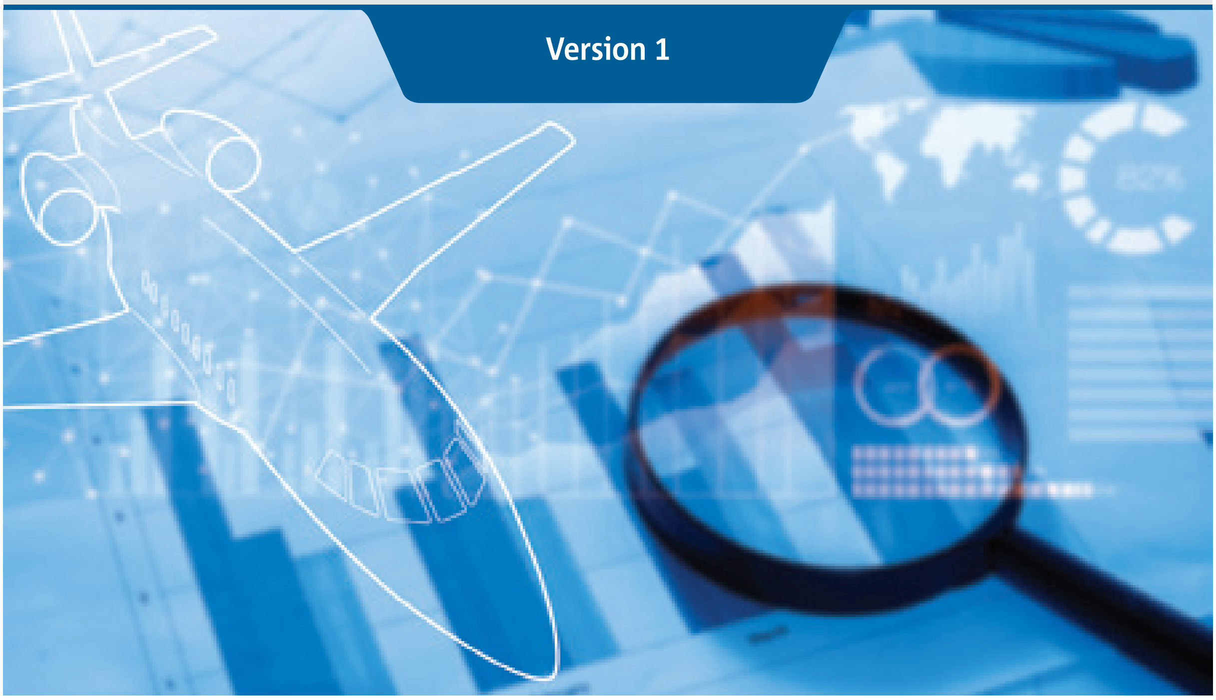
EASA
European Aviation Safety Agency

EUROPEAN OPERATORS FLIGHT DATA MONITORING
WORKING GROUP A

SAFETY PROMOTION
Good Practice document

REVIEW OF ACCIDENT PRECURSORS FOR RUNWAY EXCURSIONS

Version 1



Contents

Summary

This report summarizes a list of precursor factors for several types of runway excursion accidents. From this list several flight data measurements are proposed for further analysis and development by EOFDM WG B.

Introduction

In the context of this report, runway excursions consider the following cases:

Runway overruns: when the aircraft rollout extends beyond the end of the runway on takeoff or landing.

Runway veer-off: when the aircraft deviates laterally off the side of the runway on takeoff or landing

In order to facilitate the development of the list of recommendations to WG B and to ensure its comprehensiveness, the analysis was structured in three steps:

1) Group all types of foreseeable runway excursions into generic scenarios.

Considering the possible combinations of types of excursions (overrun or veer-off) versus the phase of flight (takeoff or landing) and also the occurrence of a rejected takeoff or not, six scenarios have been considered.

- Runway overrun on takeoff after rejected takeoff
- Runway overrun on takeoff without rejected takeoff
- Runway veer-off on takeoff without rejected takeoff
- Runway veer-off on takeoff after rejected takeoff
- Runway overrun after landing
- Runway veer-off after landing

2) Identify and justify all foreseeable precursor factors for each excursion scenario.

The factors are listed in tabular format and ordered to facilitate the construction of plausible “sequences of events”. For example, table 1 suggests that a runway overrun could be preceded by the following precursors:

Incorrect performance calculation ⇨ Slow acceleration ⇨ Rejected takeoff ⇨ Slow deceleration ⇨ overrun.

Precursors listed in the same column are assumed to be independent from each other, but possibly occurring in combination. This means that the following sequence is also plausible:

Incorrect aircraft configuration ⇨ Late rotation + slow rotation ⇨ Rejected takeoff ⇨ Reduced runway remaining after RTO ⇨ overrun.

It could be argued that “slow rotation” should be in fact preceded by “Late rotation”. Also, some of the sequences are unusual or less plausible than other such as:

Reduced elevator authority ⇨ Slow acceleration ⇨ Rejected takeoff ⇨ Reduced runway remaining after RTO ⇨ overrun

These minor inconsistencies would only be problematic in the context of a safety risk assessment, so in this application such arrangement seems to be an adequate compromise between simplicity and correctness.

The scenarios of runway excursion on takeoff were further subdivided by the occurrence of a rejected takeoff. This split does increase the complexity and length of the analysis, however it excludes some sequences which would be otherwise too illogical

CG out of limits ⇨ slow rotation ⇨ engine power increase ⇨ slow deceleration ⇨ overrun

A risk assessment would also need to consider the “safety defences” such as a go-around or a balked landing. However, in this context such breakdown is not strictly necessary and it would increase the complexity of the analysis without a significant benefit. The detection of go-arounds and balked landings are included in the list of recommendations (step #3), but not discussed in step #2.

3) Consolidate all the precursor factors identified in step #2 and produce actionable recommendations for WG B.

This consolidation is useful to reduce the number of recommendations without loss of detail. For example, the precursor “inadequate use of stopping devices” is mentioned on takeoff and landing scenarios, however only one recommendation is produced (see WGA12).

Step 1: List of Foreseeable excursion Scenarios

1. Runway overrun after RTO
2. Runway overrun on takeoff (no RTO)
3. Runway veer-off on takeoff (no RTO)
4. Runway veer-off after RTO
5. Runway overrun after landing
6. Runway veer-off after landing

Step 2: Identification of precursor factors

Accident scenario #1: Runway overrun after rejected takeoff

Table 1: Precursor factors for accident scenario #1

	Increasing “proximity” to the accident →		
Incorrect performance calculation	Slow acceleration		Reduced runway remaining after RTO
Inappropriate aircraft configuration	Aircraft malfunction	Rejected takeoff	Inadequate use of stopping devices
CG out of limits	Slow rotation		Slow deceleration
Reduced elevator authority	Late rotation		
	No liftoff after rotation		

Incorrect performance calculation: erroneous data entry or calculation errors could lead to incorrect thrust settings or incorrect V speeds.

Inappropriate aircraft configuration: failure to set the correct aircraft configuration (lifting devices, pitch trim) could cause takeoff performance problems.

CG out of limits: incorrect cargo loading is one frequent cause for this kind of events. It can cause difficulties in rotating the aircraft on takeoff (and other controllability problems while airborne).

Reduced Elevator authority: There have been several occurrences in the industry where the elevator's authority was reduced preventing adequate rotation on takeoff.

Slow acceleration: Takeoff performance problems could be caused by many different problems which are not directly measurable by FDM. The detection of a slow acceleration could be an indirect means to identify the existence of those problems as precursors for runway overruns. If the acceleration is perceived by the crew as abnormal this could also be a trigger for a rejected takeoff.

Aircraft malfunction: Most aircraft malfunctions evident to the flight crew during the takeoff run should result in rejected takeoffs. The monitoring of aircraft malfunctions is important to assess the quality of the crew's reaction and decision.

Slow rotation: an excessively slow rotation may be the consequence of other problems (incorrect loading, pilot technique, poor elevator authority, etc) and could delay the liftoff reducing the safety margin against an overrun. This could also prompt the crew to reject the takeoff at speeds above V1 which could also lead to an overrun.

Late rotation: A late rotation caused either by slow acceleration (excessive time to Vr) or by delayed action by the crew could increase the distance required for takeoff and reduce the safety margin against an overrun.

No liftoff: If after rotation the aircraft does not become airborne, the crew could decide to do a high speed rejected takeoff which could lead to an overrun. This situation may be coupled with tail strikes, where the increased drag further delays acceleration to a sufficiently high airspeed to enable liftoff.

Rejected takeoff: this is a clear indication that the crew identified a problem during the takeoff and could lead to a runway overrun under some circumstances.

Reduced runway remaining after RTO: A rejected takeoff conducted after V1, or in cases where forward acceleration is abnormally low could lead to an overrun on short runways.

Inadequate use of stopping devices: The inadequate use of stopping devices (brakes, thrust reversers, airbrakes, etc), could increase the stopping distance after a rejected takeoff and cause an overrun.

Slow deceleration: The deceleration after a rejected takeoff could be slow despite the correct use of all stopping devices (because of a technical malfunction or poor runway friction). This could eventually result in a runway overrun.

Accident Scenario #2: Runway overrun on takeoff (RTO not attempted)

➨ **Table 2:** Precursor factors for accident scenario #2

Increasing "proximity" to the accident →			
Incorrect performance calculation		No liftoff after rotation	
Inappropriate aircraft configuration	Slow acceleration	Slow rotation	Reduced runway remaining at liftoff
CG out of limits		Late rotation	
Reduced Elevator authority		Engine power increase	

Some of the contributing factors in this accident scenario have already been presented in the context of scenario #1, therefore the discussion will now be limited to the new factors.

Engine power increased: The engine power for takeoff is normally set at the start of the takeoff roll (or before, in the case of static takeoffs). An increase of engine power from a de-rated setting to full power during the takeoff run could be an indication that the crew is trying to recover from an abnormal situation which otherwise could result in a runway overrun.

Reduced runway remaining at liftoff: Abnormal situations like a slow or late rotation or delayed liftoff (with or without tail strike) could result in a takeoff run distance greater than TORA

Accident Scenario #3: Runway veer-off on takeoff (RTO not attempted)

Table 3: Precursor factors for accident scenario #3

Increasing "proximity" to the accident →	
Aircraft handling	
Crosswind	
Forward thrust asymmetry	Lateral deviation
Steering system malfunction	

Aircraft handling: inappropriate use of aircraft controls (rudder and nose wheel steering) could cause controllability problems. Also, inadvertent actuation of wheel brakes while using the rudder pedals could affect lateral controllability causing lateral deviations (as a form of pilot induced oscillations)

Crosswind: Strong crosswind may affect lateral controllability of the aircraft during takeoff.

Forward Thrust Asymmetry: regardless of the cause (technical failure or pilot error) this could affect lateral controllability causing lateral deviations if not promptly corrected.

Steering system malfunction: during the takeoff roll, problems with the steering system could affect lateral controllability causing lateral deviations

Lateral deviation: some degree of lateral deviation (or oscillation) during the takeoff run is normal, however this should be kept within certain limits and also considering the runway width.

Accident Scenario #4: Runway veer-off on takeoff (after RTO)

Table 4: Precursor factors for accident scenario #4

Increasing "proximity" to the accident →		
Rejected takeoff	Reverse thrust asymmetry	Lateral deviation
	Braking asymmetry	
	Aircraft handling	

Rejected takeoff: in the context of this scenario, the rejected takeoff is the trigger for the chain of events. However in reality it could be the consequence of numerous circumstances which are not relevant for this analysis (tower request, runway incursion by other aircraft, bird strike, or any of the factors listed in the previous accident scenario)

Reverse Thrust Asymmetry: regardless of the cause (technical failure or pilot error) this could affect lateral controllability causing lateral deviations if not promptly corrected.

Braking Asymmetry: braking asymmetry (due to malfunction or pilot error) could affect lateral controllability causing lateral deviations

Accident scenario #5: Runway overrun after landing

Table 5: Precursor factors for accident scenario #5

Increasing "proximity" to the accident →			
Poor visibility			
Tailwind	High energy over threshold	Deep landing	Inadequate use of stopping devices
Crosswind	Long flare	Abnormal runway contact	Slow deceleration
Unstable Approach	Excessive engine power during landing	Excessive energy at touchdown	
Incorrect performance calculation Inapropriate aircraft configuration			

Poor visibility: Poor visibility of the runway due to weather, insufficient lighting or even visual illusions could affect the judgment of distances by the pilot flying causing deep landings or abnormal runway contacts.

Tailwind: Tailwind will increase the ground speed during landing and consequently the airborne distance of the landing phase. This may cause deep landings.

Crosswind: Crosswind may affect the controllability of the aircraft during landing and lead to deep landings or abnormal runway contacts.

Unstable Approaches: many runway excursion accidents are associated with unstable approaches.

Inappropriate aircraft configuration: may affect landing performance and reduce safety margins.

High energy over Threshold: The height and velocity at which the runway threshold is crossed may have an important influence on the landing distance.

Long Flare: some aircraft types have a remarkable tendency to float over the runway during landing. This may cause deep landings which may subsequently increase the risk of an overrun.

Excessive engine power during landing: Failure to reduce engine power before touchdown will affect the landing performance and may reduce safety margins.

Deep landing: Deep landings are deviations to the planned landing performance and may increase the risk of overruns.

Abnormal runway contact: Bounced, off center or crabbed landings, wingtip strikes and other types of abnormal runway contact could contribute to delayed or inadequate use of stopping devices which in turn may increase the stopping distance.

Excessive energy at touchdown: the aircraft energy at touchdown has a direct effect on the landing performance and may reduce safety margins.

Inadequate use of stopping devices: stopping distance is affected by late or inadequate activation of thrust reverser, brakes (and auto-brakes), airbrakes or other stopping devices.

Slow deceleration: even with correct use of stopping devices the net acceleration could be low due to runway contamination or system failure. This will affect the stopping distance.

Accident scenario #6: Runway veer-off after landing

➨ Table 6: Precursor factors for accident scenario #6

Increasing "proximity" to the accident →			
Poor visibility		Inadequate use of stopping devices	
Crosswind	Abnormal runway contact	Braking Asymmetry	Lateral deviation
Unstable Approach		Reverse thrust asymmetry	
		Aircraft handling	

All of the contributing factors in this accident scenario have already been presented in the context of other scenarios.

Step 3: Consolidated precursors and recommendations for EOFDM Working Group B

	Excursion Scenario						
Precursor	1	2	3	4	5	6	Recommendation
Incorrect Performance calculation	●	●			●		RE01
Inappropriate aircraft configuration	●	●			●		RE02
CG out of limits	●	●					RE03
Reduced elevator authority	●	●					RE04
Slow acceleration	●	●					RE05
Aircraft malfunction	●						RE06
Slow rotation	●	●					RE07
Late rotation	●	●					RE08
No liftoff after rotation	●	●					RE09
Rejected takeoff	●			●			RE10
Runway remaining at RTO	●						RE11
Inadequate use of stopping devices	●				●	●	RE12
Slow deceleration	●				●		RE13
Engine power increased		●					RE14
Runway remaining at liftoff		●					RE15
Aircraft handling			●	●		●	RE16
Crosswind			●		●	●	RE17
Forward thrust asymmetry			●				RE18
Steering malfunction			●				RE19
Lateral deviation			●	●		●	RE20
Reverse thrust asymmetry				●		●	RE21
Braking asymmetry				●		●	RE22
Poor visibility					●	●	RE23
Tailwind					●		RE24
Excessive engine power					●		RE25
Unstable approach					●	●	RE26
High energy over threshold					●		RE27
Long flare					●		RE28
Deep landing					●		RE29
Abnormal runway contact					●	●	RE30
Go-around							RE31
Excessive energy at touchdown					●		RE32

RE01 Incorrect performance calculation: Develop means to detect erroneous data entry or calculation errors which could lead to incorrect thrust settings,incorrect V speeds or incorrect target approach speeds

RE02 Inappropriate aircraft configuration: Develop means to detect inappropriate aircraft configurations (lifting devices, pitch trim) which could cause takeoff and landing performance problems; Not all aircraft are equipped with Takeoff Configuration Warning Systems and some of these systems can't detect all types of configuration errors.

RE03 CG out of limits: Develop means to detect CG out of limits on takeoff or not consistent with pitch trim settings.

RE04 Reduced elevator authority: Develop means to detect abnormal rotation in response to elevator inputs, reduced elevator movement or excessive force required to move elevator surfaces.

RE05 Slow acceleration: Develop means to measure acceleration during the takeoff roll and detect abnormal values, taking in consideration the various factors that affect the takeoff performance.

RE06 Aircraft malfunction: Develop means to detect aircraft malfunctions which are likely to cause rejected takeoffs.,(e.g. Master Warning and Master Caution alerts and airspeed indication disagreements)

RE07 Late rotation: Develop means to detect rotations conducted after Vr or beyond the expected distance (or time) after the start of the takeoff roll.

RE08 - Slow rotation: Develop means to detect slow rotations.

RE09 - No liftoff: Develop means to measure detect late liftoff (in time and/or distance) after rotation or start of takeoff roll.

RE10 - Rejected takeoff: Develop means to identify rejected takeoffs.

RE11 Runway remaining after RTO: Develop means to estimate runway remaining ahead of the aircraft after the start of the rejected takeoff and to estimate ground distance spent during the RTO.

RE12 Inadequate use of stopping devices: Develop means to identify late or inadequate activation of thrust reverser, brakes, airbrakes or other stopping devices during rejected takeoffs and landings.

RE13 Slow deceleration: Develop means to detect slow deceleration after landing or RTO, taking in consideration the various factors that affect the landing and RTO performance.

RE14 Engine power increased: Develop means to detect engine power increase during the takeoff roll.

RE15 Runway remaining at liftoff: Develop means to estimate runway remaining ahead of the aircraft at the moment of liftoff and detect abnormal values

RE16 Aircraft handling: Develop means to monitor the use of aircraft controls (rudder and nose wheel steering) and brakes during the takeoff, rejected takeoff, and landing and detect non standard cases

RE17 Crosswind: Develop means to estimate crosswind during takeoff, approach and landing and detect abnormal values.

RE18 Forward thrust asymmetry: Develop means to identify forward thrust asymmetry during the takeoff roll.

RE19 Steering system malfunction: Develop means to identify problems with steering system which could affect lateral controllability

RE20 Lateral deviation: Develop means to identify excessive lateral deviations or oscillations during the takeoff, rejected takeoff and landing taking in consideration the runway width.

RE21 Reverse thrust asymmetry: Develop means to identify reverse thrust asymmetry during a RTO or landing

RE22 Braking asymmetry: Develop means to identify braking asymmetry during a rejected takeoff or landing (Possibly in combination with WGA12)

RE23 Poor visibility: Develop means estimate visibility conditions from METAR data, time of the day and runway lighting, so it can be used in conjunction with FDM data.

RE24 Tailwind: Develop means to estimate tailwind during takeoff, approach and landing

RE25 Excessive engine power: Develop means to monitor engine power reduction before touchdown and to identify abnormal engine utilization in this phase of the flight.

RE26 Unstable approaches: Develop means to identify and quantify unstable approaches, whether or not they result in go-around maneuvers

RE27 High energy over threshold: Develop means to estimate height, airspeed and ground speed while crossing the runway threshold.

RE28 Long flare: Develop means to detect the start of the flare and to estimate the ground distance covered from the start of the flare until touchdown.

RE29 Deep landing: Develop means to estimate the distance from the runway threshold until the touchdown point and also the runway length available after touchdown.

RE30 Abnormal runway contact: Develop means to identify and quantify bounced (main or nose wheels), off-center, ”nose-first” or asymmetrical landings.

RE31 Go-around: Develop means to identify go-arounds and balked landings

RE32 Excessive energy at touchdown: Develop means to correctly identify the touchdown instant, measure airspeed and ground speed and to identify cases of excessive energy.

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