European Aviation Safety Agency

Notice of Proposed Amendment 2017-06

Loss of control or loss of flight path during go-around or other flight phases

RMT.0647

EXECUTIVE SUMMARY

The objective of this NPA is to mitigate the safety risk of loss of the normal go-around (G/A) flight path, or loss of control of the aircraft during G/A or other flight phases executed at low-speed.

This NPA proposes to amend CS-25 to ensure that:

— the design of large aeroplanes is such that the G/A procedure with all engines operating (AEO) can be safely conducted by the flight crew without requiring exceptional piloting skills or alertness. Risk of excessive crew workload and risk of somatogravic illusion must be carefully evaluated, and design mitigation measures must be put in place if those risks are too high;

— the design of large aeroplanes provides an adequate longitudinal controllability and authority during G/A and other flight phases (focusing on low speed situations).

The proposed changes are expected to provide a fair safety benefit against an acceptable cost impact for large aeroplane manufacturers.

Action area:	Aircraft upset in flight (LOC-I)				
Affected rules:	CS-25 (Certification Specifications for Large Aeroplanes)				
Affected stakeholders:	DAHs and operators				
Driver:	Safety	**Reference:**	SR FRAN-2013-025; FRAN-2013-026; FRAN-2013-042		
Rulemaking group:	Yes	**Impact assessment:**	Full	**Procedure:**	Standard

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1. About this NPA

1.1. How this NPA was developed

The European Aviation Safety Agency (EASA) developed this NPA in line with Regulation (EC) No 216/2008[1] (hereinafter referred to as the 'Basic Regulation') and the Rulemaking Procedure[2]. This rulemaking activity is included in the EASA 5-year Rulemaking Programme under RMT.0647. The text of this NPA has been developed by EASA based on the inputs of the Rulemaking Group RMT.0647. It is hereby submitted to all interested parties[3] for consultation.

1.2. How to comment on this NPA

Please submit your comments using the automated **Comment-Response Tool (CRT)** available at **http://hub.easa.europa.eu/crt/**[4].

The deadline for submission of comments is **11 August 2017.**

1.3. The next steps

Following the closure of the public consultation period, EASA will review all comments received on the NPA.

Based on the comments received, EASA will develop a decision amending the certification specifications and acceptable means of compliance for large aeroplanes (CS-25).

The comments received and the EASA responses thereto will be reflected in a comment-response document (CRD). The CRD will be annexed to the decision.

[1] Regulation (EC) No 216/2008 of the European Parliament and of the Council of 20 February 2008 on common rules in the field of civil aviation and establishing a European Aviation Safety Agency, and repealing Council Directive 91/670/EEC, Regulation (EC) No 1592/2002 and Directive 2004/36/EC (OJ L 79, 19.3.2008, p. 1) (http://eur-lex.europa.eu/legal-content/EN/TXT/ ?qid=1467719701894&uri=CELEX:32008R0216).

[2] EASA is bound to follow a structured rulemaking process as required by Article 52(1) of Regulation (EC) No 216/2008. Such a process has been adopted by the EASA Management Board (MB) and is referred to as the 'Rulemaking Procedure'. See MB Decision No 18-2015 of 15 December 2015 replacing Decision 01/2012 concerning the procedure to be applied by EASA for the issuing of opinions, certification specifications and guidance material (http://www.easa.europa.eu/the-agency/management-board/decisions/easa-mb-decision-18-2015-rulemaking-procedure).

[3] In accordance with Article 52 of Regulation (EC) No 216/2008 and Articles 6(3) and 7) of the Rulemaking Procedure.

[4] In case of technical problems, please contact the CRT webmaster (crt@easa.europa.eu).

2. In summary: Why and what

2.1. Why we need to change the rules — issue/rationale

A number of commercial air transport large aeroplane accidents or serious incidents occurred either during/at the end of a go-around (G/A) phase, or with the aeroplane close to the ground (but not in G/A mode) and with the pilots attempting to climb. A loss of the normal G/A flight path or loss of control of the aircraft has been observed in relation to inadequate awareness of the aeroplane's state, or inadequate management by the flight crew of the relationship between pitch attitude and thrust. Unusual pitch-up trim position has also been a factor in some occurrences in other flight phases.

For more detailed analysis of the issues addressed by this proposal, please refer to the regulatory impact assessment (RIA) Section 4.1.

2.2. What we want to achieve — objectives

The overall objectives of the EASA system are defined in Article 2 of the Basic Regulation. This proposal will contribute to the achievement of the overall objectives by addressing the issues outlined in Chapter 2.1.

The specific objective is to mitigate the safety risk for large aeroplanes of loss of the normal G/A flight path, or loss of control of the aircraft during G/A or other flight phases executed at low-speed, ensuring that:

— the design of large aeroplanes is such that the G/A procedure with all engines operating (AEO) can be safely conducted by the flight crew without requiring exceptional piloting skill or alertness. The risk of excessive crew workload and the risk of somatogravic illusion must be carefully evaluated, and design mitigation measures must be put in place if those risks are too high;

— the design of large aeroplanes provides an adequate longitudinal controllability and authority during G/A and other flight phases (focusing on low speed situations).

2.3. How we want to achieve it — overview of the proposals

It is proposed to amend CS-25, applicable to all new large aeroplane designs, in order to:

— Upgrade the assessment of the G/A manoeuvre and its procedure. The objective is to evaluate if the G/A with AEO can be managed without creating excessive workload on the crew and without an excessive risk of somatogravic illusion. When an unacceptable level of risk is identified, the applicant has to implement design solutions to decrease this risk to an acceptable level. Implementing a reduced G/A thrust function is one of the possible solutions which can be used, as it allows to provide more time to the flight crew (on some two-engined aeroplanes it can range from 30 s to 1 min, assuming an average 2 000 ft/min rate of climb is maintained), and it decreases the dynamic of the manoeuvre, thus reducing the flight crew workload and mitigating the risk of mis-management of the aeroplanes' trajectory (including the effect of somatogravic illusion). As other means may be proposed by industry, this is considered as an acceptable means of compliance (AMC); the content of this AMC has been developed based on the text of the EASA Special Condition used to certify this function on Airbus aeroplanes;

— Upgrade the existing certification specifications and acceptable means of compliance related to longitudinal control and authority during G/A or other flight phases. For G/A, the aim is to demonstrate adequate longitudinal controllability and adequate stall margin during transition from any approved approach and landing configuration to G/A and up to the next flight phase and level-off (AEO and full thrust/power, different combinations of automatisms to be evaluated). For other flight phases, when the aeroplane has an automatic pitch trim function, the stabiliser (or trim tab) travel should be limited before or at stall warning activation to prevent excessive pitch trim such that it is possible to command a prompt pitch down of the aircraft for control recovery.

2.4. What are the expected benefits and drawbacks of the proposals

The expected benefits and drawbacks of the proposal are summarised below. For the full impact assessment of all options, please refer to Chapter 4.

The proposal would provide a fair safety benefit by requiring that all new CS-25 aeroplanes have design features ensuring that managing a G/A manoeuvre does not create an unacceptable risk of loss of control of the trajectory or loss of control of the aeroplane, including the risk of somatogravic illusion. Airbus, Boeing, and Fokker already developed systems to reduce the thrust during G/A; these systems avoid applying excessive thrust, thereby providing more time to the flight crew to perform the required action, and reduce the dynamic of the flight phase which decreases both risks of excessive pitch attitudes and of somatogravic illusion. Such a design improvement would also be required from other manufacturers developing aeroplanes that can also present a similar level of risk. In addition, the proposal would require manufacturers to investigate further the longitudinal controllability and authority in G/A and other flight phases, which would contribute to mitigate the risk of upset attitudes and loss of control, in particular in relation with the effect of the automatic pitch trim. The non-recurring cost (NRC) of this option is substantial for manufacturers that have not yet developed a mitigation means like a reduced G/A thrust function, however, when included in the development of an aeroplane, this is not significant relative to the overall cost of a development. Operators/owners would not face, or only negligible, recurring cost (RC) associated with these design improvements.

3. Proposed amendments and rationale in detail

The text of the amendment is arranged to show deleted text, new or amended text as shown below:

— deleted text is ~~struck through~~;

— new or amended text is highlighted in grey;

— an ellipsis '[…]' indicates that the rest of the text is unchanged.

3.1. Draft Certification Specifications (Draft EASA decision amending CS-25)

Amend CS 25.143 as follows :

CS 25.143 General
(See AMC 25.143)

(a) (See AMC 25.143(a) and (b)) The aeroplane must be safely controllable and manoeuvrable during~~–~~:
 (1) Take-off;
 (2) Climb;
 (3) Level flight;
 (4) Descent; ~~and~~
 (5) ~~Landing~~ Approach and go-around; and~~.~~
 (6) Approach and landing.

(b) (See AMC 25.143(a~~b~~) and (b)) It must be possible to make a smooth transition from one flight condition to any other flight condition without exceptional piloting skill, alertness, or strength, and without danger of exceeding the aeroplane limit-load factor under any probable operating conditions, including: ~~–~~
 (1) The sudden failure of the critical engine~~.~~ (See AMC 25.143(b)(1));
 (2) For aeroplanes with three or more engines, the sudden failure of the second critical engine when the aeroplane is in the en-route, approach, go-around, or landing configuration and is trimmed with the critical engine inoperative; ~~and~~
 (3) Configuration changes, including deployment or retraction of deceleration devices~~.~~; and
 (4) Go-around manoeuvres with all engines operating. The assessment must include, in addition to controllability and manoeuvrability aspects, the flight crew workload and the risk of somatogravic illusion (See AMC 25.143(b)(4)).

Create a new AMC 25.143(b)(4) as follows:

AMC 25.143(b)(4)
Go-around manoeuvres
1. Background

When full thrust or power is applied during a go-around, an excessive level of performance (rate of climb, accelerations) may be reached very quickly and may make it difficult for the flight crew to undertake the actions required during a go-around, especially in a constrained (air traffic control instructions, operational procedure) and rapidly changing environment.

This level of performance can also generate acceleration levels (in particular forward linear accelerations) that could lead to spatial disorientation for the flight crews (e.g. somatogravic illusion), in particular when combined with reduced visibility conditions.

Accidents and incidents have occurred during or after go-around where somatogravic illusions have led flight crews to make inappropriate nose-down inputs, leading to an aircraft upset, a loss of control, or a loss of the normal go-around flight path, and, in some cases, controlled flight into terrain with catastrophic consequences.

Other accidents resulting in loss of control were due to excessive pitch attitudes combined with a lack of crew awareness.

The risk is higher on two-engined aeroplanes because of their higher level of performance (thrust over weight ratio), but it should also be considered on other types of aeroplanes.

2. Criteria for assessing the Go-around manoeuvre risk with respect to somatogravic illusion and flight crew workload

2.1 Somatogravic illusion

It is considered that the risk of somatogravic illusion is high when combining high values of pitch-up angle, pitch rate, and longitudinal acceleration, together with a loss of outside visual reference.

2.2 Workload

In order to provide sufficient time to the flight crew for managing their tasks, and, therefore, keep the workload at a reasonable level, longitudinal acceleration and vertical speed should be constrained.

2.3 Mitigation means

Accordingly, the applicant should propose a specific mitigation means in case any of the following conditions can be encountered during a go-around manoeuvre:

— pitch rate value above 4 degrees per second;

— pitch-up attitude above 20 degrees;

— longitudinal acceleration above 3,7 km/h (2 kt) per second;

— vertical speed above 3 000 ft/min; and

— climb gradient above 22 %.

Note: Exceptions may be made for emergency scenarios.

The proposed mitigation means should:

— provide a robust method to reduce the risk identified (i.e. maintain the above parameters within a reasonable range of values); and

— be used during standard go-around procedure.

A reduced go-around thrust or power function is considered as an acceptable mitigation means (refer to Chapter 4 below).

3. Go-around scenarios to be evaluated

It is recommended to perform in flight a go-around manoeuvre with all-engines-operating (AEO) as per the standard procedure:

— with the most unfavourable and practicable combination of centre of gravity position and weight approved for landing,

— with any practicable combination of Flight Guidance/Autothrust-throttle/Autopilot to be approved, including manual,
— with a level-off altitude 1 000 ft above the go-around initiation altitude,

in order to assess the following:

- pitch controllability (see also CS 25.145(f) and related AMC);
- speed control capability;
- flight crew workload (task management in a changing environment); and
- the risk of somatogravic illusion.

4. Implementation of a reduced go-around (RGA) thrust or power function

A RGA thrust or power function may be provided such that, when a go-around is initiated with any practicable combination of Flight Guidance/Autothrust-throttle/Autopilot modes, including manual, the engine thrust or power applied is limited to maintain the performance of the aeroplane (in particular its rate of climb) at a level which is compatible with the flight crew workload during this phase, and in order to reduce the risk of somatogravic illusion for the flight crew.

This thrust or power reduction function may be available either through aircraft systems automatism or manually.

In any case, an acceptable procedure should be available in the Aeroplane Flight Manual (AFM).

4.1 Design target

RGA functions implemented by some manufacturers with a design target of 2 000 ft/min rate of climb capability have been accepted by EASA.

4.2 Cockpit indications

The following information should be indicated to the flight crew:
— the active thrust or power mode (RGA or full thrust or power); and
— in RGA mode, the level of thrust or power targeted by the system.

Thrust level tables should be provided in the AFM for manual go-around.

4.3 Evaluation

An evaluation of the go-around manoeuvre with the RGA thrust or power function should be conducted following the recommendations of Chapter 3 above.

4.4 Thrust or power mode command

It should be possible for the flight crew, at any time and without delay, to select and apply the full go-around thrust or power.

The applicant should include specific procedures for which full thrust or power may be required, such as windshear alert procedures, TCAS alert procedures, etc.

4.5 Engine failure during go-around with RGA thrust or power

When an engine failure occurs during a go-around performed with active RGA thrust or power and if the required thrust or power from the remaining engine(s), to achieve adequate performance level, cannot be applied automatically, a warning alert to the flight crew is required to trigger the thrust or power recovery action.

The procedure for recovery of the engine thrust or power setting must be demonstrated as acceptable in terms of pilot detection and required action in high workload environment.

The following items should be evaluated:

— assess the timeliness of minimum performance achievement;
— flight crew awareness (indication, alerting…);
— flight crew actions (command); and
— flight crew workload in general.

4.6 Performance published in the AFM for RGA thrust or power

It is reminded that approach climb (one-engine-inoperative) performance and landing climb (all-engines-operating) performance tables published in the AFM shall take into account the actual behaviour of thrust or power management in go-around.

Amend CS 25.145 as follows:

CS 25.145 Longitudinal control

(See AMC 25.145)

(a) (See AMC 25.145(a)) It must be possible at any point between the trim speed prescribed in CS 25.103(b)(6) and stall identification (as defined in CS 25.201(d)), to pitch the nose downward so that the acceleration to this selected trim speed is prompt with –

(1) The aeroplane trimmed at the trim speed prescribed in CS 25.103(b)(6);

(2) The most critical landing gear ~~extended~~ configuration;

(3) The wing-flaps (i) retracted and (ii) extended; and

(4) Engines thrust or ~~P~~power (i) off and (ii) at go-around setting. ~~maximum continuous power on the engines.~~

(…)

(f) It must be possible to maintain adequate longitudinal and speed control under the following conditions without exceptional piloting skill, alertness, or strength, and without danger of exceeding the aeroplane limit-load factor and while maintaining adequate stall margin throughout manoeuvre:

(1) Starting with the aeroplane in each approved approach and landing configuration, trimmed longitudinally, and with thrust or power setting per CS 25.161(c)(2), perform a go-around, transition to the next flight phase and make a smooth level-off at the desired altitude:

(i) with all engines operating and the thrust or power controls moved to the go-around power or thrust setting;

(ii) with the configuration changes, as per the approved operating procedures or conventional operating practices; and

(iii) with any practicable combination of Flight Guidance/Autothrust-throttle/Autopilot to be approved, including manual.

(2) Reasonably expected variations in service from the established approach, landing, and go-around procedures for the operation of the aeroplane (such as under or over-pitch angle target during the go-around and adverse trim positions) may not result in unsafe flight characteristics.

Amend AMC 25.145(a) as follows:

AMC 25.145(a)
Longitudinal Control – Control Near The Stall

1. CS 25.145(a) requires that there be adequate longitudinal control to promptly pitch the aeroplane nose down from at or near the stall to return to the original trim speed. The intent is to ensure sufficient pitch control for a prompt recovery if the aeroplane is inadvertently slowed to the point of the stall. Although this requirement must be met with engines thrust or power off and at go-around setting ~~maximum continuous power~~, there is no intention to require stall demonstrations at engine thrusts or powers above that specified in CS 25.201(a)(2). Instead of performing a full stall at ~~maximum continuous power~~ go-around thrust or power setting, compliance may be assessed by demonstrating sufficient static longitudinal stability and nose down control margin when the deceleration is ended at least one second past stall warning during a 0.5 m/s^2 (one knot per second) deceleration. The static longitudinal stability during the manoeuvre and the nose down control power remaining at the end of the manoeuvre must be sufficient to assure compliance with the requirement.

2. The aeroplane should be trimmed at the speed for each configuration as prescribed in CS 25.103(b)(6). The aeroplane should then be decelerated at 0.5 m/s^2 (1 knot per second) with wings level. For tests at idle thrust or power, it should be demonstrated that the nose can be pitched down from any speed between the trim speed and the stall. Typically, the most critical point is at the stall when in stall buffet. The rate of speed increase during the recovery should be adequate to promptly return to the trim point. Data from the stall characteristics test can be used to evaluate this capability at the stall. For tests at ~~maximum continuous power~~ go-around thrust or power setting, the manoeuvre does not need ~~not~~ to be continued for more than one second beyond the onset of stall warning. However, the static longitudinal stability characteristics during the manoeuvre and the nose down control power remaining at the end of the manoeuvre must be sufficient to assure that a prompt recovery to the trim speed could be attained if the aeroplane is slowed to the point of stall.

3. For aeroplanes with an automatic pitch trim function (either in manual control or automatic mode), the nose-up pitch trim travel should be limited before or at stall warning activation to prevent excessive nose-up pitch trim position such that it is possible to command a prompt pitch-down of the aeroplane for control recovery.

   The applicant may account for certain flight phases where this limit is not appropriate and provide rationale supporting theses exceptions to EASA for consideration.

   The applicant should demonstrate this feature by flight test or with a validated simulator.

   Normal and degraded flight control laws resulting from failure cases should be considered for this evaluation in conjunction with CS 25.1309 and CS 25.671.

Create a new AMC 25.145(f) as follows:

AMC25.145(f)
Longitudinal control – Go-around

1. CS 25.145(f)(1) requires that there be adequate longitudinal control to promptly pitch the aeroplane (nose down and up) and adequate speed control in order to follow or maintain the targeted trajectory during the complete manoeuvre from any approved approach and landing configuration to a go-around transition to the next flight phase and make a smooth level off at the desired altitude.

   The evaluation should be performed throughout the range of thrust-to-weight ratio to be certified, including in particular the highest thrust-to-weight ratio for the all-engines-operating condition (aeroplane at its minimum landing weight, all engines operating and the thrust or power at the go-around setting) and show adequate pitch control (no risk of excessive pitch rate or attitude, maintain adequate stall margin throughout the manoeuvre, no overshoot of the level off altitude) and adequate speed control (no risk of speed instability or exceedance of V_{FE} with the wing-flaps extended and V_{LE} with the landing gear extended).

2. Reasonably expected variations in service from established approach, landing and go-around procedures shall be evaluated and must not result in unsafe flight characteristics.

   This should include go-arounds during certification flight and simulator test programmes with combined effects of thrust or power application and nose-up trim pitching moment. This means, for an aeroplane with low engines (i.e. installed below the aeroplane centre of gravity),:

   a) with the most unfavourable combination of centre of gravity position and weight approved for landing;

   b) all engines operating and the thrust or power controls set to the (max) go-around thrust or power setting; and

   c) longitudinal control trimmed, as follows:

      i) in manual mode with a manual pitch trim, a pitch trim positioned for the approach or landing configuration, and kept at this position during the go-around phase; or

      ii) in autopilot or manual mode with an automatic pitch trim function: the most adverse position that can be sustained by the autopilot or automatic pitch trim function, limited to the available protecting/limiting features or alert (if credit can be taken from it).

Amend AMC 25.201(d) as follows:

AMC 25.201(d)
Stall Demonstration

1. The behaviour of the aeroplane includes the behaviour as affected by the normal functioning of any systems with which the aeroplane is equipped, including devices intended to alter the stalling characteristics of the aeroplane.

2. Unless the design of the automatic flight control system of the aeroplane protects against such an event, the stalling characteristics and adequacy of stall warning, when the aeroplane is stalled under the control of the automatic flight control system, should be investigated. (See also CS 25.1329(~~f~~ g).)

Amend Appendix Q as follows:

Appendix Q

Additional airworthiness requirements for approval of a Steep Approach Landing (SAL) capability

(See AMC to Appendix Q)

(…)

(SAL) 25.5 Safe operational and flight characteristics

(…)

(e) All-engines-operating steep approach.

It must be demonstrated that the aeroplane can safely transition from the all-engines-operating steep landing approach to:

(1) the all-engines-operating approach climb configuration; and

(2) the one-engine-inoperative approach climb configuration with one engine having been made inoperative,

for the following conditions:

(~~1~~i) The selected steep approach angle;

(~~2~~ii) An approach speed of $V_{REF(SAL)}$;

(~~3~~iii) The most critical weight and centre of gravity; and

(~~4~~iv) For propeller-powered aeroplanes, the propeller of the inoperative engine shall be at the position it automatically assumes following an engine failure at high power.

4. Impact assessment (IA)

4.1. What is the issue

A number of accidents or serious incidents with commercial air transport large aeroplanes occurred either during/at the end of a go-around phase, or with the aeroplane close to the ground (but not in go-around mode) and with the pilots attempting to climb. A loss of the normal go-around flight path or loss of control of the aircraft has been observed in relation to inadequate flight crew awareness of the aeroplane's state, or inadequate management by the flight crew of the relationship between pitch attitude and thrust. Unusual pitch-up trim position has also been a factor in some occurrences in other flight phases.

The focus of this NPA is on two main issues:

1. Go-around management issue

Difficulties encountered by flight crews to manage the go-around manoeuvre mainly due to the high level of aeroplane performance and to the limited available pitch authority.

2. Unusual pitch-up trim position in other flight phases

In some occurrences, unusually high pitch-up trim position observed during other flight phases at low speed (typically at or close to the stall speed) contributed to a loss of control or non-recovery after a stall.

The BEA study (ASAGA)

The above-mentioned occurrences led the French Bureau d'Enquêtes et d'Analyses pour la sécurité de l'aviation civile (BEA) to conduct the ASAGA[5] study in order to analyse this category of events (the so-called ASAGA-type events) and to identify the causal factors which contributed to such events and to suggest potential action to prevent them from reoccurring.

The first phase of the BEA work was to conduct a statistical study, primarily of the data provided by the BEA and the International Civil Aviation Organization (ICAO). During the second phase of the study, significant events were selected and analysed. Subsequently, a survey was addressed to airline pilots, and Boeing 777 and Airbus A330 simulator sessions were performed.

A number of factors contributed to the ASAGA-type accidents and serious incidents, as well as to the difficulties experienced by flight crews performing go-arounds or climbs close to the ground, in real operation or in the simulator. Among these factors, two key items linked to the design or ergonomics of the aeroplanes contribute significantly to the loss of the normal go-around flight path:

— somatogravic illusions related to excessive thrust; and

— non-detection of the position of nose-up trim by the flight crew.

This led the BEA to address the following safety recommendations to EASA in the domain of ergonomics and certification.

Limitations on available thrust

[5] Study on Aeroplane State Awareness during Go-Around (ASAGA), published in August 2013. The report is available on the Bureau d'Enquêtes et d'Analyses pour la sécurité de l'aviation civile (BEA) website at https://www.bea.aero/en/safety-studies/access-to-studies/aeroplane-state-awareness-during-go-around/.

When full thrust is applied during a go-around, an excessive climb speed can be reached very quickly, thus making it difficult for flight crews to perform the actions related to the go-around procedure. Firstly, it can be incompatible with the time required to perform the go-around and, secondly, it can be a source of the somatogravic illusions that have led flight crews to make inappropriate nose-down inputs. Certain manufacturers have already implemented a system limiting the thrust. The main objective is to give flight crews sufficient time to limit excessive sensory illusions and excessive pitch attitudes.

Consequently, the BEA recommends that:

— EASA, in coordination with major non-European aviation authorities, amends the CS-25 provisions so that aircraft manufacturers add devices to limit thrust during a go-around and to adapt it to the flight conditions. [Recommendation FRAN-2013-025]

— EASA examines, according to type certificate, the possibility of retroactively extending this measure in the context of PART 26 / CS-26, to the most high performance aircraft that have already been certified. [Recommendation FRAN-2013-026]

Go-around and position of pitch trim

A go-around performed at low speed with an unusual nose-up trim position can lead to a stall and loss of control. Before the go-around, the speed drops and the aircraft systems compensate for this loss of speed by pitching up the stabiliser more and more.

Consequently, aircraft manufacturers should develop means to prevent this type of excessive trim from occurring and/or to prevent the aircraft stabiliser from being kept in an unusual attitude during a go-around. Flight crews pay less and less attention to the position of the trim during flight. They should thus be informed as early as possible of an excessive drop in speed so that they avoid applying full thrust with an unusual position of the pitch-up trim.

In the event of an excessive nose-up pitch position that is uncontrolled, few pilots know the upset recovery procedure which consists of reducing the thrust and/or modifying the trim position.

Consequently, the BEA recommends that:

— EASA, in cooperation with the major non-European certification authorities, make mandatory the implementation of means to make crews aware of a low speed value and, where necessary, prevent an unusual nose-up trim position from occurring or being maintained. [Recommendation FRAN-2013-042]

Somatogravic illusion during go-around

The Rulemaking Group (RMG) of RMT.0647 decided to investigate the available scientific knowledge on spatial disorientation of flight crews, in particular the case of somatogravic illusion. The goal was to understand what are the parameters that can trigger or influence spatial disorientation during go-around, in order to determine how to mitigate the risk at design level.

General description of the somatogravic illusion

It is the result of a misinterpretation of a very noticeable sensation related to linear acceleration. This illusion typically occurs on a go-around when the aeroplane transitions from a slowing down to a rapid acceleration and pitch-up. The vestibular system cannot distinguish between an inertial acceleration and a component of gravity, and the rapid acceleration can be misinterpreted as a further pitching-up moment. Instrument meteorological conditions (IMC) and/or darkness contribute by removing valid visual inputs. In these conditions, a pilot may perceive the linear acceleration during the go-around as (over-)pitching of the aeroplane and may start to push the nose downward to compensate. This can result in an actual nose-down attitude and descent toward the ground.

Human models

In the area of vestibular research, studies have been performed to model the somatogravic illusion. In particular the work from Jenks Vestibular Physiology Laboratory, Massachusetts Eye and Ear Infirmary (D.M. Merfeld) is noticeable as they provided, already since early 2000, human models which have then be used in following projects to simulate vestibular illusions, including the somatogravic illusion. The models mimic human responses to a number of different paradigms, ranging from simple paradigms, like roll tilt, to complex paradigms, like post-rotational tilt and centrifugation.

The RMG liaised with TNO, as well as the BEA (who developed simulation tools based on the Merfeld's model).

TNO simulation tool

The Netherlands Organisation for Applied Scientific Research (TNO) has more than 20 years of experience in research and training with respect to spatial disorientation. For this, TNO employs the DESDEMONA simulator (acronym for <u>DES</u>orientation <u>DEMON</u>str<u>A</u>tor), a flight simulator with a special moving base, including a centrifuge, which enables the reproduction of spatial disorientation illusions. This simulator can be used for both research and training of complex situations, which typically lead to controlled flight into terrain (CFIT), or loss of control in flight (LOC-I). TNO had a leading role in the FP-7 project SUPRA (simulation of upset recovery in aviation).

TNO developed, in cooperation with Boeing, a spatial disorientation identification tool, SDiT (see paper of Mumaw et al)[6]. The model consists of transfer functions of vestibular and visual system. The inputs are the aeroplane's 3 degrees of freedom of rotation velocities, and 3 degrees of freedom gravito-inertial accelerations (e.g. from the flight data recorder (FDR) recording). The outputs are the perceived 3 accelerations, perceived 3 orientation angles (pitch, roll and yaw), and perceived angular velocities. It can flag vestibular illusions: somatogyral illusions, somatogravic illusions. The tool was validated in several flight tests with non-biased subjects that were given reduced visual references. In addition, full motion including sustainable G-loading (6-deg of freedom) simulator experiments were performed in DESDEMONA to compare the model's prediction with the responses of volunteers (for example, Nooij and Groen, 2011)[7]. These studies confirmed the model prediction, and also showed that there are variabilities between individuals.

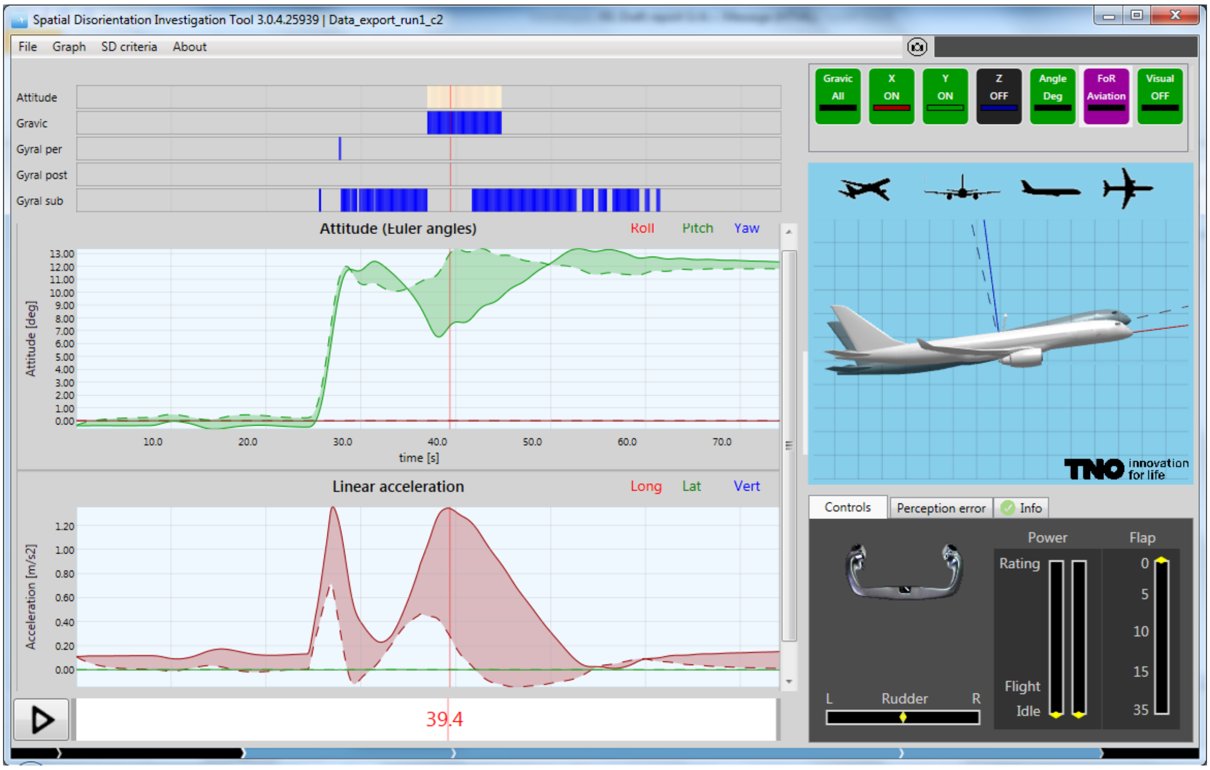
An ATPL pilot and member of the RMG participated in an experimental analysis of G/A scenarios with the support of SDiT, in <u>a fixed-base flight simulator</u>. Two Boeing 737 flight profiles were simulated and then analysed with the SDiT. In both cases the G/A was performed with autopilot engaged.

— The first profile represented a G/A with limited performance: the mass/thrust ratio was set at a fairly high level, taking a gross weight <u>(GW) of 66t</u> and applying <u>reduced G/A thrust</u>. A few seconds after the rotation, the autopilot progressively reduces the pitch angle to allow airspeed increase. Initially, the

[6] Mumaw, R.J., Groen, E.L., Fucke, L., Houben, M., Bos, J.E. (2016) A new tool for analyzing the potential influence of vestibular illusions. ISASI Forum, Journal of the International Society of Air Safety Investigators 49, 6-12.

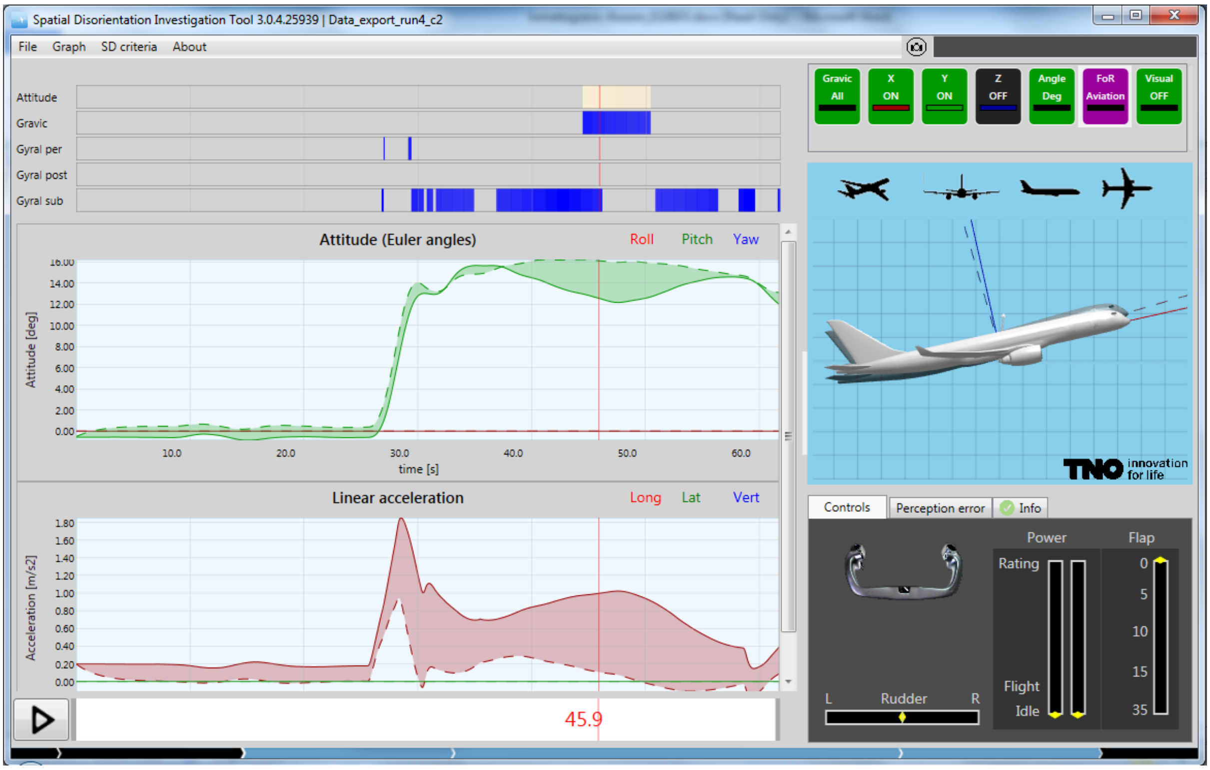
[7] Nooij, S.A.E..& Groen, E.L. Rolling into spatial disorientation: simulator demonstration of the post-roll (Gillingham) illusion. Aviat. Space Environ. Med. 82, 505-512 (2011).

perceived pitch and real pitch angles are consistent while the longitudinal (or 'linear') acceleration decreases. But when the longitudinal acceleration increases again, then the perceived pitch angle increases although the real pitch angle continues to decrease. This shows a potential risk of spatial disorientation. See the figure below:



<u>Legend</u>: Full lines represent the actual values; dashed lines represent the perceived values.

— The second profile represented a G/A with <u>higher performance</u>: the mass/thrust ratio was set at a low level, taking a <u>GW of 55t</u> and applying <u>full G/A thrust</u>. In this case, after the rotation there is no pitch reduction applied by the autopilot (because of the highest performance). However, after some time, the perceived pitch angle increases while the real pitch angle starts to decrease. A potential risk of somatogravic illusion is thus evidenced also in this case. Furthermore, this situation is maintained over a longer time period (more than 25 seconds) than in the reduced G/A thrust case above (approx. 15 seconds). See the figure below:



<u>Legend</u>: Full lines represent the actual values; dashed lines represent the perceived values.

<u>Keeping in mind the limitations of this experiment</u> (flight data from a fixed simulator processed through a tool simulating the somatogravic illusion), the analysis of the two cases concluded that:

— a situation where the perceived pitch angle diverges and becomes higher than the real pitch angle appears in both cases;

— the maximum reached delta (perceived pitch – real pitch) is similar in both cases;

— however, in the case of the full G/A thrust:

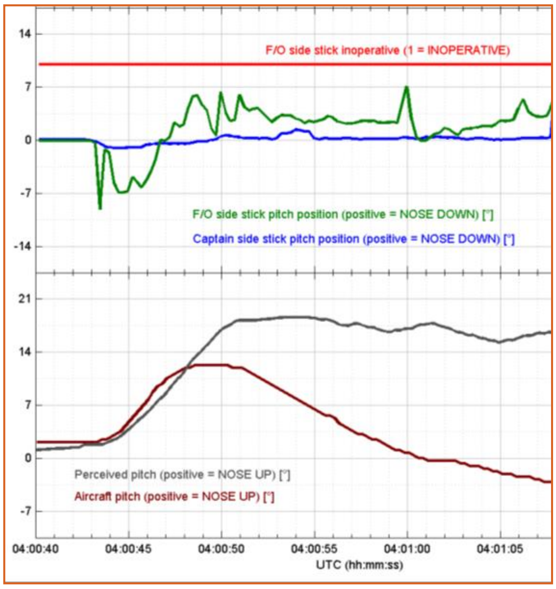
- the linear acceleration is higher;
- the situation of mismatch between perceived and real pitch is maintained over a longer time period.

BEA simulation tool

The BEA based their model on the Merfeld's model, and used it during investigation of accidents or incidents, together with FDR/CVR recordings, to evaluate perceptual illusions and spatial disorientations (in particular, for events where reduced or no visibility is involved or where the pilots do not monitor the PFD).

The input and output parameters are equivalent to the TNO model.

The capacity of the tool was illustrated taking the case of the A330 Tripoli accident. The BEA simulation clearly shows a divergence between the perceived pitch angle and the actual pitch angle during the go-around phase, as shown on the graph below:



Overall conclusion

The somatogravic illusion is created by a combination of linear acceleration, gravitational acceleration, and rotation rate. Human body sensors can convert a high linear acceleration and rotation rate into an apparent pitch angle that is significantly higher than the actual one. The duration of the acceleration is a key factor. Experimental analysis show that reducing the G/A thrust does not necessarily prevent the somatogravic illusion. However, reducing the thrust reduces the linear acceleration and the maximum perceived pitch which should mitigate the onset of the somatogravic illusion. There is also a variability of pilots sensitivity which is a function of different factors like physiology, workload and fatigue.

Additional studies may be performed to further investigate and compare the somatogravic illusion effects perceived during real flight vs. what is perceived on a full flight simulator (FFS). Depending on the type of aeroplane and the FFS used, there may be different results. For a given type of aeroplane, there may be differences between a FFS flight and a real flight, therefore. the risk of negative training should be considered.

Analysis of occurrences relevant to RMT.0647

A selection of occurrences relevant to the terms of reference (ToR) RMT.0647 was performed by the RMG. An analysis was performed by the RMG and its outcome is summarised below.

The occurrences are listed in Appendix 1 to this NPA. A short narrative is included.

As required in the ToR, two categories of occurrences were gathered and analysed:

— Category 1: occurrences during or after a go-around where a loss of the normal go-around flight path, or loss of control of the aircraft, without being caused by a technical failure on the aircraft or other abnormal external factors (collision, storm, etc.). The RMG considered as candidate the events identified by the BEA in their ASAGA study report, plus other relevant events found.

— Category 2: occurrences where an unusual pitch-up trim position, combined with high-thrust application, occurred in other flight phases, such as during a transition from descent to climb, or in cruise after an abnormal event leading to stall or close-to-stall speed situation requiring a recovery action by the pilots.

<u>Category 1 occurrences analysis</u>:
25 go-around related occurrences were identified. Refer to Appendix 1 for the list and narrative of occurrences.

Out of the 25 occurrences (12 accidents and 13 incidents):

— *<u>Contributing factors</u>*:
  - High thrust application is involved in 16 occurrences (8 accidents and 8 incidents or serious incidents),
  - Spatial disorientation in the form of somatogravic illusion is identified as probable factor in 9 occurrences (7 accidents and 2 serious incidents),
  - A pitch trim position at, or close to, the full nose-up position is involved in 7 occurrences (3 accidents and 4 incidents or serious incidents).

— *<u>Potential mitigating factors:</u>*
  - 11 occurrences (5 accidents and 6 incidents or serious incidents) could possibly have been mitigated to a certain extent by a reduced G/A thrust function,
  - 6 occurrences (2 accidents and 4 incidents or serious incidents) could possibly have been mitigated by a means to limit or correct the pitch trim travel at low speed,
  - 3 occurrences (1 accident and 2 serious incidents) would have been mitigated by compliance of the aeroplane design with the current CS 25.1329(h) specifications on low airspeed protection,
  - 2 occurrences (1 accident, 1 incident) would have been mitigated by compliance of the aeroplane design with the current CS 25.1329(l) specifications related to the autopilot behaviour.

There are, nevertheless, 10 occurrences for which the group did not identify design mitigation means. These are cases where the human factors contribution was too high. Such occurrences can, nevertheless, be mitigated by other means, like upgrade of pilots training on the conduct of G/A (with full thrust/light weight, as well as with reduced thrust when the function is available), CRM training and implementation, fatigue management, improvement of G/A published procedures, etc.

The RMG also noted that in 4 occurrences (2 accidents and 2 incidents) on Boeing aeroplanes, a reduced go-around function was available and used during these events; somatogravic illusion is a probable factor of the 2 accidents (Kazan and Osh), and it is also a suspected factor for the two incidents. This shows that limiting the thrust does not necessarily allow to prevent a go-around related occurrence.

In term of aeroplane types, mainly Airbus and Boeing types are represented in these occurrences:
— 12 Airbus (6 A300/A310, 4 A319/A320, 2 A330);
— 10 Boeing (2 B737-300, 3 B737-500, 1 B737-800, 2 B757-200, 2 B777);
— 1 Mc Donnell Douglas DC-8-63;
— 1 Swearingen SA226 TC Metro II (small aeroplane)
— 1 Bombardier DHC-8-103.

Category 2 occurrences analysis:
4 occurrences were identified. Refer to Appendix 1 for the list and narrative of occurrences.

These 4 fatal accidents could have benefited from a means to limit or correct the pitch trim travel at low speed. However, for 3 of these accidents, due to the other contributing factors of these events, this would probably have not prevented the accident.

Questionnaire sent to manufacturers of large aeroplanes

In order to seek the view of, and information from, other manufacturers not represented in the RMG, a questionnaire was sent to 12 CS-25 aeroplane manufacturers[8].
The inputs provided by the responses represent an important source of information for several sections of the impact assessment, including the problem definition, the options, and its analysis.

The questionnaire included:
— General questions on the difficulties faced by pilots during G/A, features available on their design to reduce and adapt the thrust during G/A, to limit the pitch trim position during G/A or other flight phases at low speed;
— Detailed questions on G/A thrust reduction systems in the fields of: status of implementation on the different types owned, cost impacts, issues encountered during the development, function benefits, and availability.
— Detailed questions on automatic pitch trim control systems in the fields of: status of implementation on the different types owned, presence of a travel limitation function at low speed, function availability, and presence of an alerting function.

10 manufacturers out of 12 replied (83 %).

A summary of the responses received is provided in Appendix 2 to this NPA.

These responses show that the difficulties encountered by the flight crews during G/A are more important on twin-turbofan airliners with engines mounted under the wings. The risk of somatogravic illusion is higher there. They also provide the opinion that better training of pilots to conduct a G/A is paramount, as well as the training to recognise and mitigate a somatogravic illusion.
Three of the respondent manufacturers (Airbus, Boeing and Fokker) have developed a reduced G/A thrust function, implemented on some of their aeroplanes, to mitigate the issues faced during G/A which are not limited to the somatogravic illusion, but also include the very limited time to perform all the actions required during G/A and the non-compatibility with the published G/A procedures (e.g. level-off altitude).

[8] Airbus, Boeing, Bombardier, Dassault, Gulfstream, ATR, Textron Aviation, Fokker, Sukhoi, Saab, Embraer, Learjet

4.1.1. Safety risk assessment

The application of excessive engine thrust/power during G/A, possibly combined with a pitch-up trim configuration, can lead to a loss of the normal G/A flight path or stall of the aeroplane if the pilots do not react on time to reduce the thrust and adjust the position of the trim.

Furthermore, the application of high thrust, possibly combined with a low aeroplane weight (e.g. at the end of a flight), can lead to a very high level of performance which is not adapted to the go-around phase: this leaves the pilots very limited time to cope with the actions required during this phase and thereby creates a high peak of workload. It is also often not compatible with the go-around procedure, in particular the level-off altitude. This increasing stress put on the pilots, combined with the dynamic of the flight phase, the eventual absence of visual references and surprise effects (e.g. orders from the ATC) are factors increasing the risk of somatogravic illusion.

As this kind of manoeuvre typically occurs close to the ground, there is a high risk of catastrophic consequences from the impact with the ground surface or constructions. The risk is higher for two-engined aeroplanes with wing-mounted engines, as demonstrated by the review of accidents and incidents. This is because two-engined aeroplanes have a higher amount of thrust/power in AEO configuration in order to comply with the performance certification specifications applicable to the OEI configuration. Wing-mounted engines also generate a higher pitch-up moment when thrust is applied.

Furthermore, the risk of reaching a loss-of-control situation because of unusual pitch-up trim position combined with high-thrust application also exists in other flight phases like during a transition from descent to climb, or in cruise after an abnormal event leading to stall or close-to-stall speed situation requiring a recovery action by the pilots.

4.1.2. Who is affected

Large aeroplane manufacturers, operators, and pilots of large aeroplanes are affected by this issue.

4.1.3. How could the issue/problem evolve

<u>Go-around management issue</u>

Almost all the reported occurrences involved Airbus and Boeing types of aeroplanes. Out of the three occurrences involving other types and reviewed by the RMG, only one of them could have potentially been mitigated by a design improvement (i.e. a thrust reduction system).

Both Airbus and Boeing have already developed a reduced G/A thrust function which adapts the thrust in order to reach and follow some G/A performance parameters. This is considered as a proactive action which provides safety improvement by making the G/A more manageable: this helps the pilots for the management of the thrust and pitch attitude relationship, and this provides more time to conduct all the required actions of the G/A procedure.

In the case of Boeing, 'reduced go-around thrust functions' are installed on all current production aircraft and installed on some of the older models. Here is an overall status of the Boeing fleet:

- Boeing 737: 737-300 through 737-900 are equipped with the function, as well as the new 737 MAX. The last couple of hundred 737-200's are equipped, but the remainder of 737-100 and 737-200 are not.
- Boeing 757, 767, 777, 787 are equipped.

— Boeing 747: 747-400 is equipped. 747-100 through 747-300 models are not all equipped (i.e. mixed fleet situation: some aeroplanes are equipped with a reduced go-around thrust function and the others are not equipped).

— Boeing 707, 727, DC-8, DC-9, DC-10, MD-80, MD-11 are not equipped.

Boeing, in cooperation with the European Commercial Aviation Safety Team (ECAST), also communicated on how to perform safe G/A manoeuvres, highlighting the difficulties which may be faced and how to handle them[9].

Concerning Airbus, modifications have been developed in the last years, starting with an implementation on the most recent types (A380 and A350 aircraft are all equipped now). It is now being implemented on the A320 family NEO and the A330 (CEO, and in the future NEO). Nevertheless, operators of these A320 family and A330 aeroplanes can choose to activate the option or not, for example, based on fleet mixability strategy. Only the A300/A310, the A320 family CEO, and the A340 types will not receive this function because of considerations including technical feasibility at a reasonable cost, fleet size and usage, out-of-production status, and criticality of the climb capability. To mitigate the risk on these aeroplanes, Airbus performed several activities:

— Advertisement of the 'TOGA then reduction to CLB' procedure to A320 family customers,

— Safety recommendations/reminder of good practices widely communicated within airline operators[10]. As part of it, a specific briefing for the G/A technique to be applied is recommended prior to each approach.

Therefore, various aeroplanes in the most-at-risk category (aeroplanes with two wing-mounted engines) are, or will soon be, equipped with a reduced G/A thrust function which should provide a safety improvement in the next years.

This safety benefit is, nevertheless, difficult to quantify and it should be kept in mind that accidents/incidents occurred when the function was used (on Boeing aeroplanes). Therefore, other action must be taken to mitigate the risk of loss of the normal go-around flight path or loss of control of the aircraft during G/A.

Another manufacturer, Fokker, has also developed a function which mitigates the risk of the G/A manoeuvre. The function, implemented on Fokker 70/100 aeroplanes (tail mounted twin turbofan), allows to maintain a safe pitch attitude and can reduce the thrust in order to limit the rate of climb to a reasonable value while following a target airspeed.

EASA evaluated the proportion of large aeroplanes (operated by EASA Member States operators in commercial air transport) that are equipped with a system reducing the G/A thrust.

The goal is to provide orders of magnitude on the level of equipment today and in the future, assuming that the number of manufacturers and types of aeroplanes remain as they are today. This provides a view on the

[9] Boeing AERO magazine 03Q2014, see article entitles 'Performing Safe Go-Around Maneuvers':
http://www.boeing.com/commercial/aeromagazine/articles/2014_q3/pdf/AERO_2014q3.pdf

[10] Airbus Flight Operations Briefing Notes – Approach Techniques - Aircraft Energy Management during Approach:
http://skybrary.aero/bookshelf/books/166.pdf
Airbus Flight Operations Briefing Notes – Descent management - Being Prepared for Go-Around:
http://skybrary.aero/bookshelf/books/2272.pdf
Airbus Safety First Magazine #23, January 2017, page 14 ('Introduction to the Soft Go-Around'):
http://www.airbus.com/company/aircraft-manufacture/quality-and-safety-first/library/

evolution of the fleet, if no action is taken, to change the current situation (either from rulemaking or from industry self-initiative).

Appendix 3 provides the details on how this evaluation has been performed, including the assumptions made.

The evaluation concludes that:

— for the current fleet of in-service aeroplanes: 24.8 % of the aeroplanes are equipped,

— for the future aeroplanes to be manufactured and put into service within the next 2 years: 48.3 % of the aeroplanes will be equipped, and

— for the future fleet of aeroplanes: the proportion aeroplanes equipped will gradually increase from 24.8 % to reach 48.3 % in 2041.

EASA has taken action to reinforce the G/A training requirements for pilots. SIB No 2014-09 'Aeroplane Go-around Training' was published in 2014[11]. Rulemaking task RMT.0581 on 'Loss of Control Prevention and Recovery Training' is active and aims at ensuring a better initial and recurrent training on the conduct of a G/A procedure[12]; the different possible configurations should be addressed from the one-engine-operative to the all-engine-operative/full thrust configurations, and also the training to use the reduced G/A thrust function when available. The somatogravic illusion will also be trained so that pilots are better able to recognise and react to it. These activities are considered paramount to improve the safety level in the future.

EASA is also working on regulatory measures limiting modifications to published missed-approach procedures, which is an additional element of risk for inadequate management of the go-around, as illustrated for instance in the BEA ASAGA study. This is being addressed within the framework of RMT.0464 'Requirements for air traffic services'. The first deliverable, a notice of proposed amendment, NPA 2016-09(B)[13], was published on 14 September 2016 and the consultation period, after being extended, ended on 28 February 2017.

Based on the above, it is concluded that in the absence of a regulatory action dealing with design requirements related to the G/A management, the proactive actions taken by Airbus and Boeing should contribute, together with other important efforts made to improve pilot training and missed-approach procedure management, to an improvement of the overall safety level during G/A for many of the most-at-risk aeroplanes and operations.

However, other new aeroplanes could benefit from design mitigation means allowing to limit the performance of the aeroplane and provide more time to the flight crew to conduct the G//A manoeuvre. These new aeroplanes may also have design and performance characteristics putting them in the category of aeroplanes at a higher risk in terms of G/A management. If no regulatory action is taken, it may be that these new aeroplanes are not equipped with design mitigation means (such as a G/A thrust reduction function) and could, therefore, lead to incidents or accidents.

[11] EASA Safety Information Bulletin 2014-09 dated 08 April 2014, 'Aeroplane Go-Around Training', available at: http://ad.easa.europa.eu/ad/2014-09

[12] ED Decision 2015/012/R of 4 May 2015 amending the Acceptable Means of Compliance and Guidance Material to Part-Definitions and Part-ORO of Regulation (EU) No 965/2012;
NPA 2015-13 Loss of control prevention and recovery training (https://www.easa.europa.eu/document-library/notices-of-proposed-amendment/npa-2015-13), which will be followed in 2017 by an Opinion to the European Commission for an amendment of Commission Regulation (EU) No 1178/2011, and later on by an EASA Decision containing related Acceptable Means of Compliance (AMC) and Guidance Material (GM).

[13] The NPA includes proposals to establish a detailed regulatory framework with regard to the provision of Air Traffic Services within the framework of Commission Implementing Regulation (EU) 2016/1377 on common requirements for ATM/ANS (ATM/ANS Common Requirements Regulation) within the framework of the ATM/ANS Common Requirements Regulation 2016/1377. The NPA contains, inter alia, amendments to the upcoming Executive Director Decision issuing Acceptable Means of Compliance (AMC) and Guidance Material (GM) to the ATM/ANS Common Requirements Regulation. In particular, it contains a proposed AMC addressing missed approach instructions (see AMC21 ATS.TR.210(a)(3) Operation of ATC service - MISSED APPROACHES INSTRUCTIONS). The EASA Opinion resulting from the regulatory process for RMT.0464 is planned to be published during the course of 2017.

In addition to that, the contribution of the high nose-up pitch trim seen in some of the G/A events would not be addressed; additional safety benefit can be gained by better demonstrating adequate longitudinal controllability and authority during G/A.

Unusual pitch-up trim position in other flight phases

The RMG analysed four events (accidents) where the flight crew lost control of the aircraft and did not recover. A pitch trim at, or close to, full nose-up position was present in all these events. Such pitch trim position developed when the airspeed of the aircraft decreased as a result of a technical failure on an aircraft equipment. When the aircraft approaches or reaches the stall speed, this pitch trim configuration, combined with high thrust application, substantially decreases pitch authority when the pilot attempts to recover from the upset or the stall. This, therefore, contributes to maintaining the aircraft in an inappropriate position for the recovery. On some designs, the autopilot can even continue to send pitch-up orders to the autotrim after the stall warning. The pitch trim position must then be decreased, either manually by the flight crew or by the autotrim function if available.

It is, therefore, suitable to have a means to stop or limit the pitch trim travel at low speed when approaching the stall warning. Nevertheless, the analysis of the above mentioned events concluded that the presence of such means would probably not have changed the final outcome because of other more preponderant contributing factors (for instance if the flight crew does not apply an adequate stall recovery procedure).

Actions in the area of flight crew training are initiated which can help mitigating these events. RMT.0581 on 'Loss of Control Prevention and Recovery Training' is on-going; the new training requirements will include:

— recovery from stall events in clean configuration, at low altitude and near the maximum operating altitude;

— recovery from nose-high upsets at various bank angles; and

— manual flight with and without flight directors (no autopilot, no autothrust/autothrottle, and at different control laws, where applicable).

Airbus took action to improve the aircraft design based on the lessons learnt from particular circumstances in the A320 accident in Canet-plage, being:

— the alert to 'manual pitch trim' is now maintained in abnormal attitude law;

— the auto trim function disengagement logic now disengages in normal laws also when the airspeed drops below a threshold (a value above the stall speed).

In the absence of other regulatory action dealing with design requirements, it is expected that the above mentioned actions will provide a safety improvement. The RMG did not identify a design requirement which would have substantially mitigated the four events reviewed. However, an additional safety benefit can be gained by upgrading certification specifications to ensure that the autotrim function, when installed, will stop trimming the aircraft when the airspeed approaches the stall warning speed.

Third countries

In the USA, the FAA published SAFO 15004, 'Scenario-Based Go-Around Training', in 2015[14].

4.2. How it could be achieved — options

In order to achieve the objectives mentioned in Chapter 2.2 the following options have been envisaged:

Option 0 does not propose any changes to the current regulatory framework and relies on other action already launched. Please refer to Chapter 4.1.3.

Option 1 proposes to amend CS-25, applicable to all new large aeroplane designs, in order to:

— Upgrade the assessment of the G/A manoeuvre and its procedure. The goal is to evaluate if a G/A with AEO can be managed without creating excessive workload on the crew and without an excessive risk of somatogravic illusion. When an unacceptable level of risk is identified, the applicant has to implement design solutions to decrease this risk to an acceptable level. Implementing a reduced G/A thrust function is one of the potential solutions which can be used, as it allows to provide more time to the flight crew (on some two-engined aeroplanes it can range from 30 s to 1 min, assuming an average 2 000 ft/min rate of climb is maintained), and it decreases the dynamic of the manoeuvre, thus mitigating the risk of mis-management of the aeroplanes's trajectory (including the effect of somatogravic illusion). As other means may be proposed by industry, this is considered as an acceptable means of compliance (AMC);

— Upgrade the existing specifications and acceptable means of compliance related to longitudinal control and authority during G/A or other flight phases. For G/A, the aim is to demonstrate adequate longitudinal controllability and adequate stall margin during transition from any approved approach and landing configuration to G/A and up to the next flight phase and level-off (AEO and full thrust/power, different combinations of automatisms to be evaluated). For other flight phases, when the aeroplane has an automatic pitch trim function, the stabiliser (or trim tab) travel should be limited before or at stall warning activation to prevent excessive pitch trim such that it is possible to command a prompt pitch down of the aircraft for control recovery.

Option 2 is made of Option 1 plus a Part-26/CS-26[15] regulation to require already certified large aeroplanes most-at-risk (wing-mounted twin turbofan) to implement design changes to mitigate the risk of excessive work load and somatogravic illusion during G/A. Similarly as for the new designs (CS-25), an AMC is the implementation of a reduced G/A thrust function. The scope of applicability is limited to the most-at-risk aeroplanes consistently with the history of reported occurrences.

Option 3 is Option 2 plus a Part-26/CS-26 regulation to require already certified large aeroplanes most-at-risk (wing-mounted twin turbofan) to implement design changes to improve the longitudinal controllability and authority during G/A and other flight phases. Similarly as for the new designs (CS-25), the aim is to demonstrate adequate longitudinal controllability and stall margin during the G/A, and that, for other flight phases, pitch trim surfaces travel is limited before or stall warning to prevent excessive pitch trim such that it

[14] Safety Alert for Operators 15004 dated 3/10/15, 'Scenario-Based Go-Around Training', available under: https://www.faa.gov/other_visit/aviation_industry/airline_operators/airline_safety/safo/all_safos/

[15] Existing designs can be addressed by amending Commission Regulation (EU) 2015/640 of 23 April 2015 on additional airworthiness specifications for a given type of operations and amending Regulation (EU) No 965/2012, including its annex I Part-26, which is applicable to aircraft:
(a) registered in a Member State;
(b) registered in a third country and used by an operator for which a Member State ensures oversight.

is possible to command a prompt pitch down of the aircraft for control recovery. Like Option 2, the scope of applicability is limited to the most-at-risk aeroplanes consistently with the history of reported events.

Table 1: Selected policy options

Option No	*Short title*	**Description**
0		No regulatory change (other than the ones mentioned in 4.1.3).
1		Amend CS-25 : - to upgrade the evaluation of the G/A manoeuvre (focus on workload and risk of somatogravic illusion) and mitigate any excessive risk identified; and - upgrade the demonstration of adequate longitudinal controllability and authority during go-around and other flight phases.
2		Option 1 + amend Part-26/CS-26 to require already certified large aeroplanes most-at-risk (wing-mounted twin turbofan) to implement design changes to mitigate the risk of excessive work load and somatogravic illusion during G/A.
3		Option 2 + amend Part-26/CS-26 to require already certified large aeroplanes most-at-risk (wing-mounted twin turbofan) to implement design changes to improve the longitudinal controllability and authority during go-around and other flight phases.

4.3. What are the impacts

4.3.1. Safety impact

If no regulatory action is taken (**Option 0**) the future level of risk is dependent on the implementation of other regulatory activities launched, and also on the future evolution of aeroplane designs as decided by the manufacturers.

Already launched regulatory activities are focusing on G/A safety in the domains of flight crew training and ATM/ANS rules related to missed approach procedures.

It is believed by the RMG, and also by several other manufacturers not represented in the RMG, that the effort to improve flight crew G/A training (in particular with regard to conducting G/A with all engines operating) is the most important action to improve safety, in the short and long term. This is covered by RMT.0581.

However, the design of the aeroplane can provide further safety improvement by ensuring that the G/A manoeuvre can be handled as smoothly as possible and without excessive performance levels in the longitudinal direction which can exacerbate the risk of somatogravic illusion or create unnecessary high peaks of workload for the flight crew. Airbus and Boeing, manufacturers of the majority of the most-at-risk aeroplanes (as demonstrated by reported accidents and incidents), have already taken action to implement reduced G/A thrust functions which help improving safety even without a new regulatory action on the design domain. However, some manufacturers of aeroplanes which have design chracteristics putting them in the same most-at-risk category have not yet taken action. Therefore, similar G/A accidents or incidents may happen to these aeroplanes in the future if no action is taken even if the risk would be mitigated by other existing activities (e.g. RMT.0581).

Furthermore, as highlighted by accidents and incidents involving G/A or other flight phases, there is also a need to review and upgrade requirements for longitudinal controllability and authority.

Therefore, **Option 0** is not optimal from a safety point of view, and a regulatory action in the design area has to be considered.

Option 1 addresses the points mentioned above for new designs once CS-25 has been amended. This would ensure that all manufacturers develop new designs with elements that could ensure a safer G/A manoeuvre, and also an adequate longitudinal controllability and authority when transitioning from low speed phases of flight (G/A and other fligh phases). Globally, such action could have provided some level of mitigation to 14 out of the 25 G/A-related occurrences reviewed by the RMG, as detailed below:

— 11 events (5 accidents and 6 incidents or serious incidents) could possibly have been mitigated to a certain extent by a reduced G/A thrust function,

— 6 events (2 accidents and 4 incidents or serious incidents) could possibly have been mitigated by a means to limit, or correct, the pitch trim travel at low speed.

Theoretically, an optimal safety improvement would be gained through application of retroactive requirements to improve the design of existing types of aeroplanes. In this respect, **Option 3** could be the best option.

The analysis on the need of a retroactive regulation performed by the RMG, considering the history of events to date, concluded that:

a) Go-around manoeuvre management risk mitigation

As of today, the main design means identified to further mitigate the risk of inadequate management of the G/A manoeuvre on aeroplanes most-at-risk is a reduced G/A thrust system. However, it is also recognised that the presence of this function cannot always prevent G/A events. For example, there are 4 occurrences that happened in spite of the presence and selection of a G/A thrust reduction system: B737-500 N904UA in San Francisco (incident), B737-500 D-AHLN in Bremen (incident), B737-500 VQ-BBN in Kazan (accident), B737-300 EX-37005 in Osh (accident). Somatogravic illusion as contributing factor has been considered as possible in the case of D-AHLN, and probable in the case of VQ-BBN and EX-37005.

Also, the proposal for amending CS-25 (**Option 1**) does not mandate a reduced G/A thrust function; this remains an acceptable means of compliance with a specification requiring to mitigate any excessive risk identified through a specific evaluation.

Furthermore, training to conduct G/A with AEO remains the priority action in the opinion of the RMG as this action is the one providing probably the highest and quickest mitigation and safety benefit for the full fleet of operated large transport aeroplanes. In addition, there are situations where the pilots must apply full thrust and must be able to safely manage the manoeuvre anyway (e.g. presence of windshear, avoidance manoeuvre, obstacle clearance).

The vast majority of the reported and analysed events concern Airbus and Boeing aeroplanes.

Airbus has implemented such a function on the most recent types (standard modification on A380 and A350 aircraft which are all equipped). It is now being implemented on the A320 NEO family (certified on A320 end 2016, and to be certified on the A321 in 2017) and the A330 (CEO and NEO); operators, nevertheless, can chose to select the option or not, for example based on fleet mixability strategy. Only the A300/A310, the A320 family CEO, and the A340 types will not receive this function because of considerations including technical feasibility at a reasonable cost, fleet size and usage, out-of-production status, or criticality of the climb capability.

Looking at accidents involving Airbus aircraft that will not receive a reduced G/A thrust function:

— A300/A310: 2 accidents (in 1994 and 1998) could have been mitigated by such function; however the mitigation factor is estimated to maximum 30 % by the RMG for each event; therefore the accidents may not have been avoided;

— A320 CEO family: 2 accidents (in 2000 and 2006) happened, but only 1 (the Bahrain accident) could have been mitigated by such function. The actual mitigation factor is difficult to estimate given all the other human factor issues involved in this event. A mitigation factor of 50 % may be proposed; therefore there is no certainty that the accident could have been avoided.

Boeing implemented a reduced G/A thrust function on a large portion of their fleet which includes all current production aircraft and others: last couple of hundred 737-200’s; 737-300 through 737-900; 737 MAX; some of the 747-100 to 747-300; 747-400; 757; 767; 777; 787.

All Boeing aeroplanes involved in the 4 accidents reviewed were equipped with the function. However, the function was used in only 2 of the accidents (737-500 in Kazan and 737-300 in Osh) for which somatogravic illusion is considered as a probable factor. In 1 of the other accidents (737-800 in Rostov-on-Don), the function was not used because of presence of windshear was suspected; somatogravic illusion is a probable factor. In the last accident (777 in Dubai), the flight crew pushed the TO/GA switch for an automatic G/A after touchdown; as per design an automatic G/A is not possible after touchdown, the G/A mode was not activated and, therefore, the reduced G/A could not be used.

The three events not concerning Airbus or Boeing aeroplanes involved a DC-8, a SA226 Metro, and a DHC-8. In the opinion of the RMG, the presence of a reduced G/A thrust function could have positively influenced only the SA226 event, although the outcome of the other events would not have been changed because of other involved factors.

Fokker, has also developed a function which mitigates the risk of the G/A manoeuvre. The function, implemented on Fokker 70/100 aeroplanes (tail mounted twin turbofan), allows to maintain a safe pitch attitude and can reduce the thrust in order to limit the rate of climb to a reasonable value while following a target airspeed.

Finally, a review of the registration numbers of the aeroplanes involved in the accidents (list of events identified in this RMT), where a possible mitigation by a reduced G/A thrust function is identified by the RMG, shows that all these (five) aeroplanes were registered in third countries and not under the oversight by a Member State. Therefore, they would not fall under the scope of applicability of Commission Regulation (EU) 2015/640 (Part-26).

For all these reasons, the additional safety benefit which could be brought from a retroactive mandate for a G/A risk mitigation means like the reduced G/A thrust function is considered very limited.

b) Longitudinal controllability and authority

The review of G/A related events indicates that:

— 6 events (2 accidents, 4 incidents) involved a pitch trim at, or close to, full nose-up position. Assuming the implementation of a system able to limit the travel of the pitch trim to a safe value before G/A initiation (keeping enough pitch down authority), 1 accident receives a very low estimated potential mitigation, the other accident a moderate estimated potential mitigation. For the incidents, the potential mitigation weight estimation ranges from low to moderate. In all cases, the pitch trim position is considered as a contributor, but any improvement action taken to avoid this position being selected or maintained would not guaranty that the final outcome of the event would be changed;

— The aeroplane types involved in the above events (6 A300/A310, 1 B737-300) are old ones which will be progressivelly retired from service. Nevertheless, design improvements have been brought to some models when possible.

— Costs and complexity involved in the investigation and modification of the aircraft pitch controllability, its auto trim function, or its alerting system are deemed to be very high and must be balanced by a strong safety case, which is not apparent in the opinion of the RMG.

For events in other flight phases:

— 4 accidents were reviewed where the nose-up pitch trim position contributed to the event because the flight crew did not take action to trim the aircraft;

— The estimated potential mitigation from the implementation of a system able to limit the travel of the pitch trim to a safe value is very low for 3 events, and higher for 1 event. However, this last event (A320 D-AXLA) was a very particular failure case (AoA probes were frozen because of inappropriate maintenance action) after which the aircraft flight control law was not anymore in the normal law configuration (switch to direct law and then abnormal attitude law). The manufacturer (Airbus) has implemented design changes mitigating the risk of such scenario (the PFD alert to manually pitch trim is now maintained in abnormal attitude law. The auto trim function disengagement logic has been improved, it now disengages also when the airspeed drops below a threshold (a value above the stall speed)).

The estimated safety benefit from an improvement of the pitch trim position control in these events is, therefore, very limited. Pilot training improvements to upgrade the pilots' knowledge of the different flight control laws (refer to RMT.0581 on UPRT) are considered more beneficial in terms of safety improvement.

Summary of safety impact:

Option 0 would rely on other activities to improve safety. If this option is selected, it is expected that safety of G/A manoeuvres will improve in the coming years due to the outcome of other regulatory activities (flight crew G/A training, missed approach instructions improvements), and the increase of the number of aeroplanes equipped with a reduced G/A thrust function (mainly driven by the Airbus fleet evolution). This option would not address improvements which can be made in the area of longitudinal controllability and authority.

Option 1 would allow to consolidate in CS-25 the actions already launched by Airbus, Boeing, and Fokker. This would ensure a safety improvement for all new designs from all manufacturers.

Option 2 would add a safety benefit for Airbus and Boeing aircraft that are not yet equipped with a reduced G/A thrust function. This would also require other manufacturers of aeroplanes of similar risk (wing mounted twin turbofan) to implement a mitigation means for G/A, if this has not already been done. However, no event has been reported to date on these aeroplanes. Overall, the additional safety benefit from Option 2, compared to Option 1, is considered low.

Option 3 would bring a very low additional benefit compared to Option 2.

4.3.2. Environmental impact

All options do not have significant environmental impacts.

4.3.3. Social impact

All options do not have significant social impacts.

4.3.4. Economic impact

Cost impacts is assessed mostly qualitatively in this chapter because of 1) the very limited information received by the RMG, and 2) the lack of replies to quantitative questions in the questionnaire sent to manufacturers.

Description of costs impacts falls in the following categories:

Non-recurring costs (NRC) (average cost impact per aeroplane manufacturer/type certificate holder):

— ‘very high’ impact: overall cost impact of 300 million euros or more;

— ‘high’ impact: overall cost impact between 150 and 300 million euros;

— ‘medium’ impact: overall cost impact between 50 and 150 million euros;

— ‘low’ impact: overall cost impact between 15 and 50 million euros;

— ‘very low’ impact: overall cost impact between 5 and 15 million euros;

— ‘negligible’ impact: overall cost impact up to 5 million euros.

Recurring costs (RC) (average cost impact per operator/owner of aeroplanes):

— ‘very high’ impact: overall cost impact of 30 million euros or more;

— ‘high’ impact: overall cost impact between 15 and 30 million euros;

— ‘medium’ impact: overall cost impact between 5 and 15 million euros;

— ‘low’ impact: overall cost impact between 1,5 and 5 million euros;

— ‘very low’ impact: overall cost impact between 0,5 and 1,5 million euros;

— ‘negligible’ impact: overall cost impact up to 0,5 million euros.

Option 0 is the reference option and does not create significant impacts.

Option 1: For new CS-25 aeroplane designs, the following costs are assessed:

— Non-recurring costs (NRC):

- For manufacturers, investigation of the management of the G/A manoeuvre, and eventually the development and certification of mitigation means, which could include a reduced G/A thrust function (acceptable means of compliance). In case such function would have to be developed, the NRC is estimated by the RMG to be several tenths of millions euros (50 million euros can be taken as an order of magnitude), therefore, overall the NRC would be 'medium' (ranging from 'very high' for small manufacturers to 'low' for large manufacturers). However, when included in the development of a new design type, this cost is considered as not substantial and acceptable for a CS-25 large aeroplane manufacturer.
- Upgrade of the development and certification of means to ensure adequate longitudinal controllability and authority during go-around and other flight phases. This may entail some new design specifications (if not already implemented by the manufacturer) to the pitch attitude control system and/or the (automatic) pitch trim system. The cost impact could range from 'low' to 'medium'. When embedded inside the development of a new aeroplane design, this NRC is also negligible for a CS-25 large aeroplane manufacturer.

— Recurring costs (RC):

- The implementation of a risk mitigation means for the G/A manoeuvre, and by the eventual new specifications on the pitch attitude control system and/or the (automatic) pitch trim system, would have potential hardware and software impacts. As these impacts would be integrated within the development of a new CS-25 type, they would have a 'negligible' effect on RC to be supported by operators/owners of aeroplanes. Often, software changes are the main impact.
- Maintenance or operational RC are deemed to be 'zero' or 'negligible'.
- For pilot training, if a reduced G/A thrust function is implemented, there will be a need for a specific theoritical and practical training to use it; the associated cost is considered 'negligible' compared to the overall costs of pilot type rating and recurrent traning programmes which already include various elements for the G/A manoeuvre (re-inforced by new requirements from RMT.0581).

Option 1 would create medium NRC for manufacturers when developing a new design type, but is considered acceptable. For some of them, they have anyway already developed a reduced G/A thrust function on some existing aeroplanes and would mainly have to work on longitudinal controllability and authority aspects. RC for operators/owners of aeroplanes are 'negligible'.

Option 2: This option includes the costs assessed for **Option 1** plus the costs which are applicable to already certified large aeroplanes most-at-risk (wing-mounted twin turbofan) to implement design changes to mitigate the risk of excessive work load and somatogravic illusion during G/A. A reduced G/A thrust function would be one acceptable means of compliance. The aeroplanes impacted are the ones within the scope of Commission Regulation (EU) 2015/640, i.e.:

(a) registered in a Member State;

(b) registered in a third country and used by an operator for which a Member State ensures the oversight.

— Non-recurring costs (NRC):

- Development and certification of mitigation means, which could include a reduced G/A thrust function. In case such function would have to be developed, the NRC is estimated by the RMG to be several tenths of millions euros (50 millions euros can be taken as an order of magnitude). This is considered as a 'medium' NRC for already certified aeroplanes. The technical feasibility of a reduced G/A thrust function may be challenging for the older designs that are out of production but still in service, and the NRC for these types would be higher than for modern types where implementation can be done by software updates as opposed to more complex hardware changes.

Airbus and Boeing already developed a compliant function but for a part of their fleets only, after considering different factors such as: technical feasibility at a reasonable cost, fleet size and usage, out-of-production status, or criticality of the climb capability. If full retrofit is selected, they would have to develop a function on the older types in service and within the scope of applicability of Commission Regulation 2015/640.

— Recurring costs (RC):

- Costs created by the implementation of a risk mitigation means for the G/A manoeuvre, e.g. reduced G/A thrust function. On a modern aeroplane, such mitigation means would probably create 'negligible' or none-hardware RC, but would rather essentially be managed by software for which RC impact is 'null'. Older types would face higher RC from needed hardware changes; nevertheless, such cost should be moderate and would probably fall in the 'low' or 'negligible' category for aeroplane unitary cost impact to be supported by operators/owners.
- No new maintenance or operational costs are anticipated for modern aeroplanes. For older designs, additional maintenance costs could be created, however, such costs would be 'negligible'.
- For pilot training, if a reduced G/A thrust function is implemented, there will be a need for a specific theoritical and practical training to use it. The associated cost is considered very low compared to a global pilot traning programme which already includes various elements for the G/A manoeuvre (re-inforced by new requirements from RMT.0581). Furthermore, the largest part of the fleet (Airbus and Boeing) is equipped anyway, independently of the new CS-25 specifications, and, therefore, training requirements are in place for the corresponding pilots. Overall this RC impact is 'negligible'.

In addition to <u>Option 1</u> costs, **<u>Option 2</u>** would create 'medium' NRC for manufacturers ('very high' for small manufacturers and 'low' to 'medium' for large ones) for their affected already certified aeroplanes. Furthermore the technical complexity of needed changes may be high on older types of aeroplanes, thus eventually economically not acceptable for the oldest and smallest fleets. 'Negligible' RC (or 'low' RC for older types) are expected for operators/owners.

<u>Option 3</u>: This option includes the costs assessed for **<u>Option 2</u>** plus the costs applicable to already certified large aeroplanes most-at-risk (wing-mounted twin turbofan) to implement design changes to improve the longitudinal controllability and authority during go-around and other flight phases. The aeroplanes impacted are the ones within the scope of Commission Regulation (EU) 2015/640, i.e.:

(a) registered in a Member State;

(b) registered in a third country and used by an operator for which a Member State ensures oversight.

— Non-recurring costs (NRC):

- Development and certification of means to investigate and improve the longitudinal controllability and authority during go-around and other flight phases for already certified aeroplanes. This activity may lead to a need to modify the pitch attitude control system and/or the (automatic) pitch trim system. This is considered as 'medium' NRC, potentially significant for the older types that are not produced anymore.

— Recurring costs (RC):

- Costs created by the implementation of the modification(s) to improve the longitudinal controllability and authority. This can imply light to heavy hardware changes, depending on the systems and items that are affected. Software changes would probably also be associated to harware changes. Overall these RC could be 'negligible' to 'low' for aeroplane unitary cost impact to be supported by operators/owners.
- There are potential additional maintenance and operational costs associated to the hardware changes on pitch trim control system and/or (automatic) pitch trim system. However, such costs are deemed to be 'negligible'.
- For pilot training, there could be a need to update the knowledge on the modified system(s) and operational procedure(s) if changed. This is considered as 'negligible' impact.

In addition to the impacts highlighted in Option 2, Option 3 would create further 'medium' NRC for manufacturers (siginificant for older types of aeroplanes). 'Negiligible' to 'low' RC would be created for operators/owners.

Question to stakeholders on impacts:

Stakeholders are invited to provide any other quantitative information they may find necessary to bring to the attention of EASA.

As a result, the relevant parts of the RIA might be adjusted on a case-by-case basis.

4.4. Conclusion

4.4.1. Comparison of options

Option 0 is taken as reference for the comparison of other options, and is therefore considered neutral in the table below.

	Option 0 (Reference option)	Option 1	Option 2	Option 3
Safety impact	0	++	++	++
Environmental	0	0	0	0

impact				
Social impact	0	0	0	0
Economic impact	0	- NRC: 'medium' RC: 'negligible'	- - NRC: 'medium' + high complexity for older types RC: 'negligible' to 'low'	- - - NRC: 'high' + high complexity for older types. RC: 'negligible' to 'low'
Overall safety benefit vs. cost	0	+	0	-

The selection of the best option consists in a comparison between the potential safety benefit against the associated costs for impacted stakeholders.

Option 0 is neutral. Selecting this option would mean to rely on other launched activities to improve safety (pilot training, missed approach instructions).

Option 1 would provide a fair safety benefit by requiring that all new CS-25 aeroplanes have design features which ensure that managing a G/A manoeuvre does not create an unacceptable risk of loss of control of the trajectory or loss of control of the aeroplane, including the risk of somatogravic illusion. Airbus, Boeing and Fokker already developed systems to reduce the thrust during G/A. These systems avoid applying excessive thrust and thereby providing more time to the flight crew to perform required activities, and they reduce the dynamic of the flight phase which decreases the risk of somatogravic illusion. Such design improvement effort would be required from other manufacturers developing aeroplanes that can also present a similar level of risk. In addition, Option 1 would require manufacturers to investigate further the longitudinal controllability and authority in G/A and other flight phases, which would contribute to mitigate the risk of upset attitudes and loss of control, in particular in relation with the effect of the automatic pitch trim. The NRC cost impact of this option is 'medium' for manufacturers that have not yet developed a mitigation means like a reduced G/A thrust function, however, when included in the development of an aeroplane, this is not significant relative to the overall cost of a development. Operators/owners would not face, or only negligible, RC associated to these design improvements.

Option 2 would, in addition to Option 1, mandate manufacturers that have not yet launched activities to make a risk assessment and eventually develop G/A mitigation means, like a reduced G/A thrust function, on already certified aeroplanes most-at-risk. This could address a pending risk for aeroplanes that have not yet faced reported events, and would also extend the effort to older Airbus and Boeing aeroplanes that have not been modified. For recent types the NRC is 'medium', but the RC is 'negligible' to 'low' (design changes most probably managed by software updates). For older types, such design changes can be very complex and generate higher NRC for manufacturers. For some small fleets of out of production aeroplanes this may even not be economically sustainable. RC would be also higher because of required hardware changes. Overall, it is believed that the supplementary safety benefit to be gained with Option 2 would not be high enough to balance the economic burden created for manufacturers and operators/owners.

Option 3 would, in addition to Option 2, mandate an evaluation of already certified aeroplanes most-at-risk to improve the longitudinal controllability and authority during G/A and other flight phases. Considering that

Option 2 is not deemed acceptable, and the very low additional safety benefit, Option 3 can be considered as not acceptable. This conclusion is reinforced by the additional costs created by this option.

Therefore, **Option 1** is the recommended option.

4.5. Monitoring and evaluation

As this NPA proposes changes to CS-25 that will apply to new aeroplane type designs, the monitoring of the effects created by the new specifications and acceptable means of compliance will consist of:

1) feedback from future CS-25 type certification projects, in particular the results of the G/A manoeuvre risk assessments and longitudinal controllability/authority assessments, and

2) in the long term, trend of accidents and incidents during or after G/A (i.e. loss of flight path or loss of control), or in other flight phases at low speed (where longitudinal controllability or authority is a factor).

Item 1 depends on the applications received after amendment of CS-25. A review could not be made earlier than 5 years after CS-25 amendment.

Item 2 would be available once the new type designs have entered into service and experienced sufficient flight time, which would require several years (at least 5 years to get relevant statistical information).

In addition, the changes made to CS-25 might be subject to interim/on-going/ex-post evaluation that will show what is the outcome obtained after application of the new rules, taking account of earlier predictions made in this impact assessment. The evaluation will provide an evidence-based judgement of the extent to which the proposal has been, relevant given the needs and its objectives, effective and efficient, coherent, and has achieved EU added-value. The decision whether an evaluation will be necessary will be taken based also on the monitoring results.

5. Proposed action to support implementation

— Focused communication for advisory body meeting(s) (TeB, STeB)

(Advisory body members)

N/A

— Providing supporting clarifications in electronic communication tools EASA - NAAs (CIRCABC, SINAPSE or equivalent)

(Primarily targeted audience Competent Authority)

N/A

— EASA Circular

(Primarily targeted audience Competent Authority, Industry)

N/A

— Detailed explanation with clarification and indicated hints on the EASA web

(Industry, Competent Authority)

N/A

— Dedicated thematic workshop/session

(Industry, Competent Authority)

N/A

— Series of thematic events organised on the regional principle

(Industry, Competent Authority)

N/A

— Combination of the above selected means

(Industry, Competent Authority)

N/A

6. References

6.1. Affected/Related regulations

— None.

6.2. Affected decisions

— ED Decision 2003/002/RM (CS-25).

6.3. Other reference documents

Study on Aeroplane State Awareness during Go-Around (ASAGA), published in August 2013. The report is available on the Bureau d’Enquêtes et d’Analyses pour la sécurité de l’aviation civile (BEA) website at : https://www.bea.aero/en/safety-studies/access-to-studies/aeroplane-state-awareness-during-go-around/

7. Appendices

Appendix 1: List of occurrences analysed by the RMG

Category 1 occurrences:

A/C Type & registration	Date (DD/MM/YYYY)	Location	Accident or incident	A/C damages	Fatalities	Investigation finding
A310 (turbofan) - D-AOAC (Germany)	11/02/1991	Moscow (Russia)	Incident	None	0	ON REQUEST OF ATC THE PILOT INITIATED GO-AROUND AT 1,400 FT. THE CREW FELT THAT THE A/C PITCH ATTITUDE INCREASED ABNORMALLY AND TRIED TO OVERRIDE THE NOSE-UP TENDENCY BY MOVING THE CONTROL COLUMN FORWARD. THIS CAUSED AUTOPILOT NO.1 TO DISENGAGE. DISENGAGEMENT OF THE AUTOPILOT DISABLED THE AUTOTRIM AND THE STABILIZER REMAINED IN THE FULL NOSE-UP POSITION WHILE THE CONTROL COLUMN WAS MOVED FORWARD. THE A/C PITCHED-UP AND SPEED WAS REDUCED. AT 4,000 FT THE A/C STALLED THEN CLIMBED AND STALLED AGAIN AT 5,700 FT. AT 11,755 FT, AFTER TWO ADDITIONAL STALLS CONTROL WAS REGAINED BY REDUCING THRUST AND MANUAL TRIM. THE A/C LANDED SAFELY USING MANUAL CONTROL. LACK OF CREW CO-ORDINATION AND COCKPIT RESOURCE MANAGEMENT CONTRIBUTED TO THE EVENT.

A/C Type & registration	Date (DD/MM/YYYY)	Location	Accident or incident	A/C damages	Fatalities	Investigation finding
A300-600 (turbofan) - B-1816 (China)	26/04/1994	Nagoya (Japan)	Accident	Destroyed	264	While the aircraft was making an ILS approach to runway 34 of Nagoya Airport, under manual control by the F/O, the F/O inadvertently activated the GO lever, which changed the FD (Flight Director) to GO AROUND mode and caused a thrust increase. This made the aircraft deviate above its normal glide path. The APs were subsequently engaged, with GO AROUND mode still engaged. Under these conditions the F/O continued pushing the control wheel in accordance with the CAP's instructions. As a result of this, the THS (Horizontal Stabilizer) moved to its full nose-up position and caused an abnormal out-of-trim situation. The crew continued approach, unaware of the abnormal situation. The AOA increased the Alpha Floor function was activated and the pitch angle increased. It is considered that, at this time, the CAP (who had now taken the controls), judged that landing would be difficult and opted for go-around. The aircraft began to climb steeply with a high pitch angle attitude. The CAP and the F/O did not carry out an effective recovery operation, and the aircraft stalled and crashed.

A/C Type & registration	**Date (DD/MM/YYYY)**	**Location**	**Accident or incident**	**A/C damages**	**Fatalities**	**Investigation finding**
A310 (turbofan) - YR-LCA (Romania)	24/09/1994	Paris Orly (France)	Incident	None	0	The direct causes of the unusual attitudes and the stall to which the aircraft was subjected were a movement of the THS towards the full pitch-up position and a rapid increase in thrust, both of which maneuvers were the due to the Captain, following an AFS mode reversion which was not understood. The pitch-up force caused a sudden change in attitude that the flight crew was unable to contain with the elevators.

A/C Type & registration	Date (DD/MM/YYYY)	Location	Accident or incident	A/C damages	Fatalities	Investigation finding
A310 (turbofan) - HS-TIA (Thailand)	11/12/1998	Surrathani (Thaïland)	Accident	Destroyed	101	The accident occurred because the aircraft entered into stall condition which might have been caused by the followings: 1. The pilot attempted to approach the airport in lower than minimum visibility with rain. 2. The pilot could not maintain the VOR course as set forth in the approach chart. The aircraft flew left of VOR course on every approach. 3. The pilots suffered from the accumulation of stress and were not aware of the situation until the aircraft emerged into the upset condition. 4. The pilots had not been informed of the document concerning the wide-body airplane upset recovery provided by Airbus Industrie for using in pilot training. 5. The lighting system and approach chart did not facilitate the low visibility approach. 6. Stall warning and pitch trim systems might not fully function as described in the FCOM and AMM.
A310 (turbofan) - A6-EKG (United Arab Emirates)	27/06/2000	Dubai (United Arab Emirates)	Incident	None	0	AT 500 FT AGL ON FINAL APP TO DUBAI A/P, THE TRIMMABLE HORIZONTAL STABILISER (THS) TRIM MOVED TO MAXIMUM DEFLECTION NOSE UP. THE A/C WAS BEING FLOWN MANUALLY BY THE FIRST OFFICER. SHORTLY AFTERWARDS A GO-AROUND WAS MADE DUE TO BEING HIGH AND FAST ON APP. DURING THE GO-AROUND, THE A/C PITCHED UP TO 46 DEG PITCH AND STALLED, DESPITE FULL FORWARD NOSE DOWN ELEVATOR. RECOVERY ACTION WAS MADE BY REDUCING THRUST TO IDLE. THE LOW SPEED PROTECTION SYSTEM OPERATED NORMALLY BUT THE INCREASE IN THRUST RESULTED IN A FURTHER HIGH NOSE ATTITUDE AND STALL FROM WHICH THE CAPTAIN RECOVERED USING SAME RECOVERY ACTION. NO TECHNICAL REASON FOR THE THS

A/C Type & registration	Date (DD/MM/YYYY)	Location	Accident or incident	A/C damages	Fatalities	Investigation finding
						MOVEMENT HAS BEEN FOUND.
A320 (turbofan) - A4O-EK (Oman)	23/08/2000	Bahrain	Accident	Destroyed	143	The individual factors during the approach and final phases of the flight were: -non-adherence to standard operating procedures (SOPs) by the captain; -the first officer not drawing the attention of the captain to the deviations of the aircraft from the standard flight parameters and profile; -the spatial disorientation and information overload experienced by the flight crew; -and, the non-effective response by the flight crew to the ground proximity warnings. The systemic factors that could have led to these individual factors were: a lack of a crew resources management (CRM) training programme; inadequacy in some of the airline's A320 flight crew training programmes; problems in the airline's flight data analysis system and flight safety department which were not functioning satisfactorily; organisational and management issues within the airline; and safety oversight factors by the regulator.

A/C Type & registration	Date (DD/MM/YYYY)	Location	Accident or incident	A/C damages	Fatalities	Investigation finding
A320 (turbofan) - EK-32009 (Armenia)	03/05/2006	Black sea (Russia)	Accident	Destroyed	113	The fatal crash of the "Armavia" A-320 EK-32009 was a CFIT accident that happened due to collision with the water while carrying-out a climbing manoeuvre after an aborted approach to Sochi airport at night with weather conditions below the established minima for runway 06. While performing the climb with the autopilot disengaged, the Captain, being in a psychoemotional stress condition, made nose down control inputs due to the loss of pitch and roll awareness. This started the abnormal situation. Subsequently the Captain's inputs in the pitch channel were insufficient to prevent development of the abnormal situation into the catastrophic one. Along with the inadequate control inputs of the Captain, the contributing factors to development of the abnormal situation into the catastrophic one were also the lack of necessary monitoring of the aircraft descent parameters (pitch attitude, altitude, vertical speed) by the co-pilot and the absence of proper reaction by the crew to the EGPWS warning.
A330-200 (turbofan) - F-GZCC (France)	30/03/2007	Abidjan (Ivory Coast)	Serious incident	None	0	During the final approach, the flight crew faces a significant tail wind. At around 100ft, the tail wind increases beyond 10 kts. The Captain, PF, decided to abort the approach. The G/A altitude is quickly reached, the PF uses the elevator to decrease the pitch and reduces the thrust. The speed increases rapidly and the indication LVR CLB flashes on the FMA. Meanwhile, additional pitch down actions are recorded and the pitch decreases to negative values. The vertical speed reaches -4000ft/min. The PF reacts with a pitch up action, the PNF intervenes too. Sink Rate and Pull Up alarms are triggered by the GPWS. The rest of the flight and landing happen normally.

A/C Type & registration	**Date (DD/MM/YYYY)**	**Location**	**Accident or incident**	**A/C damages**	**Fatalities**	**Investigation finding**
A320 (turbofan) - VH-VQT (Australia)	21/07/2007	Melbourne (Australia)	Serious incident	None	0	During an approach to Melbourne Airport, Victoria in instrument meteorological conditions, the flight crew did not have the required visual reference at the missed approach point and commenced a missed approach (go-around). The pilot in command (PIC) did not move the thrust levers to the correct position to allow the aircraft flight mode to correctly transition to the go-around phase. That led to crew confusion, which was compounded by alerts and warnings that distracted them; the end result was a higher-than-normal and unexpected workload, and the crew being unaware of the aircraft's current flight mode. The aircraft was not in the correct flight mode for a period of 48 seconds and during that time, reached a minimum recorded height of 38 ft above the runway. Subsequently, the PIC moved the thrust levers to the correct position, the flight mode transitioned to the go-around phase and the aircraft responded normally.
A319 (turbofan) - F-GRHU (France)	23/09/2009	Paris CDG (France)	Serious incident	None	0	During go around initiation, the PF did not set the throttle to the TOGA position, the rest of actions though being performed consistently with the procedure. The AP engagement has been performed without checking the adequacy of the selected modes and the FMA displays. During this dynamic phase, the flight crew momentarily lost the control of the trajectory. The attitude was not monitored.

A/C Type & registration	**Date (DD/MM/YYYY)**	**Location**	**Accident or incident**	**A/C damages**	**Fatalities**	**Investigation finding**
A300 B4 (turbofan) - XA-TUE (Mexico)	13/04/2010	Monterrey (Mexico)	Accident	Destroyed	6	During the descent, the aircraft was configured late for landing. Then, the final checklist was performed below 1000ft AGL interrupted several times by the search of the runway. ATS being disengaged and engine on idle, the speed decreased during around 30 seconds from 134kt down to around 110kt without crew reaction. Actions to level off the aircraft at MDA by pulling on the control column between resulted in speed further decay while aircraft was pitching up. The low energy alpha floor protection activated, advancing the engine throttles and was continued by crew action on throttles up to the forward limit. Stick shaker and stall warning triggered at 04:15:24. The CPT reacted to the stick shaker and stall warning activation by quickly advancing throttles until forward limit (55° TLA) and announced Go-around. AP was disengaged. The control column was pushed forward to counteract the resulting pitching up moment. An abnormal force of approximately 8kg was applied on the control column during 30 seconds while no action on the trim setting was performed. Between 04:15:54 and 04:16:35: - The aircraft started to climb from 1750ft to 3800ft while pitching up from an initial pitch attitude of 5° to reach 41° - The speed initially increased up to 140kt (04:16:10) and then decreased to reach a minimum value below 70kt at 04:16:35. - Control column was maintained full forward from 04:16:00 to 04:16:35 - At 04:16:27, stick shaker followed by stall warning triggered. - The aircraft stalled

A/C Type & registration	Date (DD/MM/YYYY)	Location	Accident or incident	A/C damages	Fatalities	Investigation finding
A330-200 (turbofan) - 5A-ONG (Libya)	12/05/2010	Tripoli (Libya)	Accident	Destroyed	103	Based on elements from the investigation, the accident resulted from: - The lack of common action plan during the approach and a final approach continued below the MDA, without ground visual reference acquired. - The inappropriate application of flight control inputs during a go- around and on the activation of TAWS warnings, - The lack of monitoring and controlling of the flight path. These events can be explained by the following factors: - Limited CRM on approach that degraded during the missed approach. This degradation was probably amplified by numerous radio-communications during the final approach and the crew's state of fatigue, - Aircraft control inputs typical in the occurrence of somatogravic perceptual illusions, - Inappropriate systematic analysis of flight data and feedback mechanism within the AFRIQIYAH Airways. - Non adherence to the company operation manual, SOP and standard terminology. In addition, the investigation committee found the following as contributing factors to the accident: - Weather available to the crew did not reflect the actual weather situation in the final approach segment at Tripoli International Airport. - In adequacy of training received by the crew. - Occupancy of tower frequency by both air and ground movements control.

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B737-500 (turbofan) - N904UA (USA)	29/10/1995	San Francisco (USA)	Incident	None	0	FOLLOWING A TEST FLIGHT THE PILOT WAS GIVEN A GO-AROUND BY APP CONTROL. HE SELECTED THE TAKE-OFF AND GO-AROUND SWITCH AND ENGINE POWER INCREASED. THE A/C BEGAN TO PITCH UP AND DID NOT STOP AT THE GO-AROUND ATTITUDE. PITCH INCREASED TO 45 DEG NOSEUP AND THE STICK SHAKER ACTIVATED. THE PILOT COULD NOT OVERCOME THE INCREASE IN PITCH. THE A/C STALLED, THE NOSE DROPPED AND THE A/C ROLLED. THE PILOT INCREASED THE ROLL. AS THE NOSE DROPPED THROUGH THE HORIZON AIRSPEED INCREASED AND THE PILOT RECOVERED TO WINGS-LEVEL.
B737-500 (turbofan) - D-AHLN (Germany)	27/04/1998	Bremen (Germany)	Incident	None	0	DURING FINAL APP AN UNSAFE NOSE GEAR INDICATION LED TO A GO-AROUND. DURING CLIMB-OUT BOTH FLIGHT DIRECTORS AND AUTOTHRUST WERE ON. AFTER GEAR RETRACTION FLAPS WERE SET AT 15 DEG. A FURTHER FLAP RETRACTION WAS DELAYED BY DISCUSSIONS WITH GROUND CONTROL REGARDING CHANGING THE DEPARTURE PROCEDURE BECAUSE OF THE WEATHER. HIGH THRUST AND LOW A/C WEIGHT RESULTED IN A CLIMB RATE UP TO 4,800 FT/MIN. THE ALTITUDE CAPTURE FOR A 3,000 FT LEVEL OFF WAS AT 1,500 FT AGL WHEN THE TOGA MODE SWITCHED TO MCP SPEED MODE. PITCH ATTITUDE HAD NOW INCREASED TO 24 DEG NOSE UP. THEREAFTER, THE FLIGHT DIRECTOR PITCH BAR COMMANDED A NOSE DOWN, WHICH THE PILOT FOLLOWED BY MANUAL NOSE DOWN TRIM INPUT. THIS LASTED 4 SEC DUE TO THE SLOW REACTION OF THE A/C. THE PILOT WAS NOT AWARE THAT WITH FLAPS AT 15 DEG, THE HORIZONTAL STABILIZER MANUAL TRIM SPEED OPERATES AT A MAXIMUM VALUE OF 0.6 DEG/SEC. THE STABILIZER RAN INTO FULL NOSE DOWN TRIM. THE PITCH ATTITUDE WAS PASSING 10 DEG NOSE-UP WHEN

A/C Type & registration	Date (DD/MM/YYYY)	Location	Accident or incident	A/C damages	Fatalities	Investigation finding
						FDR SHOWED A SHORT-TIME NOSE-DOWN ELEVATOR DEFLECTION AND A REDUCTION OF THRUST LEVER ANGLE. THE PILOT SAID THAT HE THEN DISENGAGED THE AUTOTHRUST BUT THERE WAS NO SUCH INDICATION FROM THE FDR. WHEN THE PILOT NOTICED THE NOSE DOWN TRIM HE PULLED THE CONTROL WHEEL VERY HARD AND RETAINED FULL CONTROL AFTER SOME SECONDS. THE FOLLOWING WERE RECORDED: PITCH ALTITUDE -24 DEG, ANGLE OF ATTACK -12 DEG, VERTICAL G -0.4. AFTER FIXING THE UNSAFE GEAR INDICATION BY CHANGING TWO BULBS THE A/C LANDED SAFELY.
B757-200 (turbofan) - TF-FIO (Iceland)	21/01/2002	Gardermoen (Norway)	Serious incident	None	0	ILS approach was initially conducted by autopilot, but as the A/C never became properly stabilized on GP, the autopilot was disconnected. The commander flew the A/C manually, and complained about his GP data frequently missing. The F/O did not take any actions to this. His instruments were functioning normally. At 580 ft, approach was still not stabilized (above GP), and PIC initiated missed approach. Pitch was increased to 20 deg., and speed decreasing to its peak of 137 kt. To avoid stalling the A/C the PIC lowered the nose abruptly, to gain more speed. The control column was returned to neutral for a short moment. Then another abrupt nose-down control movement was made, causing a pitch attitude to -49 deg. This dive was not recovered until 321 ft AGL and 251 kt airspeed. During this incidence, aural warnings had been present, like "terrain" and "too low terrain". The recovery of the dive continued with a pitch attitude of approx. +40 deg., and the flight continued normally, but with several abrupt control inputs. Load factors during these abnormal maneuvers were measured to be -0.6 and +3,59 g's. The A/C made a normal landing on the 2. attempt.

A/C Type & registration	**Date (DD/MM/YYYY)**	**Location**	**Accident or incident**	**A/C damages**	**Fatalities**	**Investigation finding**
						The mass and balance of the aircraft were within the normal operating limits at the time of the incident.

A/C Type & registration	Date (DD/MM/YYYY)	Location	Accident or incident	A/C damages	Fatalities	Investigation finding
B737-3Q8 (turbofan) - G-THOF (United Kingdom)	23/09/2007	Bournemouth airport (United Kingdom)	Serious incident	None	0	The co-pilot was PF and the Captain was PM. During an ILS approach to their base, the autothrottle (AT) disconnected without being noticed by the flight crew just after the aircraft had captured the G/S. The thrust was at idle. The autopilot adjusted the pitch and gradually increased the nose-up pitch to minimise G/S deviation as the airspeed decayed. After selecting flaps 40, the Captain realised that the aircraft's IAS was 125 kt (Vref-10 kt). The altitude was then about 1,500 ft. The Captain took over the controls and initiated a go-around. About 2 seconds later the stick-shaker (stall warning) activated. The Captain moved the thrust levers fully forward and pushed forward the control column. The AP mode changed to CWS. The pitch attitude stabilised at 5° noseup. The minimum airspeed at this time was 101 kt. The engine thrust continued to increase, the AP disengaged, the pitch attitude started to increase again and the stick-shaker activated again. Despite the Captain's nose-down input, the nose-up pitch increased to 22°. The stall warning ceased, but activated again a few seconds later, just as the flaps were retracting, and the pitch attitude increased again, through 27° nose-up. The co-pilot called out "High Pitch". The Captain replied "I have full forward stick". The pitch attitude increased above 36° nose-up, with a CAS of 107 kt, and the aircraft was in a left roll (~13°). A sharp rudder input brought the wings level, but the aircraft was stalled with a peak pitch attitude of 44° nose-up. The pitch attitude started to decrease, and the airspeed continued to decrease for a few seconds, reaching a minimum of 82 kt when the pitch attitude was 33° nose-up. After reaching 2,500 ft, the aeroplane started to lose altitude. The Captain reduced the thrust slightly and managed to regain control of the aircraft at about 2,000 ft. It

A/C Type & registration	Date (DD/MM/YYYY)	Location	Accident or incident	A/C damages	Fatalities	Investigation finding
						was at this point that the flight crew made the first manual nose-down trim input. The crew performed a second approach, during which the AP and the AT operated nominally.
B757-200 (turbofan) - G-MONK (United Kingdom)	13/12/2008	London Gatwick (United Kingdom)	Serious incident	None	0	During an approach, in demanding weather conditions, the crew inadvertently left the speedbrakes deployed with the auto-throttle disengaged; the aircraft's speed decayed until the stick shaker activated. The Quick Reference Handbook (QRH) actions for stick shaker activation were not completed properly and during the go-around the speedbrakes remained extended. Subsequently, the Flight Director Pitch Bars disappeared from the Primary Flying Displays (PFDs) and the commander became disorientated. He handed over control to the co-pilot and stowed the speedbrakes realising that they were still deployed. The crew

A/C Type & registration	Date (DD/MM/YYYY)	Location	Accident or incident	A/C damages	Fatalities	Investigation finding
						subsequently completed an uneventful ILS and landed safely.
B777 (turbofan) - F-GSPP (France)	16/11/2011	Paris CDG (France)	Serious incident	None	0	This serious incident was due to the inadequate monitoring of flight parameters by the flight crew. The following factors contributed to this: - Partial execution of the go-around procedure; - Inadequate management of the automatic systems during execution; - The conflict of plans of action between respecting the operators instruction and continuing the landing, which seemed to be safely possible according to the manufacturer.

A/C Type & registration	**Date (DD/MM/YYYY)**	**Location**	**Accident or incident**	**A/C damages**	**Fatalities**	**Investigation finding**
B737-53A (turbofan) - VQ-BBN (Bermuda)	17/11/2013	Kazan airport (Russia)	Accident	Destroyed	50	Performing go-around flight maneuver the crew didn't identify the autopilot overriding and allowed the aircraft nose up upset. Lack of PIC's skill of aircraft upset recovery resulted in significant deceleration, spatial disorientation and aircraft steep dive (pitch down angle up to 75°) down to ground impact. Go-around flight maneuver was caused by the aircraft non-landing setting running out to the RWY that was caused by "Map shift" effect (aircraft position indication error by airbone systems) by the rate of 4 km, the crew disability to perform composite aircraft navigation and navigation with adequate accuracy as well as absence of ATM active assistance during long monitoring of significant deviations from the approach pattern. The mentionned contributing factors include the following ones: - not identification of the autopilot overriding by the crew and late interference with aircraft that resulted in aircraft nose up upset; - possible effect of somatic gravitational illusions.

A/C Type & registration	Date (DD/MM/YYYY)	Location	Accident or incident	A/C damages	Fatalities	Investigation finding
B737-3YO (turbofan) - EX-37005 (Kyrgyzstan)	22/11/2015	Osh airport (Russia)	Accident	Substantial damages from hard landing and RWY excursion	0	At 23:56L the captain consulted with weather forecasters at Osh, who indicated the weather would be better than METARs and SPECIs suggested and advised the weather would improve to a visibility of 600 meters horizontally and 200 feet vertically at 00:30L. The captain therefore decided to depart at 00:00L Nov 22nd 2015. The aircraft was finally taxiing for departure from Osh at 01:04L, during taxi the actual weather report from Osh was received and indicated visibility of 200-800 meters horizontally and 200 feet vertically sometimes reducing to 100 feet. Following departure at 01:08L Air Traffic Control advised at 01:18L visibility at Osh had improved to 1700meters horizontally and 200 feet verticaly. While descending to FL070 at Osh at 01:38L ATC advised visibility was 900 meters horizontally and 100 feet vertically and queried whether the aircraft would commence the approach. The crew continued the approach. At 01:43L ATC advised the visibility had reduced to 500 meters horizontally and 100 feet vertically. At 01:44L the crew advised they were going around, the aircraft however collided with the runway within the touch down zone at +3.96G. While climbing out the crew queried weather and subsequently decided to return to Bishkek. The aircraft climbed to FL150, the crew intended to climb higher. However, as result of the impact on the runway two hydraulic systems had failed and the right hand engine showed increasing problems including decreasing oil pressure and rising EGT. The crew assessed their options to divert to Bishkek and decided to land at Osh despite the weather

A/C Type & registration	Date (DD/MM/YYYY)	Location	Accident or incident	A/C damages	Fatalities	Investigation finding
						conditions present. The right hand engine was shut down and the aircraft returned to Osh for an emergency landing, touched down about 1063 meters past the runway threshold and overran the end of the runway by 529 meters. The MAK reported 6 passengers received "moderate" injuries during the landing, 5 passengers received minor injuries during the landing.

A/C Type & registration	Date (DD/MM/YYYY)	Location	Accident or incident	A/C damages	Fatalities	Investigation finding
B737-800 (turbofan) - A6-FDN (United Arab Emirates)	19/03/2016	Rostov-on-Don airport (Russia)	Accident	Destroyed	62	On March 19, 2016 a Boeing 737-800 aircraft registered A6-FDN operated by Fly Dubai, while executing a recurrent approach at night time in IMC at Rostov-on-Don Airdrome with landing heading 218˚, the crew went around from the height of 220 m (4.5 KM before the runway) with vertical speed of up to 20 mps setting the engines to max takeoff/goaround thrust. Both approaches (from the height of about 600 m) were performed with autopilot and autothrottle disengaged in flight director mode without significant heading or altitude deviations from the glideslope. One of the possible causes of the go-around decision could have been the 20 kt increase of indicated speed to as much as 176 kt within 3 seconds, which might have been an indication of windshear. In the course of the go-around the crew set flaps to 15˚ and retracted the landing gear. At a height of 1900 ft, (approx. 600m) after reaching a pitch of 18˚, the PF pushed on the control column, which led to a decrease in vertical acceleration of up to 0.5, increase in forward speed and, consequentially, automatic retraction of flaps from 15˚ to 10˚ at a speed of over 200 kt. The short term decrease in engine thrust within 3 seconds resulted in decreasing speed and flap extension to 15˚, although the following crew inputs to regain max takeoff/goaround thrust led to speed increase and reiterated automatic flaps retraction to 10˚. The flaps remained in the latter configuration until impact. The PF, by pulling up the control column, continued climbing with a vertical speed of as much as 16 mps. At a height of 900 m, there was a simultaneous control column nose down input and stabilizer nose down deflection from -2.5 deg to +2.5 deg (the FDR

A/C Type & registration	Date (DD/MM/YYYY)	Location	Accident or incident	A/C damages	Fatalities	Investigation finding
						recorded a nose down stabilizer input from the stabilizer trim switch of the control wheel lasting 12 sec), as a result the aircraft, having climbed to about 1000 m, turned into descent with negative vertical acceleration of -1g. The following crew recovery actions did not allow to avoid an impact with the ground. The aircraft hit the runway about 120 m from the threshold with a speed of over 600 km/h and over 50˚ nose down pitch.

A/C Type & registration	Date (DD/MM/YYYY)	Location	Accident or incident	A/C damages	Fatalities	Investigation finding
B777-31H (turbofan) - A6-EMW (United Arab Emirates)	03/08/2016	Dubai (United Arab Emirates)	Accident	Destroyed	1	As the flight neared Dubai, the crew received the automatic terminal information service (ATIS) Information Zulu, which included a windshear warning for all runways. During the approach, at 0836:00, with the autothrottle system in SPEED mode, as the Aircraft descended through a radio altitude (RA) of 1,100 feet, at 152 knots IAS, the wind direction started to change from a headwind component of 8 knots to a tailwind component. The autopilot was disengaged at approximately 920 feet RA and the approach continued with the autothrottle connected. As the Aircraft descended through 700 feet RA at 0836:22, and at 154 knots IAS, it was subjected to a tailwind component which gradually increased to a maximum of 16 knots. At 0837:07, 159 knots IAS, 35 feet RA, the PF started to flare the Aircraft. The autothrottle mode transitioned to IDLE and both thrust levers were moving towards the idle position. At 0837:12, 160 knots IAS, and 5 feet RA, five seconds before touchdown, the wind direction again started to change to a headwind. As recorded by the Aircraft flight data recorder, the weight-on-wheels sensors indicated that the right main landing gear touched down at 0837:17, approximately 1,100 meters from the runway 12L threshold at 162 knots IAS, followed three seconds later by the left main landing gear. The nose landing gear remained in the air. At 0837:19, the Aircraft runway awareness advisory system (RAAS) aural message “LONG LANDING, LONG LANDING” was annunciated. At 0837:23, the Aircraft became airborne in an attempt to go-around and was subjected to a headwind component until impact. At 0837:27, the flap lever was moved to the 20 position. Two seconds

A/C Type & registration	Date (DD/MM/YYYY)	Location	Accident or incident	A/C damages	Fatalities	Investigation finding
						later the landing gear lever was selected to the UP position. Subsequently, the landing gear unlocked and began to retract. At 0837:28, the air traffic control tower issued a clearance to continue straight ahead and climb to 4,000 feet. The clearance was read back correctly. The Aircraft reached a maximum height of approximately 85 feet RA at 134 knots IAS, with the landing gear in transit to the retracted position. The Aircraft then began to sink back onto the runway. Both crewmembers recalled seeing the IAS decreasing and the Copilot called out “Check speed.” At 0837:35, three seconds before impact with the runway, both thrust levers were moved from the idle position to full forward. The autothrottle transitioned from IDLE to THRUST mode. Approximately one second later, a ground proximity warning system (GPWS) aural warning of “DON’T SINK, DON’T SINK” was annunciated. One second before impact, both engines started to respond to the thrust lever movement showing an increase in related parameters. At 0837:38, the Aircraft aft fuselage impacted the runway abeam the November 7 intersection at 125 knots, with a nose-up pitch angle of 9.5 degrees, and at a rate of descent of 900 feet per minute. This was followed by the impact of the engines on the runway. The three landing gears were still in transit to the retracted position. As the Aircraft slid along the runway, the No.2 engine-pylon assembly separated from the right hand (RH) wing. From a runway camera recording, an intense fuel fed fire was observed to start in the area of the damaged No.2 engine-pylon wing attachment area. The Aircraft continued to slide along the runway on the lower fuselage, the outboard RH wing, and the

A/C Type & registration	Date (DD/MM/YYYY)	Location	Accident or incident	A/C damages	Fatalities	Investigation finding
						No.1 engine. An incipient fire started on the underside of the No.1 engine.

A/C Type & registration	Date (DD/MM/YYYY)	Location	Accident or incident	A/C damages	Fatalities	Investigation finding
DC-8-63 (turbofan) - N794AL (USA)	15/02/1992	Swanton (USA)	Accident	Destroyed	4	ATI Flight 805 departed from Seattle at 23:20 for a flight to Toledo. The 1st officer was flying the ILS approach to runway 07. For undetermined reasons, he failed to properly capture the ILS localizer and/or glide slope during the approach. At 03:13 the captain decided to carry out a go-around. The aircraft was vectored onto a base leg and given a heading of 100deg to intercept the final approach course again. With a 35 knots crosswind (at 180deg) on the approach the 1st officer had trouble capturing the localizer/glide slope. At 03:24, as the 1st officer was attempting to stabilize the approach, 3 GPWS glide slope warnings and sink rate warnings sounded. The captain took over control at 03:24:17 and performed another missed approach manoeuvre. He became spatially disoriented and inadvertently allowed an unusual attitude to develop with bank angles up to 80deg and pitch angles up to 25deg. When in a nose-low and left bank angle attitude, control of the airplane was transferred back to the 1st officer who began levelling the wings and raising the nose of the airplane. Impact with the ground occurred before the unusual attitude recovery was completed. PROBABLE CAUSE: "The failure of the flight crew to properly recognize or recover in a timely manner from the unusual aircraft attitude that resulted from the captain's apparent spatial disorientation, resulting from physiological factors and/or a failed attitude director."

A/C Type & registration	Date (DD/MM/YYYY)	Location	Accident or incident	A/C damages	Fatalities	Investigation finding
Swearingen SA226 TC Metro II (turboprop) - C-GYPA (Canada)	11/10/2001	Shamattawa, Canada	Accident	Destroyed	2	Approaching Shamattawa, the crew began a descent to the 100 nautical mile minimum safe altitude of 2300 feet above sea level (asl) and, when clear of an overcast cloud layer at about 3000 feet asl, attempted a night, visual approach to Runway 01. The aircraft was too high and too fast on final approach and the crew elected to carry out a missed approach. Approximately 30 seconds after the power was increased, at 2333, the aircraft flew into trees slightly to the left of the runway centreline and about 2600 feet from the departure end of Runway 01. The aircraft was equipped with a cockpit voice recorder (CVR) that indicated the crew were in control of the aircraft; they did not express any concern prior to impact. The aircraft broke apart along a wreckage trail of about 850 feet. The loss of visual references as the aircraft accelerated along the runway and past the lights of the community were ideal for the onset of somatogravic illusion in the pilot flying. Even 7 seconds prior to impact, the captain believed that he was climbing to 1000 feet above ground level. The captain's performance was consistent with his being unable to distinguish the imposed acceleration as the aircraft speed increased from that of gravity and, although he probably thought the aircraft was climbing, it was not. The first officer may also have been influenced by the somatogravic illusion. During the 30 seconds of the missed approach, his tasks were to react to the captain's commands and to monitor the instruments. Apparently the first officer did not observe anything remarkable or he would have alerted the captain that the aircraft was not climbing. It is possible that he was distracted by the sudden sound of the NDB identifiers just after the

A/C Type & registration	Date (DD/MM/YYYY)	Location	Accident or incident	A/C damages	Fatalities	Investigation finding
						missed approach was initiated. The NDB receiver was turned off just prior to impact, and since the control head is on the first officer's side of the cockpit, it was likely he who turned the NDB off. Given the short duration of the overshoot and the tasks that the first officer was performing, it is probable that he had a false perception that the aircraft was climbing.

A/C Type & registration	**Date (DD/MM/YYYY)**	**Location**	**Accident or incident**	**A/C damages**	**Fatalities**	**Investigation finding**
DHC-8-103 (turboprop) - LN-WIU (Norway)	02/12/2010	Svolvær Airport Helle (Norway)	Serious incident	None	0	The incident probably occurred as a result of the aircraft suddenly being subjected to significant variations in wind direction and/or wind speed. The wind also probably impacted the aircraft during the seconds the crew had to regain control. Information about observed wind has lead AIBN to believe that the aircraft may have been exposed to a significant wind shear, for example as a result of sudden loss of headwind or maybe even tailwind, due to a gust from a CB in the area. It is also possible that this came in an unfortunate combination with mechanical turbulence in the area due to the south-westerly gale. The Accident Investigation Board assessed that the risk of spatial disorientation was great in this instance, as the Commander flew on visual without visible horizon and in complete darkness. In particular, the powerful longitudinal acceleration during the initial increase in engine power could have caused so-called somatogravic illusion, a false sense of the nose of the aircraft raising. A possible illusion could explain some apparent discrepancies and circumstances which otherwise do not appear logical in this case. Specifically why the crew did not perceive just how low they were, why they reacted the way they did when exposed to a wind shear, and why they ended up with different perceptions of what had actually happened.

Category 2 occurrences:

A/C Type & registration	Date	Location	Accident or incident	A/C damages	Fatalities	Investigation report finding
A320 (turbofan) - D-AXLA (Germany)	27/11/2008	Canet-plage (France)	Accident	Destroyed	7	The accident was caused by the loss of control of the aeroplane by the crew following the improvised demonstration of the functioning of the angle of attack protections, while the blockage of the angle of attack sensors made it impossible for these protections to trigger. The crew was not aware of the blockage of the angle of attack sensors. They did not take into account the speeds mentioned in the programme of checks available to them and consequently did not stop the demonstration before the stall. The loss of control was caused by a thrust increase performed with a full pitch-up horizontal stabilizer position. This pitch trim position combined with the high thrust resulted in a lack of pitch down authority to the pilot. The PF made no inputs on the horizontal stabilizer nor did he reduce the thrust; the PNF did not intervene. This seems to indicate that none of them were aware that the automatic trim system, which relieves the pilot of any actions to trim the aeroplane, was no longer available.

B737-800 - TC-JGE (Turkey)	25/02/2009	Amsterdam (Netherlands)	Accident	Destroyed	9	During the accident flight, while executing the approach by means of the instrument landing system with the right autopilot engaged, the left radio altimeter system showed an incorrect height of -8 feet on the left primary flight display. This incorrect value of -8 feet resulted in activation of the 'retard flare' mode of the autothrottle, whereby the thrust of both engines was reduced to a minimal value (approach idle) in preparation for the last phase of the landing.[...] The right autopilot (using data from the right radio altimeter) followed the glide slope signal. As the airspeed continued to drop, the aircraft's pitch attitude kept increasing. The crew failed to recognise the airspeed decay and the pitch increase until the moment the stick shaker was activated. Subsequently the approach to stall recovery procedure was not executed properly, causing the aircraft to stall and crash. <u>Recovery behaviour</u>: Investigation was also performed into the recovery characteristics of the B737-800 at the moment of the approach to stall warning onset, with and without autopilot engaged. Maximum thrust was selected 1 second after the stickshaker warning to account for reaction time. The aircraft was flown with autopilot engaged and the stabiliser trimmed until an airspeed slightly above the approach to stall warning onset speed. With this speed the stabiliser reached its airplane nose-up stop (full nose-up electrical trim) and could not be trimmed further in the nose-up direction. This was also the case with flight TK1951. Because of the stabiliser's maximum nose-up moment and corresponding low speed just above the stall speed, which was beyond the FAR 25.103 criteria, the effectiveness of the elevator might be less than demonstrated during certification tests. With the selection of maximum thrust, with underwing engines, an additional pitch-up moment is produced. If the speed is sufficiently low, nose down trimming is necessary to maintain full pitch authority. This situation was confirmed during the M-Cab sessions. <u>Manual recovery</u> During the manual recovery, under the above

						given conditions, it was necessary to push the control column fully forward in order to prevent the pitch value from becoming higher than the pitch limit indicator leading to aircraft stall. As the recovery progressed it was not always possible to maintain the aircraft pitch at or below the pitch limit indicator without trimming the stabiliser in most cases, but adequate elevator authority was available for at least 40 seconds before trimming was required. Control forces were maximum between 30-50 pounds and such that with one hand full forward control column deflection was possible. Evaluations of various recovery techniques showed that timely application of thrust could ensure recovery after stick shaker. In the event that thrust was not applied within a few seconds of stick shaker, the airplane could still be recovered by making control inputs to prevent the airplane from stalling.
A330 (turbofan) - F-GZCP (France)	01/06/2009	Atlantic ocean	Accident	Destroyed	228	The accident resulted from the following succession of events: - Temporary inconsistency between the airspeed measurements, likely following the obstruction of the Pitot probes by ice crystals that, in particular, caused the autopilot disconnection and the reconfiguration to alternate law; - Inappropriate control inputs that destabilized the flight path; - The lack of any link by the crew between the loss of indicated speeds called out and the appropriate procedure; - The late identification by the PNF of the deviation from the flight path and the insufficient correction applied by the PF; - The crew not identifying the approach to stall, their lack of immediate response and the exit from the flight envelope;

						- The crew's failure to diagnose the stall situation and consequently a lack of inputs that would have made it possible to recover from it.
MD-83 (turbofan) - EC-LTV (Spain)	24/07/2014	Gossi region, Mali	Accident	Destroyed	116	The aeroplane took off at night from Ouagadougou airport at about 1 h 15 bound for Algiers. During the climb, the crew made several heading changes to avoid a stormy area before reaching cruise level FL 310. A few minutes later, the aeroplane's speed, piloted by the autothrottle, decreased due to the obstruction of the pressure sensors on the engine nose cones, likely by ice crystals. The autopilot then progressively increased the aeroplane's pitch attitude to maintain the altitude, until the aeroplane stalled. The aeroplane's stall was not recovered. The aeroplane maintained its nose-up attitude and left bank while the control surfaces remained mainly deflected in a pitch-down attitude and with a right bank. The aeroplane struck the ground at high speed. The accident resulted from a combination of the following events: - non-activation by the crew of the engine's anti-icing system ; - obstruction of the PT2 pressure sensors, likely by ice crystals, leading to erroneous EPR values that caused the autothrottle to limit the thrust delivered by the engines below the level of thrust required to maintain FL310 ; - the crew's late reaction to the decrease in speed and to the erroneous EPR values, possibly linked to the workload associated with avoiding the convective system and to the difficulties in communicating with air traffic control ;

						- the crew's lack of reaction to the appearance of buffet, the stickshaker and the stall warning ; - the absence of appropriate flight control inputs by the crew to recover from the stall situation.

Appendix 2: Synthesis of the responses to the questionnaire sent to large aeroplanes manufacturers – RMT.0647

1) General questions

a. Difficulties faced during go-around (G/A) come from the following factors:

— When aircraft (a/c) are not provided with attitude limitation function,
— When a stabiliser trim control system is not integrated with an elevator control,
— High pitch-up moment on two-engined a/c with engines under the wing,
— High thrust/weight ratio on two-engined a/c at the end of a flight: higher pitch rates than usual, high pitch values, and high vertical speeds,
— When full thrust is applied during G/A, excessive climb speed can be reached very quickly, making it difficult for flight crews to perform the activities related to the G/A procedure: not compatible with time available (high workload in short time), source of somatogravic illusion,
— G/A could be associated with a disruptive element, before or during the application of thrust, which startles the crew (e.g. unexpected ATC constraints, automatic system inputs which are not in line with the G/A, unfavourable meteorological environment),
— High work load phase,
— Inoperative CRM and lack of PM,
— Inadequate training and knowledge of systems; pilots are not comfortable, they rarely practice G/A in the a/c; they should be trained to perform most dynamic G/A on actual light-weight a/c rather than on simulators,
— Human factors issue because pilots do not anticipate sufficiently the G/A option during approach.

Some manufacturers highlighted the importance of a better training; they have taken action to recommend better training:
— Surprise effects should be included in the training,
— Different scenarios should be used, AEO in addition to OEI,
— Emphasising trust in instruments,
— Communication and task sharing between PF-PM,
— Somatogravic illusion should be trained (recognise and mitigate).

Three manufacturers have developed a reduced G/A thrust function to mitigate the above issues.
One regional turboprop manufacturer stated it did not have problems with this topic. Another manufacturer of turboprop and turbofan (fuselage-mounted) also stated it has no problems, however, the turbofan aircraft have a function which can reduce thrust and limit pitch attitude.

b. Introduction of thrust reduction systems

3 manufacturers introduced such systems.
Normally, maximum thrust can still be selected by the flight crew (FC) (but one manufacturer did not specify if this is possible with its design).

c. Introduction of features which can ensure pitch trim control for the go-around phase or other flight phases

3 manufacturers have designs with flight-envelope-protection functions which provide some kind of protection against miss-trim. The details on how these functions work and their availabilities can vary between types and manufacturers.

d. Positive and negative aspects of introducing a go-around thrust reduction system

<u>Positive aspects:</u>

— less energy during light weight G/A,
— less pitch attitude during the G/A,
— less acceleration during the G/A,
— more time available for the pilots,
— improved pilots workload,
— reduced probability of loss of control (LOC) during G/A due to situational awareness enhancement and reduction of spatial disorientation,
— same standards/training as for heavier aeroplanes,
— comfort for pilot and passengers.

<u>Negative aspects:</u>

— controls/logics needed to allow full thrust application which introduces uncertainty,
— crew will not get used to proper associated feeling 'the lighter the a/c, the more energetic the G/A',
— reducing the frequency of cases when pilots feel high thrust application during G/A (not limited by a system) negatively affects pilots readiness/proficiency,
— analysing adapted power is adding workload to the crew,
— development costs involved,
— implementation costs involved,
— training definition and implementation costs involved,
— solutions may involve multidisciplinar areas (flight controls, engines - FADEC, flight guidance, etc.),
— solutions may require higher levels of assurance for some systems (design assurance level),
— design integration to avoid unintended consequences is always a challenge with new systems,
— difficult system integration especially for types which rely on manual power setting (with a risk that the wrong setting is used),
— financial burden for both the manufacturer and the operators (with, according to the 2 turboprop manufacturers, no associated safety improvement)

2) G/A thrust reduction systems

a. Aeroplanes NOT equipped with a go-around thrust reduction (GATR) system

3 manufacturers have implemented it on some of their types.
5 manufacturers have not decided to implement a function, 1 of them is considering it.
When not implemented the reasons provided are:

— No reported incident or accident,
— Regional operations have reduced exposure to the risk (CG/weight envelope),
— Lack of regulation on G/A thrust reduction systems,

— The efforts to implement a function,
— Dot not see the necessity of such system (turboprop),
— Production stopped,
— Climb capability not critical,
— Cost vs fleet size and usage,
— Required hardware and software modifications on older generation aeroplanes,
— Mitigation means found through procedure on some types (e.g. TOGA then reduction to CLB) and communications to operators,
— From a turboprop manufacturer: pilots should be trained to adapt the engine power to the path requirements. So the available flying cues should allow the pilot to adapt the power to the desired path and speed.

b. Aeroplanes equipped with a GATR system

<u>Info on system implementation by 3 manufacturers:</u>

1 manufacturer developed the function recently, it has been certified first as a modification; first on the 2 most recent types, and then on some older types where the design impact remains acceptable. For the 2 most recent types, retrofit has been done and all customers take the option on production aeroplanes. For other types where the modification has been certified, the option is available in production and retrofit is possible; the operator decides after considering their mixed fleet strategy.
Criteria used to establish whether the system should be implemented: thrust/weight ratio, climb capability at all weights, industrial complexity to address all configurations (for retrofit), fleet size (for a/c not anymore in production). All a/c, including quads, were potential candidates for the introduction of the function.
Figures are provided on the number of a/c equipped.
1 manufacturer developed the function earlier and has implemented it on all its production aeroplanes. It was certified as part of the TC/ATC.
No figures provided on the number of a/c equipped.
1 manufacturer developed the function on one of its two types as part of the original type design.

<u>Cost assessments (only 1 manufacturer replied):</u>

Development costs:
On existing types: high non recurring cost (NRC) because it requires specific (engine and systems) supplier development costs, specific integration work, ground testing, and flight test program. No figures are provided.
New types: Cost is less because of part of the overall development and validation work plan.

Cost of installation on a newly manufactured a/c:
No additional recurring cost (RC). Only installation of relevant software standards (ATA22, 31, 73) are needed. No hardware change to the a/c.

Cost of installation of the system on already manufactured a/c (retrofit):
Need to retrofit relevant software standards on some types. RC for the operator is very limited.
Other a/c types (the most recent ones) have the function capability in EIS standards.

Maintenance costs
None

Costs for crew training

Maintenance:
Initial: none; Recurrent: none.
Pilots:
Initial: none specified, it is part of the SOP. Recurrent: Training centres define their programme; corresponding costs cannot be assessed.

Issues encountered with the go-around thrust reduction system:

None reported by the responders.
Frequency of use of the function by the pilots: unknown.
Benefits:
Safety: No statistics available. It is expected that, with the soft G/A as the SOP, events with excessive energy as one of primary causes should be prevented by a correct application of the soft G/A mode.
Fuel consumption: Marginal effect.
Time saving: Not assessed, it is very dependent on the operational parameters (airport, procedures, weight, altitude, etc.)

Go-around thrust reduction system availability

Manual mode: Yes (but A/TR must be armed on some a/c)
Autopilot selected mode: Yes (as long as A/TR is armed or 'On' on some a/c)
Autopilot managed mode: Yes (if applicable)
With the auto-thrust function on or off? Armed/active or not?: Armed or on.

3) Pitch trim control systems

a. Which ones of your aeroplanes types are equipped with an automatic pitch trim function (either in manual control or autopilot mode), which ones are not?

All a/c have a kind of automatic pitch trim function, however, there are different designs (e.g. using a movable horizontal stabilizer or elevator trim tabs).
The availability of the auto trim function is also variable. On some a/c it is available in all modes, on some a/c it is available only when autopilot is engaged. In case of degraded flight control modes, the function may be lost.

b. Feature limiting the horizontal stabiliser nose up travel at low speed?

6 manufacturers have types with some kind of travel-limitation functions, however, the way they work is variable.
2 manufacturers have systems without limitation (turboprop a/c using elevator tabs).
A/c with fly-by-wire design and flight envelope protection can use various parameters to inhibit the pitch control demand (AOA, pitch, speed, etc.).
Availability of the feature: For a/c equipped with this feature, it is available in manual and autopilot modes.
No detail was provided on the cases where this feature would not be available. It is understood that the feature is available as long as the automatic pitch trim function is not inhibited or lost in normal cases. It may be lost in failure cases, this depends on the design.

c. Is there a means, on your aeroplanes, to alert the flight crew when the pitch trim is in an inappropriate position for the flight phase (e.g. excessive nose up trim position)? Please describe which kind of alert (aural, visual…) is provided to the flight crew for the different piloting modes (manual, autopilot).

No a/c has such a specific alert**.** However, some aircraft have other means to detect abnormal pitch trim position like:

— Stabiliser cannot be inappropriately positioned (i.e. in a position that could somehow affect any pitch manoeuvre) per design,
— Alerts in case of failure conditions (e.g. jam, runaway, mis-trim, etc.),
— Alerts in case of abnormal configuration (e.g. T/O configuration, out of trim).

d. For your aeroplanes, did you investigate longitudinal control characteristics beyond the current CS 25.143 and 25.145 requirements, in particular cases where the pitch trim is commanded at its maximum nose up position (either manually or by an automatic trim system)? If yes, please explain what has been investigated and the finding.

Manufacturers either did not investigate characteristics beyond the certification requirements, they decline to provide information, or the investigations were limited to practicable manoeuvres and expected THS settings.

Appendix 3: Evaluation of the proportion of large aeroplanes (operated by EASA Member States operators in commercial air transport) that are equipped with a system reducing the G/A thrust

EASA evaluated the proportion of large aeroplanes operated by EASA Member States operators that are or will be equipped with a system reducing the G/A thrust.

Part A: Current fleet of in-service aeroplanes

The information on the total number of aeroplanes from a database[16] was integrated with information provided by manufacturers who specified which aeroplane types are actually equipped. The information below provides a snapshot view on the current fleet as of 10 January 2017.

The following criteria were used when selecting the information from the database:

1) Aeroplanes certified in the CS-25 category (large aeroplanes)
2) Aeroplanes operated in commercial air transport (CAT)
3) Aeroplanes operated by EASA MS operators

The following table shows the aeroplane manufacturers, the corresponding aeroplane types, the aeroplanes equipped with a go-around thrust reduction system, and the ones which are not equipped.

Aeroplane Manufacturer	Aeroplane Type	Without system	With system
Aerospatiale	Corvette	2	
Airbus	A300	26	
Airbus	A310	6	
Airbus	A318	28	
Airbus	A319	488	
Airbus	A320	892	
Airbus	A321	301	
Airbus	A330	228	
Airbus	A340	130	
Airbus	A350		8
Airbus	A380		36
Aircraft Industries - Let	L-410	34	
Antonov	An-26	11	
ATR	ATR 42	74	
ATR	ATR 72	211	
BAE SYSTEMS (Avro)	RJ Avroliner	60	

[16] Ascend Fleets from FlightGlobal

Aeroplane Manufacturer	Aeroplane Type	Without system	With system
BAE SYSTEMS (HS)	125/Hawker	10	
BAE SYSTEMS (HS)	146	23	
BAE SYSTEMS (HS)	ATP	36	
BAE SYSTEMS (Jetstream)	Jetstream 31	30	
BAE SYSTEMS (Jetstream)	Jetstream 41	22	
Beechcraft Corp	King Air 350	12	
Boeing	717	18	
Boeing	727	4	
Boeing	737 (CFMI)		209
Boeing	737 (JT8D)	1	
Boeing	737 (NG)		840
Boeing	747	3	145
Boeing	757		129
Boeing	767		82
Boeing	777		201
Boeing	787		83
Boeing (McDonnell-Douglas)	MD-11	14	
Boeing (McDonnell-Douglas)	MD-80	30	
Bombardier (Canadair)	Challenger 300	48	
Bombardier (Canadair)	Challenger 350	33	
Bombardier (Canadair)	Challenger 600 / 601 / 604 / 605	121	
Bombardier (Canadair)	Challenger 650	5	
Bombardier (Canadair)	CRJ Regional Jet	42	
Bombardier (Canadair)	CRJ1000 Regional Jet	32	
Bombardier (Canadair)	CRJ700 Regional Jet	17	
Bombardier (Canadair)	CRJ900 Regional Jet	58	
Bombardier (Canadair)	CSeries	7	
Bombardier (Canadair)	Global 5000	46	
Bombardier (Canadair)	Global Express/Global 6000	158	
Bombardier (de Havilland)	Dash 8	214	
Bombardier (de Havilland)	DHC-7	1	
Bombardier (Learjet)	Learjet 24	1	
Bombardier (Learjet)	Learjet 25	2	
Bombardier (Learjet)	Learjet 31	8	
Bombardier (Learjet)	Learjet 35	27	
Bombardier (Learjet)	Learjet 36	1	
Bombardier (Learjet)	Learjet 40	13	

Aeroplane Manufacturer	Aeroplane Type	Without system	With system
Bombardier (Learjet)	Learjet 45	33	
Bombardier (Learjet)	Learjet 55	9	
Bombardier (Learjet)	Learjet 60	36	
Bombardier (Learjet)	Learjet 75	6	
Bombardier (Shorts)	360	6	
Cessna	Citation Bravo	34	
Cessna	Citation Encore	9	
Cessna	Citation Excel	24	
Cessna	Citation II	39	
Cessna	Citation III	8	
Cessna	Citation Latitude	3	
Cessna	Citation S/II	4	
Cessna	Citation Sovereign	32	
Cessna	Citation Ultra	6	
Cessna	Citation V	5	
Cessna	Citation VI	2	
Cessna	Citation VII	9	
Cessna	Citation X	16	
Cessna	Citation XLS	118	
Cessna	CJ3	54	
Cessna	CJ4	25	
Dassault Aviation	Falcon 10/100	6	
Dassault Aviation	Falcon 20/200	6	
Dassault Aviation	Falcon 2000	111	
Dassault Aviation	Falcon 50	21	
Dassault Aviation	Falcon 7X	106	
Dassault Aviation	Falcon 8X	2	
Dassault Aviation	Falcon 900	88	
Embraer	170	34	
Embraer	175	42	
Embraer	190	115	
Embraer	195	61	
Embraer	EMB-120 Brasilia	14	
Embraer	ERJ-135	87	
Embraer	ERJ-140	9	
Embraer	ERJ-145	68	
Embraer	Legacy 450	2	

Aeroplane Manufacturer	Aeroplane Type	Without system	With system
Embraer	Legacy 500	3	
Embraer	Phenom 300	57	
Fairchild (Swearingen)	Merlin III	1	
Fairchild/Dornier	Dornier 328	27	
Fairchild/Dornier	Dornier 328JET	19	
Fokker	F100		31
Fokker	F50	30	
Fokker	F70		17
Fokker	F27	5	
Gulfstream Aerospace	Gulfstream G280	9	
Gulfstream Aerospace	Gulfstream G450	24	
Gulfstream Aerospace	Gulfstream G550	64	
Gulfstream Aerospace	Gulfstream G650	33	
Gulfstream Aerospace	Gulfstream IV	7	
Gulfstream Aerospace	Gulfstream V	6	
Harbin Embraer Aircraft Industry	ERJ-145	7	
Hawker Beechcraft	125/Hawker	73	
Hawker Beechcraft	Beech 1900	29	
Hawker Beechcraft	Hawker 400/Beechjet 400	30	
Hawker Beechcraft	Hawker 4000	5	
Hawker Beechcraft	King Air 300	4	
Hawker Beechcraft	King Air 350	26	
Israel Aerospace Industries	Astra/G100	4	
Israel Aerospace Industries	Gulfstream G150	6	
Israel Aerospace Industries	Gulfstream G200 (IAI Galaxy)	23	
Mitsubishi	MU-300 Diamond	1	
Saab	2000	33	
Saab	340	70	
United Aircraft Corporation (Sukhoi)	Superjet 100	4	
United Aircraft Corporation (Yakovlev)	Yak-40	1	
United Aircraft Corporation (Yakovlev)	Yak-42	1	
WSK-PZL Mielec	An-28/M28	12	
Grand Total		**5,392**	**1,781**

Therefore, around a quarter (24.8 %) of the current fleet is equipped.

Part B: Aeroplanes to be manufactured and put into service in the next 2 years

This part provides a view on the level of equipment of aeroplanes to be manufactured and put into service in the next 2 years (2017-2018). The information on the total number of aeroplanes from a database[17] was integrated with information provided by manufacturers who specified which aeroplanes are actually equipped. The result of this assessment is used as a basis for the assessment of the future fleet provided in part C of this appendix.

The following criteria were used when selecting the information from the database:
1) Aeroplanes certified in the CS-25 category (large aeroplanes)
2) Aeroplanes operated in commercial air transport (CAT)
3) Aeroplanes operated by EASA MS operators
4) Average age of aeroplanes between 0 and 2 years[18]

Another important assumption had to be made: for some Airbus types the system will remain optional, based on customer's request. In these cases, it was assumed that 50 % of the aeroplanes will be equipped.

[17] Ascend Fleets from FlightGlobal
[18] The reason why two years have been included is to have a more detailed statistical basis in order to calculate the evolution of aircraft fleet with/without the system in the future. Indeed by taking only one year the overproduction/underproduction of one aircraft type could influence the final result.

Aeroplane Manufacturer	Aeroplane Type	Total	With system	Without system
Airbus	A320	125[19]	63	63
Airbus	A321	49[20]	25	25
Airbus	A330	16	8	8
Airbus	A350	8	8	0
Airbus	A380	3	3	0
Aircraft Industries - Let	L-410	5	0	5
ATR	ATR 42	1	0	1
ATR	ATR 72	33	0	33
Beechcraft Corp	King Air 350	5	0	5
Boeing	737 (NG)	141	141	0
Boeing	747	6	6	0
Boeing	777	17	17	0
Boeing	787	51	51	0
Bombardier (Canadair)	Challenger 350	21	0	21
Bombardier (Canadair)	Challenger 600 / 601 / 604 / 605	3	0	3
Bombardier (Canadair)	Challenger 650	5	0	5
Bombardier (Canadair)	CRJ1000 Regional Jet	9	0	9
Bombardier (Canadair)	CSeries	7	0	7
Bombardier (Canadair)	Global 5000	2	0	2
Bombardier (Canadair)	Global Express / Global 6000	29	0	29
Bombardier (de Havilland)	Dash 8	7	0	7
Bombardier (Learjet)	Learjet 75	3	0	3
Cessna	Citation Latitude	3	0	3
Cessna	Citation Sovereign	2	0	2
Cessna	Citation XLS	7	0	7
Cessna	CJ3	4	0	4
Cessna	CJ4	7	0	7
Dassault Aviation	Falcon 2000	10	0	10
Dassault Aviation	Falcon 7X	8	0	8
Dassault Aviation	Falcon 8X	2	0	2
Dassault Aviation	Falcon 900	1	0	1
Embraer	175	4	0	4
Embraer	190	3	0	3
Embraer	ERJ-135	6	0	6

[19] Difference due to rounding.
[20] Difference due to rounding.

Aeroplane Manufacturer	Aeroplane Type	Total	With system	Without system
Embraer	Legacy 450	2	0	2
Embraer	Legacy 500	2	0	2
Embraer	Phenom 300	24	0	24
Gulfstream Aerospace	Gulfstream G280	4	0	4
Gulfstream Aerospace	Gulfstream G550	2	0	2
Gulfstream Aerospace	Gulfstream G650	14	0	14
Hawker Beechcraft	King Air 350	1	0	1
United Aircraft Corporation (Sukhoi)	Superjet 100	3	0	3
WSK-PZL Mielec	An-28/M28	9	0	9
Grand Total		**664**	321	343

This leads to the following results, that are used in part C below:
— New aeroplanes equipped: 48.34 %
— New aeroplanes not equipped: 51.66 %

Part C: Future fleet of aeroplanes

This part provides a view on the evolution of proportion of aeroplanes equipped with a G/A thrust reduction system up to 2050. This assessment is based on the results of part A and part B of this appendix.
The proportion of aeroplanes equipped determined in part A is shown for year 2017 below. For the following years, the new aeroplanes equipped with a system (calculated in Part B) affect gradually the final percentage of aeroplanes (by replacing the ones leaving the in-service fleet).
As from the year 2041, the percentage of aeroplanes with/without a G/A thrust reduction system remains stable. This prediction up to 2050 is based on assumptions and only gives an indication.

Year	Without system	With system
2017	75.2 %	24.8 %
2018	73.4 %	26.6 %
2019	72.6 %	27.4 %
2020	71.9 %	28.1 %
2021	71.2 %	28.8 %
2022	70.4 %	29.6 %
2023	69.6 %	30.4 %
2024	68.9 %	31.1 %
2025	68.2 %	31.8 %
2026	67.2 %	32.8 %
2027	66.0 %	34.0 %
2028	64.9 %	35.1 %

Year	Without system	With system
2029	63.8 %	36.2 %
2030	63.0 %	37.0 %
2031	62.1 %	37.9 %
2032	61.2 %	38.8 %
2033	59.9 %	40.1 %
2034	58.6 %	41.4 %
2035	57.0 %	43.0 %
2036	55.7 %	44.3 %
2037	54.9 %	45.1 %
2038	54.3 %	45.7 %
2039	53.6 %	46.4 %
2040	52.9 %	47.1 %
2041	52.4 %	47.6 %
2042	51.9 %	48.1 %
2043	51.7 %	48.3 %
2044	51.7 %	48.3 %
2045	51.7 %	48.3 %
2046	51.7 %	48.3 %
2047	51.7 %	48.3 %
2048	51.7 %	48.3 %
2049	51.7 %	48.3 %
2050	51.7 %	48.3 %