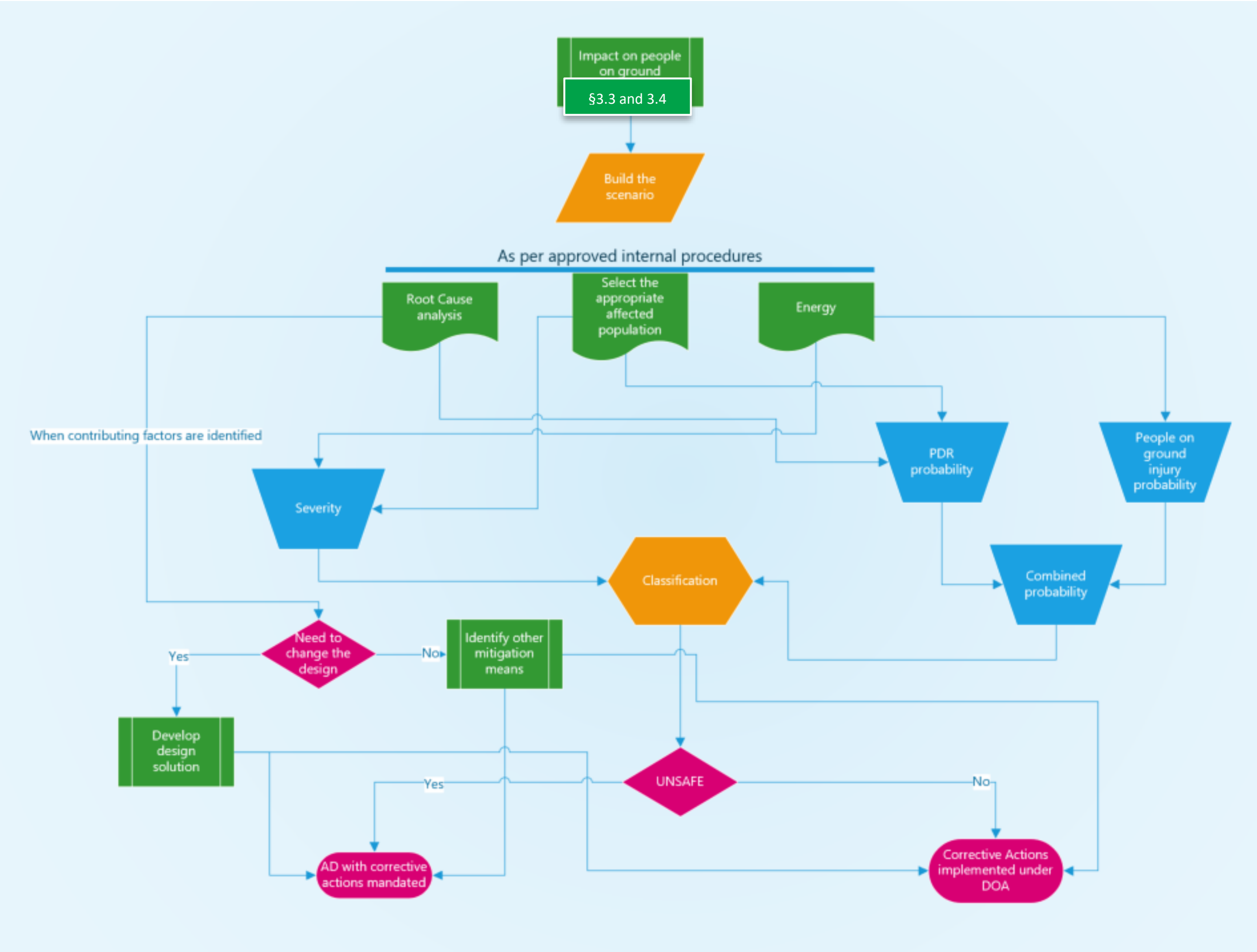

Figure 3-WF step 2b