Published August 2013

Study

on Aeroplane State Awareness during Go-Around

BEA

Bureau d'Enquêtes et d'Analyses pour la sécurité de l'aviation civile

Ministère de l'Ecologie, du Développement durable et de l'Energie

FOREWORD

The BEA is the French authority for safety investigations in civil aviation. The sole objective of its investigations and studies is to improve aviation safety and shall in no case be concerned with apportioning blame or liability. The BEA's investigations are separate from and without prejudice to any judicial or administrative proceedings to apportion blame or liability.

This study is based on the results of closed investigations conducted by the BEA or by non-French investigation authorities.

This is a courtesy translation by the BEA of the Study. As accurate as the translation may be, the original text in French is the work of reference. ADDITION

ADDITION

In order to clarify Safety Recommendation [FRAN-2013-023] in this courtesy translation, three words have been added to improve understanding thereof.

CONTENTS

GLOSSARY

ADIRU	Air Data and Inertial Reference Unit
A/THR	Auto-Thrust
ADREP	Accident Data Reporting System
AIDS	FAA Accident/Incident Data System
AP	Autopilot
ASAGA	Aeroplane State Awareness during Go-Around
ASRS	NASA Aviation Safety Reporting System http://asrs.arc.nasa.gov/
AT	Auto-Throttle
ATC	Air Traffic Control
ATSB	Australian Transport Safety Board
BEA	*Bureau d'Enquêtes et d'Analyse pour la sécurité de l'aviation civile* (French authority responsible for safety investigations in civil aviation)
CAST	Commercial Aviation Safety Team
CAVOK	Ceiling and Visibility OK
CFIT	Controlled Flight Into Terrain
CP	Co-Pilot
CPL	Commercial Pilot Licence
CR	Check-Ride
CRM	Crew Resource Management
CS 25	Certification Specification 25
CVR	Cockpit Voice Recorder
DME	Distance Measuring Equipment
DSAC	French civil aviation safety directorate
EASA	European Aviation Safety Agency
ECAM	Electronic Centralized Aircraft Monitoring
ECCAIRS	European Co-ordination Centre for Accident and Incident Reporting Systems
(E)GPWS	(Enhanced) Ground Proximity Warning System
FAA	Federal Aviation Administration
FAF	Final Approach Fix
FC	Flight Crew
FCL	Flight Crew Licence
FCOM	Flight Crew Operational Manual
FCP	Flight Control Panel
FCU	Flight Control Unit
FD	Flight Director
FDR	Flight Data Recorder
FFS	Full Flight Simulator
FFS	Full Flight Simulator
FL	Flight Level
FMA	Flight Mode Annunciator
FMC	Flight Management Computer
FMS	Flight Management System
FSTD	Flight Simulation Training Devices
FTO	Flight Training Organisation
GA	Go-Around
GPS	Global Positioning System
ICAO	International Civil Aviation Organisation
IFR	Instrument Flight Rules
ILS	Instrument Landing System
IMC	Instrument Meteorological Condition

ISAE	*Institut Supérieur de l'Aéronautique et de l'Espace* (School of aerospace engineering in Toulouse, France)
LOFT	Line Oriented Flight Training
LT	Line Training
MCC	Multi Crew Cooperation
MCP	Main Control Panel
MPA	Multi Pilot Aircraft
ND	Navigation Display
NM	Nautical Miles
NTSB	National Transportation Safety Board
OCV	*Organisme du Contrôle en Vol* (French organisation concerned with flight safety)
ORA	Organisation Requirements for Aircrew
PANS-OPS	Procedures for Air Navigation Services - Aircraft Operations
PF	Pilot Flying
PFD	Primary Flight Display
PM	Pilot Monitoring
PNF/PM	Pilot Non Flying
QRH	Quick Reference Hand Book
SID	Standard Instrument Departure
SOP	Standard Operating Procedure
STAR	Standard Terminal Arrival Route
TOGA	Take-Off Go-around
TR	Type Rating
TRI/E	Type Rating Instructor/Examiner
TRTO	Type Rating Training Organisation
TSB	Transportation Safety Board of Canada
VFE	Maximum Speed with Flaps Extended
VLS	Lowest Selectable Speed
VOR	VHF Omnidirectional Range
ZFTT	Zero Fight Time Training
ZI	Zone of Interest

CONTEXT AND ORGANISATION OF THE STUDY

Towards the end of the 2000's, the BEA observed that a number of public air transport accidents or serious incidents were caused by a problem relating to "aeroplane state awareness during go-around" (ASAGA), which may otherwise be described as a loss of control of the flight path during or at the end of a go-around manoeuvre (GA). Other events revealed inadequate management by the flight crew of the relationship between pitch attitude and thrust, with go-around mode not engaged, but with the aeroplane close to the ground and with the crew attempting to climb.

Moreover, these events seemed to have some common features, such as startle effect, the phenomenon of excessive preoccupation by at least one member of the crew, poor communication between crew members and difficulties in managing the automatic systems.

A study was thus initiated with a view to:
- Listing and analysing the factors common to these events;
- Suggesting strategies to prevent their recurrence.

The following organisations were invited to participate in the study:

- Air France
- Corsair
- XL Airways France
- The *Organisme du Contrôle en Vol* (OCV) (the French flight safety organisation)
- The *Direction de la Sécurité de l'Aviation Civile* (DSAC) (the French civil aviation safety directorate)
- The manufacturer Airbus
- The manufacturer Boeing
- The National Transportation Safety Board (NTSB)
- The European Aviation Safety Agency (EASA)
- The International Civil Aviation Organisation (ICAO)
- The *Institut Supérieur de l'Aéronautique et de l'Espace* (ISAE) (School of aerospace engineering)
- A pilot specialising in human factors and pilot training,
- Dédale, a company specialising in human factors and risk management.

During the study, contacts were made with the FAA and with the international Commercial Aviation Safety Team (CAST).

The first phase of the work was a statistical study, primarily of data provided by the BEA and ICAO. During a second phase of the study, significant events were selected and analysed. Subsequently, a survey was sent out to airline pilots and simulator sessions were performed on Boeing 777 and Airbus A330.

All the results were then analysed and presented to the participants in the study.

This report includes 34 safety recommendations.

1 - STATISTICAL STUDY

1.1 Introduction

The BEA is responsible for investigating all public transport accidents that occur in France. It also participates in investigations conducted into accidents outside France involving aircraft of French design and manufacture, notably Airbus aircraft, as State of Design and Manufacture.

In 2009 and 2010, the BEA thus participated in investigations into the following events:

- The fatal accident to an Airbus A310 on 29 June 2009 at Moroni (Comoros);
- The fatal accident to an Airbus A300 B4 on 13 April 2010 at Monterrey (Mexico);
- The fatal accident to an Airbus A330-200 on 12 May 2010 at Tripoli (Libya).

The first accident occurred during final approach in full thrust configuration and with a high nose-up attitude. The two other accidents occurred during go-around.

Prompted by these three accidents, the BEA decided to launch an overall study into aeroplane state awareness during go-around (ASAGA).

The purpose of the study was to:

- List and study the ASAGA-type events that have occurred in public transport over the last 25 years;
- Determine and analyse the common factors in these events;
- Suggest strategies to prevent their recurrence.

Initially, the BEA searched for ASAGA-type events in the database maintained by the International Civil Aviation Organisation (ICAO), and then in its own internal database. It then broadened its search to include data from American agencies.

1.2 Data obtained from ICAO

In accordance with international standards[1], ICAO must be notified of all accidents and serious incidents that occur in public transport involving an aircraft with a maximum take-off weight of more than 2,250 kg. The organisation uses the database system operated by the *European Co-ordination Centre for Accident and Incident Reporting Systems* (ECCAIRS) to record the events reported to ICAO in accordance with the ADREP procedure.

ICAO provided its database to the BEA. It contained 20,490 occurrences, mainly described in the English language.

The BEA restricted its selection to events involving aeroplanes. It did not consider any events caused by the following circumstances:

- BIRD: Birdstrike,
- CABIN: Cabin safety events,
- F-NI: Fire/smoke (non-impact),
- GCOL: Ground collision,
- LOC-G: Loss of control - Ground,
- MAC: Airprox/near miss/mid-air collision,
- RAMP: Ground handling,
- RE: Runway excursion,

[1] Annex 13, Chapter 7: ADREP reports.

- RI-A: Runway incursion – Animal,
- RI-VAP: Runway incursion – vehicle/aircraft/person,
- RI-O: Runway incursion – Other,
- RI-VA: Runway incursion – vehicle or aircraft,
- SCF-PP: Powerplant failure or malfunction,
- SEC: Security-related problems.

The study also excluded events that occurred during parking, taxiing, at take-off and "en-route".

The study included all events that included at least one of the words: "go", "around", "missed", "remise", "gaz", "rdg", "meta", "haga", "frustrado".

Twenty-one events were ultimately selected based on their correspondence to the study criteria. The aircrafts involved were primarily manufactured by Airbus and Boeing, in comparable proportions. Eleven ASAGA-type events occurred between 2000 and 2009, compared with 10 between 1985 and 2000.

However, at least 2 events that occurred before 31 December 2009 did not appear. These events were:

- The serious incident to an A310 on 24 September 1994 at Orly (France);
- The serious incident to a B737 on 23 September 2007 at Bournemouth (United Kingdom).

These two events should have been present in the ICAO database. The ICAO database was therefore not exhaustive. Consequently, the BEA searched its own database and asked the NTSB to search its database.

1.3 BEA Data

The BEA searched its database using the same search criteria as it had used for the ICAO database.

The search brought to light fourteen accidents and serious incidents. Five of these had not been found in the ICAO database search. They are available in the appendices.

Moreover, 4 ASAGA-type investigations were not analysed since they were on-going as of 1st December 2012. These were:

- The fatal accident to an Airbus A310 on 29 June 2009 at Moroni (Comoros);
- The fatal accident to an Airbus A300 B4 on 13 April 2010 at Monterrey (Mexico);
- The fatal accident to an A330-200 on 12 May 2010 at Tripoli (Libya);
- The serious incident to a Boeing B777 on 20 November 2011 at Charles-de-Gaulle (France).

1.4 Data obtained from the NTSB

Events investigated by the NTSB

At the request of the BEA, the NTSB searched its database using the criteria used to search the ICAO database and generated a 177-page table. This table included a large number of light aircraft. Only 2 events satisfied the inclusion criteria for the study. They are included in the appendices.

Events occurring outside the United States to aircraft of American design

The NTSB informed the BEA that it does not record detailed information in its own database about events in which it is involved as an accredited representative.

The NTSB suggested that data involving these investigations should be obtained directly from the States of Occurrence.

The BEA was thus unable to make an exhaustive evaluation of ASAGA-type events relating to Boeing aircraft that occurred outside of the United States.

1.5 Data obtained from the FAA

The FAA searched the AIDS and ASRS databases, and that of the NTSB. After studying the results, the BEA selected 9 anonymous reports submitted voluntarily that are presented in detail in the appendices.

These reports relate primarily to Airbus, Boeing and Bombardier aircraft. A summarised presentation of these events is included in section 2.2.

1.6 Summary

Twenty-one ASAGA-type events were selected from the 20,490 in the ICAO database. They relate primarily to Boeing and Airbus aeroplanes, since these account for almost 90% of the global fleet of public transport aircraft whose weight is over 5.7 tonnes.

The NTSB accident and incident database did not contain significant data regarding ASAGA type events occurring in the United States. However, anonymous reports indicate that some ASAGA events involving heavy aircraft have occurred in the United States where the commercial traffic is the most extensive in the world.

Moreover, the NTSB does not maintain a database of events that occur outside the United States involving aircraft of American design and manufacture. Therefore, it was unfortunately not possible to identify any additional ASAGA- type events involving U.S. manufactured aircraft and in particular those of Boeing types.

Between 1985 and 2010, at least 25 ASAGA-type accidents or serious incidents were reported (21 obtained from the ICAO database and 4 from that of the BEA). While these events are fairly infrequent, their consequences are serious. The risk of an accident is thus difficult to estimate since it is the product of the probability of occurrence and the severity

In order to improve its evaluation of the risk, the BEA compared the annual number of victims of ASAGA-type accidents with the total number recorded by ICAO in public transport (PT). The results are presented in the table below:

Year	Number of fatalities in PT	Number of fatalities in ASAGA-type accidents	Rate as a %	Number of ASAGA-type fatal accidents
2010	406	109	26.85	2
2009	795	161	20.25	2
2008	703	15	2.13	2
2007	816	0	0	0
2006	482	113	23.44	1
2005	746	0	0	0
2004	485	0	0	0
2003	563	0	0	0
2002	903	0	0	0
2001	986	2	0.20	1
2000	976	143	14.65	1
1999	576	0	0	0
1998	940	101	10.74	1
1997	1111	0	0	0
1996	1290	0	0	0
1995	1204	0	0	0
1994	1565	264	16.87	1
1993	1432	0	0	0
1992	1561	4	0.26	1
1991	1272	0	0	0
1990	483	0	0	0
1989	1525	0	0	0
1988	1338	3	0.22	1
1987	1203	0	0	0
1986	719	0	0	0
1985	1916	41	2.04	2
TOTAL	25996	954	3.67	15

World-wide figures for fatalities caused by ASAGA-type accidents in public transport.

Thus, even though the number of ASAGA-type events is relatively low, each of them produces a high number of casualties, which justifies taking specific prevention measures.

1.7 Data obtained from CAST

The Commercial Aviation Safety Team (CAST) is the result of a partnership between the authorities and aeronautical industries. Its aim is to identify and promote the best safety initiatives. The FAA, EASA, Airbus, Boeing, Airlines for America (A4A), the Airline Pilots Association (ALPA) and the Flight Safety Foundation (FSF) all participate in it.

CAST is made up of three entities:

- JSAT performs in-depth analysis and proposes numerous recommendations;
- JSIT evaluates and selects these recommendations;
- JIMDAT monitors their implementation.

In August 2008, CAT published a report that is available at the following address: http://www.cast-safety.org/pdf/cast_automation_aug08.pdf.

This report notably states that:

The Team reviewed automation policies from 16 air carriers to identify common concepts in order to build a set of industry practices that could establish a baseline for an industry-wide automation policy.
The Team found that a fundamental problem applied to almost all cases in the dataset: the flight crew did not comprehend what the automation was doing, or did not know how to manipulate the automation to eliminate the error. In such cases, when the crew changed automation levels they often exacerbated the problem.
In all 50 cases, pilots were unable return the aircraft to the desired flight path in a timely manner. This was due to two root causes: inadequate training and system knowledge; and the unexpected incompatibility of the automation system with the flight regime confronting pilots in their normal duties

Two JSAT working groups linked to the ASAGA study have since been launched:

- *Attitude Awareness group*
- *Energy State Awareness group.*

As of 1st October 2012, no report has been published by these two JSAT/CAST groups.

In 2011, the BEA met with teams from CAST, the NTSB and the FAA. The various entities agreed that the CFIT categorisation did not correspond to the events defined by the BEA as being "Loss of control of the flight path in the approach phase during a go-around manoeuvre". Equally, the term *Loss of Control during Go-around (LCGA)* is too simplistic. The term *Aeroplane State Awareness during Go-Around (ASAGA)* was then proposed by the members to express the phenomenon defined by the BEA. In relation to the issues to be considered by the study, the following factors were mentioned:

- Position of the horizontal stabilizer trim when close to the full nose-up position;
- Insufficient CRM, notably with regard to the contribution from the Pilot Monitoring (PM/PNF/PM[2]);
- Unfamiliarity with automatic systems;
- Spatial disorientation;
- Somatogravic illusions;
- Interference from ATC.

[2] In 2013, Airbus adopted the term PM in place of PNF/PM.

2 - IN-DEPTH STUDY OF A SELECTION OF EVENTS

2.1 Summary of events

With a view to identifying common aspects, the BEA selected and studied 10 accidents and serious incidents, in addition to a selection of 6 summaries taken from the various databases searched.

These events are summarised below in chronological order, and are described in detail later in this section.

ACCIDENT/INCIDENT
Event 1 - A310 Surat-Thani 11/12/1998
Event 2 - A320 Bahrein 23/08/2000
Event 3 - A320 Sochi 2/05/2006
Event 4 - A320 Naples 09/2006
Event 5 - A330 Abidjan 30/03/2007
Event 6 - A320 Melbourne 21/07/2007
Event 7 - B737 Bournemouth 23/09/2007
Event 8 - A320 Perpignan 27/11/2008
Event 9 - A319 Roissy 23/09/2009
Event 10 - A380 New York 11/10/2010

6 summaries of events (accidents/incidents or ASRS events) obtained from the various international databases searched were also selected and are in the appendices.

Event 11 - B757 Gardemoen 22/01/2002
Event 12 - B737 Bremen 27/04/1998
Event 13 - SA226 Shamattawa 11/10/2001
Event 14 - CRJ700 XXXX XXXX ASRS
Event 15 - A320 XXXX XXXX ASRS
Event 16 - B737-800 XXXX XXXX ASRS

Event 1

Type of event	Accident
Date and time:	11 December 1998
Place	On approach to Surat-Thani (Thailand)
Aircraft	A310
Reference	Paper report only

History of flight

About half-an-hour after taking-off, the Surat-Thani approach controller cleared the flight crew to perform a VOR-DME approach at night to runway 22. The Captain was PF. The surface wind was calm, visibility was 1,500 metres, the cloud base was at 1,800 feet and there was light rain. Based on FDR parameters, at an altitude of about 2,000 feet, a wind from 020° of 25 kt had been calculated for the three approaches.

When the crew called-out that it was passing the FAF, the airport controller cleared the crew to land on runway 22. One minute later, when about 3 NM from the runway, the crew indicated that it had the runway in sight. The autopilot was disengaged at 696 feet. The controller replied that he could see the aeroplane. Despite this, the Captain decided to abort the approach and to perform a second one since he considered that the aeroplane's flight path was too far to the left of the final approach segment. He indicated during the go-around that the aeroplane's vertical speed was high. The co-pilot (PNF/PM) replied that it was "probably because of the plane's low weight.

During the second approach, performed with autopilot engaged, the crew did not have the runway in sight. The Captain informed the co-pilot that he was not on the radial of the final approach segment and stated that it would be difficult to land if the flight path was not corrected. The crew saw the runway very near to the aeroplane on the right side, but could not land. The Captain decided once again to abort the approach and to make a third attempt.

The Captain announced to the passengers that he was going to attempt a third landing approach and that, if landing was not possible, he would have to return to Bangkok. The airport controller cleared the crew to land on runway 22. The co-pilot read back the clearance and radar contact was lost soon afterwards.

During the third approach, the Captain indicated that the aeroplane was too near to the runway to attempt a landing. When initiating the go-around, he triggered the "GO Levers", an action he had not taken during the first two go-arounds.

Due to the combined effect of the increase in thrust and the PF's use of the electric trim (a switch on the sidestick) for a nose-up trim, the nose-up pitching moment generated during the third approach was much greater than that generated during the first two approaches. The aircraft's nose-up pitch, combined with the loss of situational awareness (as evidenced by discussions about this go-around during the return to Bangkok) resulted in the aircraft stalling.

The PF made his first pitch input on the sidestick when the pitch attitude reached 36 degrees. The FCOM recommends a maximum pitch attitude of 18 degrees. During the stall, nose-up inputs on the sidestick were recorded. Similarly, the first input to counter the roll was taken when the roll angle was 50 degrees.

During all three approaches, the PF flew too far to the left of the radial of the final approach segment and did not correct this deviation. Moreover, his last skills checks revealed that he was not very familiar with non-precision approaches.

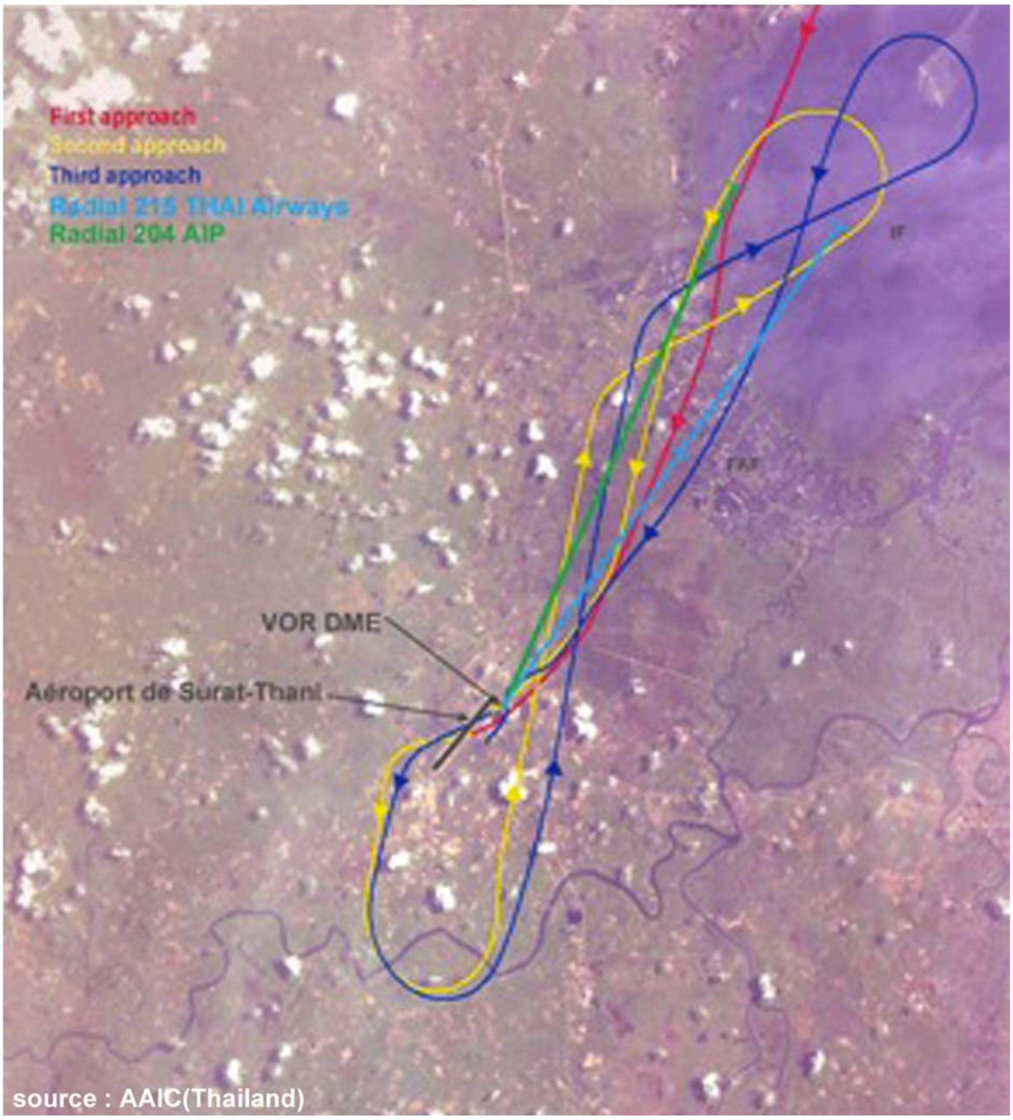

Figure 1 : Approach from 11.37.33 UTC to 12.07.35 UTC

Recommendations

Several safety recommendations were issued. Specifically,

- Regarding upset recovery training:

Pilots should undergo aeroplane upset recovery training

- Regarding CRM:

Aviation personnel should attend CRM training on human factors training manual ICAO document 9683-AN/950

Event 2

Type of event	Accident
Date and time:	23 August 2000
Place	On approach to Bahrain
Aircraft	A320
Reference	http://www.bea.aero/docspa/2000/a40-ek000823a/htm/a40-ek000823a.html

History of flight

The Captain (PF) made a direct VOR DME approach to runway 12 at night under CAVOK meteorological conditions, with the airport in sight. The approach was not stabilised since the airspeed was excessive and the flaps configuration was not standard. The aeroplane flew over the FAF at 223 kt, although the calculated airspeed on the FMS was 136 kt. During the descent, the AP and FD were disengaged and the aeroplane was flown manually. When at a height of 500 ft, the aircraft's airspeed was 198 kt and the flaps were in position 2 instead of FULL. The landing gear was extended.

The Captain decided to fly a 360° to the left on short final. The Captain ordered flaps 3 and then FULL. During the turn, the height ranged from 965 ft to 332 ft and the bank angle exceeded 25° on several occasions. No callouts from the co-pilot were recorded.

The aircraft's flight path crossed the runway centreline perpendicularly. Just as the co-pilot indicated that he had seen it, the Captain called out that they had overshot the runway centreline and then veered to the left. The pitch attitude increased gradually to 14 degrees nose-up, and then dropped to 9 degrees nose-down. The Captain requested that the PNF/PM tell the controller that they were going to perform a go-around. The thrust levers were pushed forwards to the TOGA detent. The flaps were set at position 3 and the landing gear was retracted. The pitch attitude reduced to 6° nose-up instead of increasing to 15° nose-up as recommended in the GA procedure, which generated a rapid increase in airspeed. However, the altitude increased steadily due to the nose-up pitch attitude.

Just as the controller offered new radar vectoring which was accepted by the crew, the master warning associated with VFE overspeed condition sounded. The latter was called out by the PNF/PM. The Captain asked the co-pilot to retract the flaps, without specifying a position. The Captain then held the sidestick forward of the neutral position for 11 seconds, even though the aeroplane's height was 1,050 ft. The investigation considered that the most likely explanation for this nose-down input at night was a somatogravic illusion. The PFD was nonetheless correctly displaying the aircraft's true pitch attitude. The report indicates that this pitch attitude information was not used by the Captain since he was mentally overloaded, while his attention was monopolized by monitoring the airspeed.

The pitch attitude reduced rapidly due to the nose-down input, reaching 12° nose-down. The "sink rate" aural warning from the GPWS sounded and the Captain pushed the sidestick forward. The "pull-up" warning then sounded and continued until the aircraft's impact with the sea. There was no verbal communication between the flight crew members after the activation of the GPWS warning. A few seconds before the impact, the Captain pulled back on the sidestick. The last recording obtained from the FDR indicated airspeed of 282 kt and a pitch attitude of 6° nose-down.

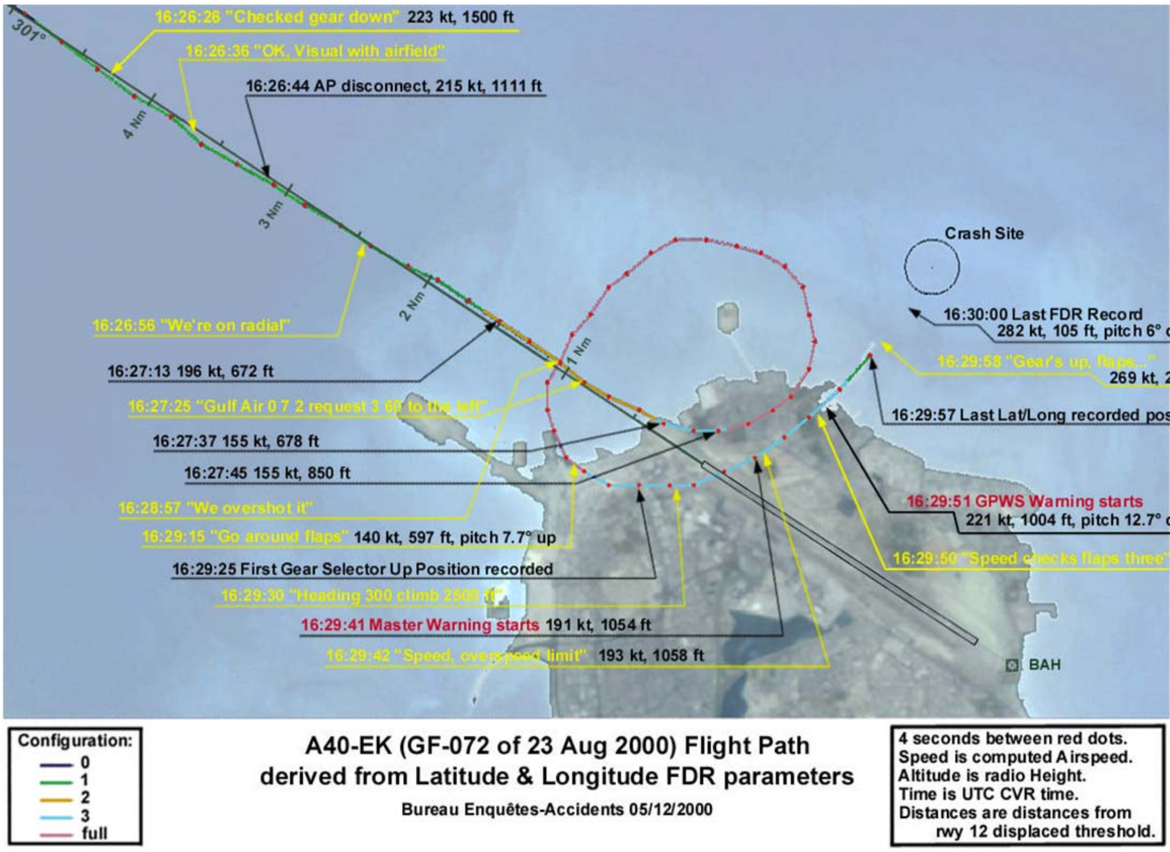

Figure 2

Analysis / Conclusion

The report indicates that the Captain's nose-down inputs can probably be explained by an incorrect perception of a nose-up attitude, characteristic of a somatogravic illusion.

The co-pilot was reserved and did not perform his monitoring duties, notably during the 360° turn. Moreover, the investigation commission highlighted the non-compliance with the SOP and the violations of operational procedures. The go-around could also be perceived as being a failure for the Captain. The CRM between the crew members was inadequate. The commission of inquiry also pointed to the inadequate reaction by the crew to the GPWS warnings. Finally, systemic malfunctions within the airline and the regulatory authority were highlighted.

Recommendations

Several recommendations were issued, including a review of the procedures, training in compliance with SOP's, reinforcing of the co-pilot's role , training to deal with the risk associated with CFIT and training in GPWS warnings:

To ensure that Gulf Air reviews and enhances, in accordance with DGCAM regulatory requirements, the A320 flight crew training programmes to ensure full compliance with the standard operating procedures, and increase the effectiveness of the first officer. The training in CFIT avoidance and GPWS responses should be augmented by including it in the recurrent training programme, with a detailed syllabus in accordance with DGCAM requirements. The Approach-and-Landing Accident Reduction (ALAR) toolkit produced by the Flight Safety Foundation, with extensive airline industry input, could be a key element in the updated training programme. (B-01-3)

Event 3

Type of event	Accident
Date and time:	2 May 2006
Place	On approach to Sochi
Aircraft	A320
Reference	http://www.bea.aero/docspa/2006/ek-9060502/pdf/ek-9060502.pdf Report issued by the MAK

History of flight

The crew was performing an ILS approach to Sochi at night. The meteorological conditions were close to the airport minima and the co-pilot (PNF/PM) indicated that he was tired. The aircraft was under radar vectoring for an ILS approach. The autopilot was engaged in LOC and G/S modes, with these modes displayed on the FMA, and the aeroplane was in its landing configuration with the gear down and full flaps.
When the aeroplane reached an altitude of about 1,200 feet, and due to a lowering of the cloud base to below the minima for the procedure, the controller ordered the aircraft to abort its descent, to turn to the right and to climb to the altitude required for the go-around procedure i.e. 600 m. The crew confirmed and pressed the Push To Level Off button, which brought the aircraft to level flight. The AP mode then changed to HDG, V/S (0 ft/min). The crew selected a heading of 172° to turn to the right. The controller repeated his instruction to go around and the crew selected, undoubtedly unintentionally, an altitude of 3,200 feet instead of 2,100 feet and activated OPEN CLIMB mode. The pitch attitude increased rapidly to 21° nose-up. The airspeed dropped to slightly under VLS and the SPEED SPEED SPEED aural warning was triggered. The PF reacted by moving the thrust levers to the TOGA detent and by disengaging the AP without, however, retracting the landing gear or flaps. At this point, the aeroplane was in a bank turn to the right, with the landing gear and flaps extended, with full thrust and a nose-up attitude. Since the lateral mode was GA TRK, the FD's roll bar moved gradually to the left-hand stop.

As soon as the AP was disengaged, the Captain pushed the sidestick forward. However, the aeroplane continued to climb and its airspeed increased rapidly. When the airspeed reached about 160 knots, an altitude of 2,100 ft was selected, the aeroplane was at 1,500 feet and OPEN CLB mode was engaged. When the LVR CLB message flashed on the FMA, the Captain moved the thrust levers back to the FLEX/MCT detent and then to CLB. This had the effect of changing the A/THR mode on the FMA. The target airspeed became the GREEN DOT speed. The Captain made a number of left sidestick inputs, and almost completely countered the right bank.

The Captain then pushed the sidestick forwards several times. The investigation suggested that the nose-down inputs on the stick may have been caused by somatogravic illusions and/or by the speed approaching VFE[3]. The aural and visual MASTER WARNING triggered due to VFE being exceeded. The aeroplane bank increased to the right and the airspeed continued to increase. The flaps were retracted. Finally, at airspeed of 210 knots, the GPWS warning triggered. DUAL INPUT controls were recorded on the sidesticks. These inputs were in opposite directions, primarily sideways to the right on the Captain's side, and sideways to the left on the co-pilot's side. The pitch attitude remained negative until the impact with the sea.

[3] Pages 46 and 47 of the report published by the MAK. In the context of a loss of situational awareness, the hypothesis is that the VFE displayed in red on the PFD's speed tape being reached from above might have prompted the pilot to push forward instead of pulling back.

Analysis

The report suggests that it is possible to hypothesize that the nose-down inputs may have been due to somatogravic illusions and/or by the speed approaching VFE[4]. The commission of inquiry referred to the pilots' loss of situational awareness in pitch and roll, and inadequate or even non-existent CRM during the go-around phase and until the end of the flight. It also concluded that the Captain had engaged the aircraft in an abnormal situation and that, with the exception of his responses to requests, the co-pilot did not perform his monitoring role adequately. It also highlighted the lack of an appropriate reaction from the flight crew to the GPWS warning.

Recommendations

Several recommendations were made:

- regarding improvements to simulator training:

To review the necessity of enhancing crew simulator training in the section on flying in Flight Director mode, especially during approach and go-around;

To consider the necessity of enhanced simulator training for A320 crews.

- regarding spatial disorientation:

To organize and conduct research into the conditions under which a crew may lose spatial orientation and/or upset aircraft attitude may develop, and to issue practical recommendations to enhance flight safety. In particular, to evaluate the effect of in-flight acceleration illusions. Based on the research, to develop and introduce a specialized course for recurrent training of crews that should contain both classroom and flying training.

- regarding understanding automation:

To introduce in the A320 FCOM information clarifying specific features of activation of the OPEN CLIMB mode in various flight conditions.

- regarding low energy flight:

To introduce in the A320 FCOM a warning about possible activation of the LOW ENERGY WARNING, when the aircraft performs manoeuvres in the landing configuration with considerable changes in pitch and roll angles.

The official report includes comments from the BEA which stress the importance of the startle effect on the flight crew caused by the ATC changing the go-around procedure by giving heading and altitude instructions. Moreover, the BEA emphasised the disruption caused by the ATC message during the go-around.

The crew, now sure that they were going to land, did not expect any more disruptions. The order to stop the descent, which arrived forty-six seconds later, was thus completely unexpected and ran counter to the pilots' mental representation of the situation. This destabilised the crew, already annoyed and against the controller, in particular the Captain, who reacted to this instruction rapidly and, it appears, without developing any strategy. Further, the nature of the instructions, oriented on piloting actions instead of

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[4] Pages 46 and 47 of the report published by the MAK. In the context of a loss of situational awareness, the hypothesis is that the VFE displayed in red on the PFD's speed tape being reached from above might have prompted the pilot to push forward instead of pulling back.

consisting of an explicit order to abort the approach, may have contributed to the pilot's disorientation. The pilot carried out the instructions received in succession, but did not appear to have immediately adopted the missed approach procedure. This did not allow trained reflexes to cut in and probably contributed to his forgetting to retract the flaps, for example. Finally, during the missed approach, the Co-pilot's attention was partially distracted from following the manoeuvre by the long message from the controller that gave new instructions for the go-around and a new approach. Thus, he only intervened tardily to draw the Captain's attention to the aeroplane's attitude.

Event 4

Type of event	Serious incident
Date and time:	September 2006
Place	On approach to Naples
Aircraft	A320
Reference	Internal airline analysis

Note: no official report has been produced by an investigation agency regarding this incident. The information provided below is taken from the airline's report.

History of flight

The co-pilot (PF) performed a non-precision approach in managed mode with AP engaged to runway 06 at Naples airport At 2,100 ft QNH, on passing the minimums, the AP disengaged at the moment that the crew started a go-around. The thrust levers were pushed forward to the TOGA detent.

Engine RPM increased and the pitch attitude increased from 1.1° nose-up to 4.2° nose-up. No input on the sidesticks was recorded for 21 seconds after the AP disengaged. The pitch attitude then decreased gradually from 4.2° nose-up to 1.8° nose-down. Neither the co-pilot nor the Captain noticed the failure to attain a go-around pitch attitude, nor the resulting vertical flight path anomaly. When the airspeed reached 188 knots, approaching the VFE of 195 knots, both the Captain and the co-pilot applied a nose-up input, simultaneously, on their sidesticks. The aeroplane experienced a vertical acceleration of 1.65 G and the pitch attitude increased to 14.4° nose-up. The aeroplane began a climb to an altitude of 4,000 ft QNH, as selected on the FCU. AP 1 was then engaged. The aircraft subsequently landed without encountering any problems.

The internal investigation found that the disengagement of the AP was not noticed by the co-pilot. It had been noticed by the Captain (PNF/PM) who thought that the co-pilot had switched to manual mode.

Note: The particular functions and modes selected (a managed final approach with AP) resulted in the AP disengaging at MDA – 50 feet. This disengagement coincided with the instant when the levers were pushed forward to the TOGA detent to initiate a go-around.

Analysis / Conclusion

When performing a go-around at the minimums, the aeroplane must follow a climbing flight path. The deviation from the flight path that occurred in this case was not immediately noticed by the co-pilot or by the Captain. During this phase, the crew lost control of the flight path.

The investigation considered that the cause was an automatic (normal) disengagement of the AP that was not noticed by the co-pilot (PF).

Prompted by this incident, slight differences were identified between the information provided in Airbus's FCOM and in the airline's Operations Manual. These differences related to the pitch attitude/thrust sequence, the "Go-Around/Flaps" callout and the go-arounds initiated from an intermediate altitude.

Event 5

Type of event	Serious incident
Date and time:	30 March 2007
Place	On approach to Abidjan
Aircraft	A330
Reference	Internal airline report

Note: no official report has been produced by an investigation authority regarding this incident. The information provided below is taken from the airline's report.

History of flight

The crew performed an ILS approach at night to runway 21 at Abidjan, in stormy meteorological conditions, with a very changeable wind. The Captain (PF) disengaged the AP to fly manually at about 1,400 ft.

During the final approach, the tailwind component displayed on the ND increased to more than 10 kt. At a height of about 80 ft the Captain decided to abort the approach. The initial phase of the go-around was performed in accordance with the procedure, with "TOGA" thrust selected, an initial pitch attitude of about 12.5°, a retraction of the flaps to position 3 and the retraction of the landing gear. The Captain had previously selected a go-around altitude of 1,700 ft, instead of 2,200 ft.

The mode displayed on the FMA switched to ALT* at a height of between 900 and 1,000 ft[5], associated with the altitude alert[6] aural warning. The PF then applied nose-down inputs to reduce the pitch attitude. He also reduced the thrust, by moving the levers to the CLIMB detent. The maximum altitude recorded was 1,220 ft. The levers being moved to the MCT detent was recorded eight seconds later, which resulting in a flashing message "LVR CLB"[7] being displayed on the FMA.

A GPWS alert was triggered at about 1,000 ft. The pitch attitude was then 8.8° nose-down. The first pitch attitude correction was recorded at about 870 ft, i.e. two to three seconds after the alert. The pitch response was initially moderate - the pitch attitude changed from 9.5° nose-down to 2.5° nose-down. The thrust levers were then moved forwards to the TOGA detent. Three seconds later, a more definite input was recorded, which was likely due to the application of the GPWS "pull Up" emergency manoeuvre. The aeroplane climbed to an altitude of 3,000 ft.

The crew subsequently performed a new approach and landed on runway 03.

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[5] ALT* mode guides the aeroplane so that it can capture the altitude selected on the FCU. The mode engages when the aeroplane reaches the altitude capture zone, defined notably by the aeroplane's vertical speed.

[6] The "altitude alert" warning is generated when the aeroplane approaches the selected flight level or altitude. It triggers when the aeroplane is 750 ft from the selected altitude. It is a specific aural warning, and is combined with a yellow or amber flashing on the PFD's altitude window.

[7] This message flashes in white in the first column of the FMA. It advises the crew that the normal position of the thrust levers is in the CLB position.

Event 6

Type of event	Serious incident
Date and time	21 July 2007
Place	On approach to Melbourne
Aircraft	A320 -232
Reference	www.atsb.gov.au/media/793232/ao2007044.pdf

History of flight

The Captain (PF) performed an ILS approach to runway 27 with autopilot engaged. There was some fog at the airport. During the approach briefing, the crew had discussed the likelihood of having to perform a go-around. The very high probability of having to abort the approach was confirmed by hearing numerous messages reporting go-arounds during the approach.

At the decision height, the crew did not have the required external visual references and the Captain performed a go-around. He moved the thrust levers beyond the FLX/MCT detent - without going as far as the TOGA detent – before bringing them back into the FLX/MCT detent. When the PF called out the go-around the PNF/PM set the slats and flaps control to position 3. The AP only disengaged 4 seconds later, with the aircraft at an altitude of 57 feet. The EGPWS warning sounded. The aeroplane started to climb 3 seconds later. The landing gear was retracted. The aircraft continued to climb and, at a radio altitude of 281 feet, autothrust was engaged. The thrust levers were then moved to the CLIMB detent. The aeroplane levelled off at about 650 feet and remained at that altitude for 12 s. The AP was then engaged and the aeroplane commenced a shallow descent to 570 feet. At this point the EGPWS warning sounded again. The AP disengaged. The thrust levers were then moved to the TOGA detent. The aeroplane then continued its climb, without encountering any problems. The crew attempted a second approach which was unsuccessful due to the weather conditions. The go-around was performed automatically, with the thrust levers moved immediately to the TOGA detent. The Captain then decided to divert to Avalon Airport.

Operation of the automatic systems

When the approach modes (G/S and LOC) are selected, LAND mode engages automatically below 400 feet. It is displayed in green, boxed, on the FMA, occupying the display windows for the vertical and horizontal modes

Moving the thrust levers to the TOGA detent engages the go-around modes, i.e. SRS (vertical, GA/TRACK (lateral) and activates the flight plan of the FMS. The autothrust transitions to MAN TOGA mode. Once this phase has been activated, the crew can adjust the thrust as required to limit the vertical speed. During this incident, the thrust levers were not placed in the TOGA detent. The go-around modes were not therefore activated and the aeroplane remained in LAND mode.

According to the investigation report, the PF thought that he had moved the thrust levers to the TOGA detent. It took approximately 48 seconds for his intention to initiate a go-around phase to be effectively implemented with the thrust levers in the TOGA detent and SRS mode engaged.

The procedure was initiated, but was suspended when the EGPWS alert was triggered. The aircraft manufacturer's FCOM includes a go-around procedure which specifies "Check and announce the FMA", so that the crew is aware as soon as possible of the aeroplane's current flight mode (item No.3 of the procedure).

Prior to the incident, the aircraft operator introduced a change to this procedure. As a result of the change, the requirement to check and announce the FMA status was moved to item 9. Consequently, the crew did not have the time to check what was displayed on the FMA. The crew did not therefore know the aeroplane's current flight modes when the go-around was initiated.

The triggering of the warnings used up a great deal of crew resources, and the crew did not detect that the aeroplane was continuing its descent to a height of 38 feet. Moreover, the crew also failed to notice that the aircraft was accelerating to the limit speeds for the slats/flaps 3 configuration

Conclusion of the investigation report

The PF did not move the thrust levers to the TOGA detent. The change made by the aircraft operator to the go-around procedure resulted in the flight crew being unaware of the flight mode status of the aeroplane. The aircraft operator did not conduct a risk analysis when changing the procedure

The two pilots received their initial endorsement training from a third party training provider. Moreover, the procedures used by the operator were not known to this TRTO. The aircraft operator did not apply the current regulation regarding the training of its flight crew.

The ATSB highlighted the safety risks raised by the investigation, and notably in relation to changes to the procedure

- ***The aircraft operator did not conduct a risk analysis when changing the go-around procedure, nor did its safety management system require one to be conducted.***

- ***The aircraft operator had changed the standard operating procedure for the go-around. The change resulted in the flight crew being unaware of the flight mode status of the aircraft during the first part of the first missed approach.***

Event 7

Type of event	Serious incident
Date and time	23 September 2007
Place	On approach to Bournemouth
Aircraft	B737-300
Reference	http://www.aaib.gov.uk/publications/formal_reports/3_2009_g_thof/g_thof_report_sections.cfm

History of flight

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° nose-up. 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 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.

Analysis/Conclusion

The crew did not notice the highly nose-up position of the trim, and took a long time to correct it. Although the aircraft did not have an autotrim function when flown manually, the AP moves it as required. Even if the Captain had advanced the thrust levers to maximum before the stall (and even before the activation of the stick-shaker) the aeroplane was trimmed to a fairly high nose-up level. The normal acceleration never exceeded 1.3 g.

The investigation identified the following causes:

- The aeroplane decelerated during an instrument approach, at a speed that was clearly below that which was commanded, with the engines on idle. Despite the

application of full thrust, the aeroplane stalled, after which the crew did not correctly undertake actions that would allow the situation to be resolved.
- The position of the THS, combined with the application of full thrust, exceeded the authority of the elevator.

In addition, the crew did not notice AT disengagement. The cause of the AT disengagement was not found.

Lessons learned / Recommendations

As a result of the airline's internal procedures, the seriousness of the event was not appreciated until 12 days after the event, by which time the data recorders had been overwritten. Only the data from the QAR could be analysed. The AAIB made three recommendations: They relate to:

- the AT warning system

It is recommended that Boeing, in conjunction with the Federal Aviation Administration, conduct a study of the efficacy of the Boeing 737-300/400/500 autothrottle warning system and if necessary take steps to improve crew alerting. (Safety Recommendation 2009-043)

- amending regulation CS 25 to ensure that the flight crew is suitably alerted of flight control system failures (including AT)

It is recommended that the European Aviation Safety Agency review the requirements of Certification Standard 25 to ensure that the disengagement of autoflight controls, including autothrottle, is suitably alerted to flight crews. (Safety Recommendation 2009-044)

- amending the QRH's "approach to stall" procedure such that the act of trimming forward is clearly presented as an action which may be necessary to regain pitch control authority.

It is recommended that Boeing clarify the wording of the Boeing 737 300-500 approach to stall recovery Quick Reference Handbook Non-normal Manoeuvres to ensure that pilots are aware that trimming forward may be required to enhance pitch control authority. (Safety Recommendation 2009-045)

Event 8

Type of event	Accident
Date and time	27 November 2008
Place	On approach to Perpignan
Aircraft	A320-232
Reference	http://www.bea.aero/docspa/2008/d-la081127.en/pdf/d-la081127.en.pdf

History of flight

Flight GXL888T was aeroplane training performed at the end of a leasing period, prior to returning the aeroplane to its owner. The Captain was PF and the co-pilot was PNF/PM. A third pilot employed by the airline that owned the aeroplane was seated in the cockpit's central seat to observe and monitor the checks. The programme of checks could not be performed in general air traffic so the flight was shortened. The crew then adapted the programme of checks in an improvised manner, to accommodate the constraints of the flight plan and the air traffic control services.

In level flight at FL 320, angle of attack sensors 1 and 2 stopped moving and their positions did not change until the end of the flight. This anomaly was not detected by the flight crew. During the approach to Perpignan airport, shortly before overflying the initial approach fix, the crew decided, without preparation, and specifically without calling out the minimum theoretical airspeeds indicated in the document at their disposal, to carry out the check on the angle of attack protections in normal law, at an altitude of about 4,000 feet.

However, the blockage of angle of attack sensors 1 and 2 at identical values disabled the operation of the protections and led to an erroneous display of the characteristic speeds for these protections. The crew waited for the triggering of these protections while allowing the airspeed to fall. The stall warning in normal law triggered for the first time at an angle of attack close to the theoretical angle of attack in landing configuration. During the deceleration, the horizontal stabiliser trim was gradually moved to its full nose-up position. The horizontal stabiliser remained in this position until the end of the flight. The Captain reacted in accordance with the approach-to-stall technique, by increasing engine thrust and reducing the pitch attitude.

The flight control law passed shortly afterwards from normal to direct due to a difference in measured airspeed. The auto-trim system was thus no longer available. Under the combined effect of the thrust and the increase in speed, the aeroplane was subjected to a pitch-up moment that the Captain could not counter without an input on the trim wheel or without reducing the engine thrust for a prolonged period.

Due to the position of the stabiliser and the pitch-up moment generated by the engines at maximum thrust, the crew lost control of the aeroplane during the go-around. The aeroplane was completely destroyed on impact with the surface of the sea.

Analysis

The investigation concluded that the accident resulted from the crew's loss of control of the aeroplane following the improvised demonstration of the operation 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. The crew did not take into account the speeds mentioned in the programme of checks available to it, and consequently did not abort the demonstration before the stall.
Some of the factors that contributed to the accident were:

- the decision to carry out the demonstration at low altitude;
- the crew's management, during the go-around, of the large increase in pitch attitude; the crew not identifying the full nose-up position of the horizontal stabiliser, nor acting on the trim wheel to correct it, nor reducing engine thrust.

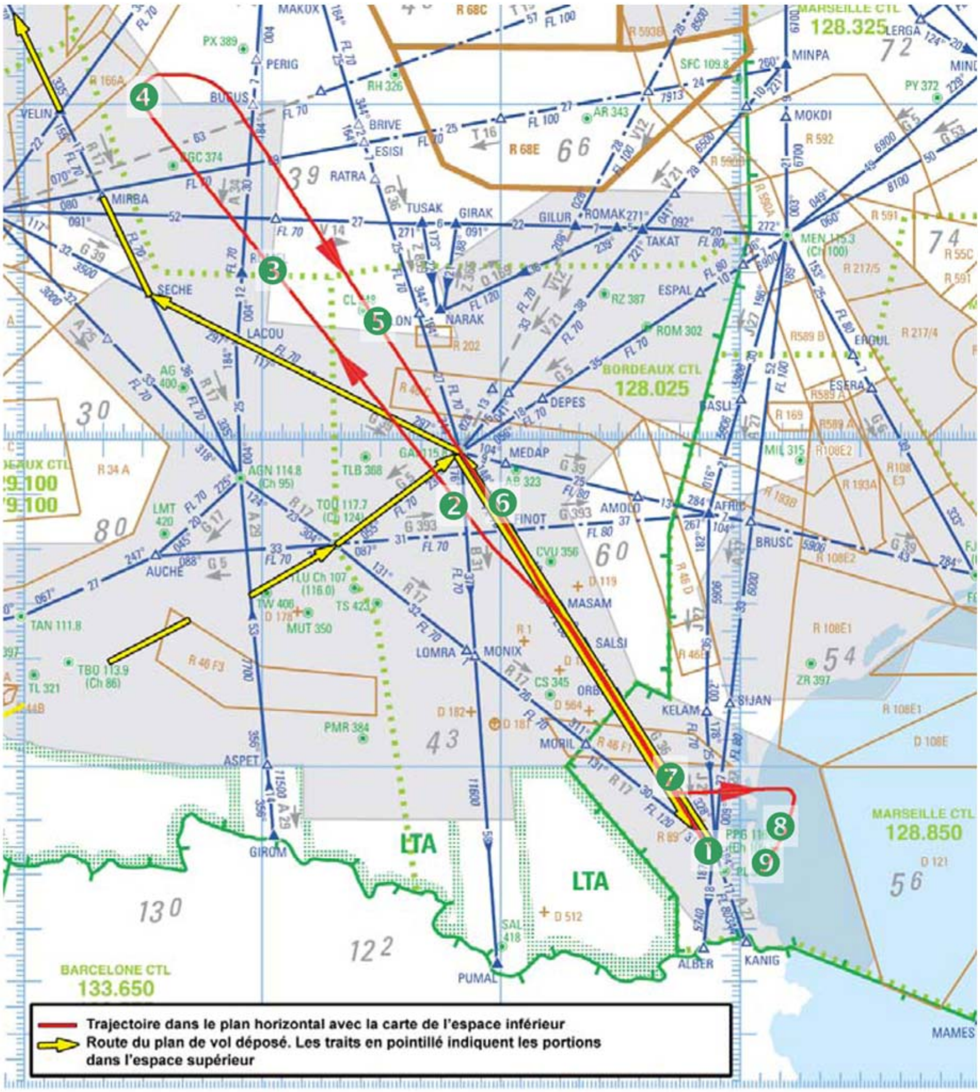
The following factors probably contributed to the accident:

- inadequate coordination between an atypical team composed of three airline pilots in the cockpit;
- the fatigue that may have reduced the crew's awareness of the various items of information relating to the state of the systems.

Recommendations

The BEA issued various safety recommendations:

- **that EASA undertake a safety study with a view to improving the certification standards of warning systems for crews during reconfigurations of flight control systems or the training of crews in identifying these reconfigurations and determining the immediate operational consequences**
- **that EASA, in cooperation with manufacturers, improve training exercises and techniques relating to approach-to-stall to ensure control of the aeroplane in the pitch axis.**



1. 14 h 44
   Takeoff from Perpignan aerodrome
2. 14 h 52
   The controller told the crew that they could not perform a “360”
3. Between 15 h 04 et 15 h 06
   Blockage of angle of attack sensors 1 and 2
4. 15 h 12
   Turn back
5. 15 h 22
   Arrival at FL 390
6. 15 h 26
   Beginning of descent
7. 15 h 34 min 34 s
   Co-pilot: “(…) we'll appreciate a radar vector the approach”
8. 15 h 43 min 41 s
   Thrust levers on IDLE
   Beginning of the check on the low speed angle of attack protections
9. 15 h 45 min 05 s
   Stall warning

Figure 3 : Trajectory of the GXL888T

Event 9

Type of event	Serious incident
Date and time	23 September 2009
Place	On approach to Roissy, France
Aircraft	A319-111
Reference	http://www.bea.aero/docspa/2009/f-hu090923/pdf/f-hu090923.pdf French only

Description of the incident

The Captain (PF) performed an ILS CAT 1 approach to runway 27 R in manual mode and without A/THR. At the minimums, at 200 feet, the Captain could not see the runway and decided to go around. He engaged the autopilot. The aeroplane continued to descend and an EGPWS alert triggered. The lowest height recorded was 76 feet. The EGPWS alert and/or seeing the ground triggered a response from the Captain who disengaged the AP and pitched the aeroplane with a 10° nose-up pitch attitude.

The Captain made three attempts to engage the AP, each of which resulted in the same nose-down response from the aeroplane. During the approach briefing, the Captain indicated that, in the event of a go-around, he would perform a “soft” go-around and would push forward the thrust levers to the TOGA detent and then to CLIMB. The Captain thought that he had set the levers in the TOGA detent, when in fact he had set them in the FLX/MCT detent. Moreover, he was surprised by the response from the aeroplane, notably the change to a nose-down pitch attitude, and the rapid increase in speed. He then pulled back the thrust levers to the CLB detent to reduce the speed.

Operation of the automatic systems

When approach modes (G/S and LOC) are selected, LAND mode engages automatically below 400 feet. During this incident, the thrust levers were not placed in the TOGA detent. The go-around modes were not therefore activated and the aeroplane remained in LAND mode.

With AP engaged in LAND mode, the systems attempted to keep to the glide path (a pitch attitude of 3.9° nose-down). The thrust selected resulted in a rapid increase in speed.

The crew took five seconds to respond and move the thrust levers from IDLE to MCT/FLX. This is a long time in this context in which initiating maximum thrust must be as rapid as possible. It corresponded to the Captain’s desire to perform this manoeuvre “softly”.
The rapid engagement of the AP did not correspond to a shared plan of action. From this moment on, the teamwork within the crew broke down; the co-pilot did not understand what the Captain was doing.

Analysis

The Captain was surprised by the reaction of the aeroplane. It is likely that he focused his attention on the increase in speed, and attempted to avoid triggering the VFE warning by reducing the thrust.

The information provided by the FMA did not correspond to a go-around. The Captain apparently did not notice this information. Neither did the co-pilot warn the Captain about the observed differences in thrust, speed, pitch attitude, height or the information from the FMA.

This serious incident of loss of altitude during a go-around was specifically due to:

- the non-activation of go-around modes due to the thrust levers being placed in the wrong detent;
- the inappropriate engagement of autopilot;
- the lack of monitoring of the pitch attitude.

The following factors may have contributed to the incident:

- lack of precision in the wording of the procedure provided to the crew;
- a deviation from the procedure regarding compliance with the operating limits.

Recommendations

The BEA issued 2 recommendations, one of which recommends that:

- **the DSAC work with the manufacturer and with aircraft operators to conduct a review of go-around procedures in order to ensure that they match the objectives of this manoeuvre.**

Event 10

Type of event	Incident
Date and time	11 October 2010
Place	On approach to New York JFK
Aircraft	A380
Reference	ASAGA study

History of flight

The aeroplane had just made a transatlantic flight. During the approach to runway 31 L with radar vectoring, the co-pilot (PF) performed a LH downwind leg at 3,000 ft. The Captain was PNF/PM, and stated that he was tired.

The AP and A/THR were engaged, the flaps were in CONF 1. LOC mode was armed and an altitude of 2,000 ft was selected. During the last turn, the aeroplane started its descent. During the final approach, the crew received visual approach clearance. The PF selected a speed of 210 kt. The FMA modes displayed were THR IDLE/OPEN DES/HDG.

The PF did not engage GLIDE mode and the aeroplane passed above the glide path. The PF then disengaged the AP and continued the final approach manually. He did not disengage the FD.

With the aeroplane above its glide path at an altitude of 2,800 feet, the flaps were extended to CONF 2 and the landing gear was extended. The thrust level ordered by the A/THR was idle.

At about 2,200 feet, ALT* mode engaged. The aeroplane was 5 NM from the runway threshold, and its speed was 210 kt.

The PF continued the manual descent. When the aeroplane was 4 NM from the runway threshold, its altitude was 1,840 feet and it was two dots above the glide path. The vertical bar on the FD moved gradually to its upper stop. The vertical speed was 1,600 ft/min and the airbrakes were extended to FULL position. The modes displayed on the FMA were SPEED/ALT/LOC*

For this runway, the stabilisation altitude is 500 ft and the go-around height is 1,000 ft, which leaves very little time to perform a go-around procedure.

At about 1,600 feet, an altitude of 1,000 ft was displayed. The PF manually intercepted the localizer and ordered the extension of the flaps to CONF 3. The approach was not stabilised and the speed was still too high (210 kt). The flaps were maintained in CONF 2, and then retracted to CONF 1. The localizer was captured at about 1,300 feet and the FMA displayed SPEED/ALT/LOC. At 680 ft, the flaps were reset to CONF 2. The aeroplane was still above the glide slope and 1 NM from the runway threshold. At 480 feet, the approach had still not been stabilised and the speed remained at 210 kt. The Captain ordered a go-around, which surprised the co-pilot who was focused on the landing.

The go-around was executed manually, and the thrust levers were pushed forwards into the TOGA detent. The FMA displayed GA modes, and the pitch attitude was 0°.

The Captain contacted ATC on four occasions to request a stabilisation attitude higher than that indicated in the procedure. These communications took up 13 of the 45 seconds of the duration of the go-around.

The PF pulled back the thrust levers to the MCT detect, which the PNF/PM did not notice.
The aeroplane's pitch attitude was approximately 2.5° nose-up. The flaps were not retracted one notch.
The speed exceeded the VFE for CONF 2 by about 12 knots. The overspeed warning (CRC) triggered at VFE+4 kt. The flaps started to retract, ordered by the FLAP LOAD RELIEF protection.

The aeroplane climbed through 660 ft with a positive vertical speed of 3,400 ft/min. ALT* mode engaged, and two seconds later the flaps were retracted to CONF 1. VFE had been exceeded for 12 seconds. The bar on the FD moved below the aeroplane symbol, requesting a reduction in pitch attitude. The vertical speed at this point was about 4,200 ft/min.

As it climbed through 850 ft, LVR CLIMB flashed on the FMA, but the levers were not pulled back into the CLIMB detent. The aeroplane continued to climb in MCT mode, above the go-around altitude (1,000 ft) with a vertical speed of 4,000 ft/min. During a first stabilisation at about 1,600 ft, the crew banked to the left, accelerating to a maximum of 301 kt. The thrust levers were pulled back to CLIMB. The A/THR re-engaged in SPEED mode and the effective thrust reduced to IDLE. After ATC clearance at crew's request, the aeroplane climbed to an altitude of 2,000 ft at a speed of 220 kt for a downwind leg. The aeroplane later landed without incident on runway 31 L.

Analysis

The small difference between the decision altitudes and the recovery altitude for the go-around gave the crew little time to manage the rapid rise of a light aircraft with high thrust.

2.2 Summary

An analysis table of the events mentioned in sections 2.1 is provided in appendix 3.

It shows the following:

Recurrent aspects

The events studied exclusively involved twin-engine aeroplanes, except for one event which involved a four-jet aeroplane. All of the ASAGA-type accidents occurred with all engines running, except for that of the Port Sudan 737. At the end of their flights twinjets are relatively light and available thrust is much greater than that actually needed.

With the exception of two events (6, 13), significant speed and pitch attitude excursions occurred, leading to excursions in climb speed and altitude.

In all these events, a disruption occurred soon after a higher level of thrust was ordered and generated potentially hazardous manoeuvres. In some cases this disruption was aggravated by other factors, and surprised the crew.

External visibility

Six events (1, 8, 10, 14, 15, 16) occurred during the day with no apparent visibility problems; the visibility was not specified in one case (4); and for nine cases (2, 3, 4, 5, 7, 8, 11, 12, 13) the aeroplane was flying in IMC which probably aggravated the situation.

Role of the PNF/PM

In eleven cases (2, 4, 5, 6, 7, 8, 11, 13, 14, 15, 16) the PNF/PM performed the initial tasks specified for a go-around (landing gear, flaps). In these eleven cases, four PNF/PM inputs had beneficial effects (4, 5, 7, 14) in terms of enabling the PF to regain control, one had a negative effect (15), and 6 had no effect (2, 6, 8, 11, 13, 16). No comment can be made for four cases (1, 3, 9, 12).

However, after these initial inputs, insufficient monitoring by the PNF/PM was mentioned in nine cases.

Origin of the disruptions

In ten cases (1, 2, 3, 5, 7, 8, 9, 10, 12, 16) the strong and quick-acting nose-up pitching moment generated by the engines, at low speed, placed the pilot in a situation that necessitated a high level of vigilance. Any additional disruption might take up a significant portion of the attention necessary for flying.

The causes of this disruption were extremely diverse, but many were unexpectedly amplified (to a secondary degree, but in all cases significantly) by the automatic systems.

The cause was a technical problem in four cases (7, 8, 11, 12).

Incorrect selection of the go-around altitude was the cause in 2 cases (3, 5).

Failure to select TOGA thrust was the cause in 2 cases (6, 9), which triggered the inappropriate operation of the automatic systems and created confusion.

Failure to comply with approach or final paths, instigated by the ATC (14, 15) or the pilot (2, 13) can be mentioned in 4 cases.

Amplifying factors

The unexpected or overlooked operation of the AP and/or of the horizontal stabilizer trim is a confirmed aggravating factor in 8 cases (1, 4, 6, 7, 8, 9, 12, 16). Parameter and automatic systems monitoring was not possible.

The involvement of spurious parasitic sensations (somatogravic illusions) is mentioned four times (2, 3, 5, 13) and suspected two times (11, 12).

Warnings or alerts were considered as possible disruptions in four cases (2, 3, 5, 6,). It is likely that VFE overspeed warnings contributed towards focussing attention on the CAS in all the cases except for two, for which the changes in airspeed were uncertain (6, 13).

Focussing of attention was likely in two cases (for event 10 on ILS information, and for event 13 on visual navigation).

FMA

Modes that did not comply with modes expected for a go-around appeared during events 4, 5, 6, 9, 10 and 13.

ATC

The intervention of ATC was a contributory factor in cases 3, 10, 12, 14, 15 and 16. In case 3, a change to the procedure in terms of heading and altitude is mentioned. In case 10, a change in altitude was requested by the crew since the go-around altitude was too low.

CRM

CRM failures were mentioned for all the accidents.

Thrust levers on Airbus

In cases 2, 3 and 5, the thrust levers were not pushed forwards into the TOGA detent during the go-around.

In case 10, the levers were not pulled back into the CLIMB detent.

In case 7, the levers were placed in the MCT detent, after being placed in TOGA and then in CLIMB.

3 - FLIGHT CREW SURVEY

3.1 Survey execution details

3.1.1 Participation in the survey

A survey was circulated amongst the flight crew of the following French airlines: Aigle Azur, Air France, Airlinair, Brit'Air, CorsairFly, Europe Airpost, Regional. Some British airlines were also invited to participate: BMI, British Airways, EasyJet and Thomson Fly.

The objective was to draw from their experience to:

- Gain a better understanding of the difficulties associated with a go-around;
- Collect accounts of their go-around experiences in flight and on a simulator;
- Determine, statistically, any contributory factors revealed by the survey.

The crews were invited to complete, anonymously, a questionnaire hosted on the BEA website. In total, 950 pilots participated, and 831 completed questionnaires were submitted at the end of the process by the pilots. The 831 respondents had a variable degree of experience.

3.1.2 Conducting the survey

The questionnaire can still be accessed at (http://www.bea.aero/etudes/parg/parg.php). The questions were divided into different sections, relating to:

- Quantifying the number of go-arounds performed and the principal reasons for these go-arounds;
- The respondent's experience as an airline pilot, the difficulties encountered and their accounts of them;
- Experiences during simulator sessions;
- Feedback from any instructors completing the questionnaire;
- Training;
- The respondent's qualifications and profile.

The questionnaire consisted primarily of yes/no or multiple-choice questions. The few open questions were asked about their experience. The specific difficulties encountered when performing a go-around were expressed on a scale from 1 (not difficult) to 4 (very difficult).

3.2 Results

All 831 responses were studied. The analysis was divided into three parts:

- A statistical analysis of the overall results;
- Analysis of accounts from pilots;
- Analysis of accounts from instructors.

With regard to the accounts, there were 90 cases of observations and opinions regarding in-flight incidents, and 72 cases of observations and opinions expressed by pilots who were also instructors.

3.2.1 Statistical results

General statistics

Before detailing the results of the survey, the BEA estimated the number of go-arounds performed by a pilot during his/her career, based on the figures communicated by Air France and those supplied by the main European airports. In general, these showed:

- Between 2 and 4 go-arounds per one thousand flights are recorded each year
- A medium-haul flight crew performs on average one go-around a year
- A long-haul flight crew performs on average one go-around every 5 to 10 years.

In addition, the main factors triggering a go-around are proportionately as follows (source Air France):
- Meteorological conditions (tailwind, windshear, turbulence)
- Conduct of flight (Unstabilised approach, GPWS warning)
- ATC (runway occupied, separation, ATC request for go-around).

Results for the population of pilots that replied to the survey

Eight of the 831 pilots had never performed a go-around when flying either as PF or PNF/PM. As PF, 474 of the flight crew (57%) had performed fewer than 5 GA's, 31 pilots had never performed a GA. As PNF/PM, 594 of the flight crew (71.5%) had performed fewer than 5 GA's, 53 pilots had never performed a GA.

449 flight crew (54%) had performed between 4 GA's or less as a PF and 4 GA's or less as PNF/PM. In other words, more than half of the pilots had performed fewer than 9 GA's at that stage of their careers. The pilots were also asked to indicate the number of GA'S for each of their type ratings.

Type of aeroplane	Number of go-arounds performed						Percentage of all flight crew who expressed an opinion
	0	1	2	3	4	5 or more	
A300/A310	12	16	24	7	6	12	9.3
A320	11	39	94	106	108	224	70.0
A330/A340	27	47	45	33	17	17	22.4
A380	14	6	1	0	1	3	3.0
B727	11	8	11	7	2	6	5.4
B737	10	31	54	36	21	50	24.3
B737NG	9	9	9	4	4	7	5.1
B757/767	16	7	8	4	3	11	5.9
B747	21	42	58	27	15	20	22.0
B777	37	47	45	26	4	12	20.6
MD80 B717	7	2	4	2	1	3	2.3
F70 / F100	8	6	5	8	1	8	4.3
ERJ135 - ERJ145	4	6	15	16	14	24	9.5
ERJ170 - ER190	7	4	12	2	2	23	3.6
CRJ100 - CRJ200 - CRJ700 - CRJ1000	6	3	5	4	3	15	4.3
BAE146	7	4	10	11	4	10	5.5
TURBOPROP AIRCRAFT	7	35	37	25	14	83	24.2
OTHERS	7	10	19	11	4	68	14.3

This table shows that most of the pilots hold or have held A320 type rating. There was a second group, in terms of number of respondents, for the A330-A340, B737, B777 and B747 families of aircraft.

Reason for the go-around

The reasons why a go-around was performed were attributed equally to:

- ATC involvement
- specific meteorological conditions
- an unstabilised approach.

These three factors accounted for 70 to 80% of all responses.
30% of the pilots performed at least one GA when flying below the minimums.

Specific difficulties encountered in flight

On average, 60% of the pilots indicated that they had encountered difficulties during a GA.

365 pilots (44 %) provided a description of the difficulties encountered during their GA. Almost half of these pilots (42% - 153) also indicated that they had encountered difficulties during simulator sessions.

Difficulties expressed	***not or a little difficult as a %ge***	***difficult or very difficult as a %ge***	***no answer as a %ge***
Getting and maintaining pitch angle	66.8	11.6	21.6
Thrust management	53.2	28.8	18.0
Horizontal flight path management	48.9	28.8	22.3
Vertical flight path management: go-around altitude capture	35.2	49.0	15.8
Aircraft configuration management	44.2	38.5	17.3
Autosystem management	36.5	46.2	17.3
Trim management	61.3	4.9	33.8
CRM: decision making	51.4	26.9	21.7
CRM: task sharing	61.4	15.9	22.7
CRM: compliance with SOP	47.9	32.6	19.5
Visual scan management/focussing	39.7	37.3	23
Coping with acceleration-related spatial disorientation	58.9	14.2	26.9
Coping with the modification of the flight path on ATC request	38.9	37.8	23.3

When the account was provided by an instructor, s/he was invited to describe any specific difficulties encountered by pilots under instruction.

Difficulties expressed	*not or a little difficult as a %ge*	*difficult or very difficult as a %ge*	*no answer as a %ge*
Getting and maintaining pitch angle	28.3	58.3	13.4
Thrust management	43.3	42.5	14.2
Horizontal flight path management	37.0	40.9	22.1
Vertical flight path management: go-around altitude capture	21.2	63.9	14.9
Aircraft configuration management	39.4	42.5	18.1
Autosystem management	20.5	66.9	12.6
Trim management	46.5	8.6	44.9
CRM: decision making	28.3	48.9	22.8
CRM: task sharing	52.0	20.5	27.5
CRM: compliance with SOP	49.6	24.4	26
Visual scan management/focussing	26.8	53.5	19.7
Coping with acceleration-related spatial disorientation	48.0	15.0	37.0
Coping with the modification of the flight path on ATC request	39.4	29.9	30.7

Thus, the main difficulties indicated by the pilots were capturing the stabilisation altitude and autosystem management. In contrast, trim management, thrust management and task sharing do not appear to be major difficulties.

The main difficulties observed by the instructors were capturing the stabilisation altitude (81%), autosystem management (72%) and pitch angle capture and maintaining (69%). Difficulties were also identified, by more than 50% of the instructors, relating to horizontal flight path management, visual scan management and decision making.

Training

The pilots surveyed indicated that, overall, they were sufficiently well trained in GA'S with one engine out (85% of the pilots). However, almost half of the pilots indicated that they were not sufficiently well trained in GA'S with all engines in operation. This figure was even higher for the pilots who indicated that they had encountered difficulties in flight. Initial training was not put forward as a cause of the difficulties encountered

Moreover, the pilots suggested ways in which go-around training could be improved. Most of these suggestions can be summarised as follows:

- Changes to ATC procedures:
    - To increase the stabilisation altitude: "increase the go-around altitudes when they are too low"
    - To simplify flight paths: "Make sure that at least some of the flight path is simple (constant altitude or constant heading) rather than combining a bank with one or more changes of altitude)". "Ideally, if there is no terrain restriction, the flight path should go straight ahead in line with the runway and climbing to a height of more than 3,000 ft. The flight paths are all too often complicated, with banks early on in the manoeuvre and altitudes that are too low".

- To restrict radio messages during the phases that require all the crew's attention.

- Changes to operators' procedures:
  - To go back to a simple procedure which should: "1) indicate the pitch attitude to avoid a CFIT. 2) indicate the thrust needed to move away from the ground and climb steadily. 3) describe the checks of the automatic systems. 4) include the retraction of the landing gear and flaps. 5) describe the flight path for coming round to land",
  - To delay the retraction of the gear and flaps, notably on the latest generation aeroplanes: "when all the engines are in operation, the retraction of the gear and flaps is not immediately necessary and can be delayed. Letting the crew focus on the critical aircraft handling inputs (capturing the pitch attitude, precise selection of the TOGA thrust and then of the thrust required) is more important than rushing into gear and flap retraction actions and their corresponding callouts which occupy a great deal of mental resources."
  - To "specify that the PF or the PNF/PM should call out the pitch attitude"

- Improve pilot support systems by:
  - Simplifying the automatic systems: "it's difficult to stay in the loop when the automatic systems do a job that's judged to be ineffective."

- Improve training by:
  - Increasing the frequency of training on go-arounds with all engines in operation: include GA'S with all engines in operation in simulator sessions, with the reason for the GA'S not indicated in the programme, and left to the instructor's discretion"
  - Providing training in "high energy status" go-arounds: "perform high energy status GA, which are more like a change of configuration and of plan of action".
  - Conducting training in actual GA'S during aeroplane training.

- Teach and describe a standard visual scan: "Where should the PF or the PNF/PM be looking?" or "look at [….] for the information?"

- Improve flight simulators

3.2.2 Pilot's accounts

254 of the 831 pilots (31%) recounted their experiences in a more detailed way. Among these accounts, only a limited number were selected due to the wide variety of cases (description of situations, of difficulties, statements of opinions and comments).
90 accounts were finally selected for further analysis since they provided a detailed description of the pilot's experience of a go-around. The analysis of the accounts was a two-phase process.

The first phase identified, significantly, the following difficulties:

- ATC requests for a change to the flight path,
- Communication from ATC directed at the crew at bad times in the go-around manoeuvre, or changes of frequency initiated prematurely,
- Procedures featuring a low recovery altitude,
- Errors when engaging TOGA mode,
- The difficulty in maintaining the flight path under maximum thrust.

The second phase broke down the 90 accounts and used this information to produce two tables. The first is descriptive. The second, which is more subjective, is based on the judgement of the experts who participated in the study. Among them were the founder of the Airbus Training Center and some specialists in human factors.

Reason for the go-around

The figure below highlights the fact that the difficulties are encountered in all the go-arounds, irrespective of the cause. In overall terms, the distribution indicated reflects the reasons that triggered a go-around. 54 pilots answered this question.

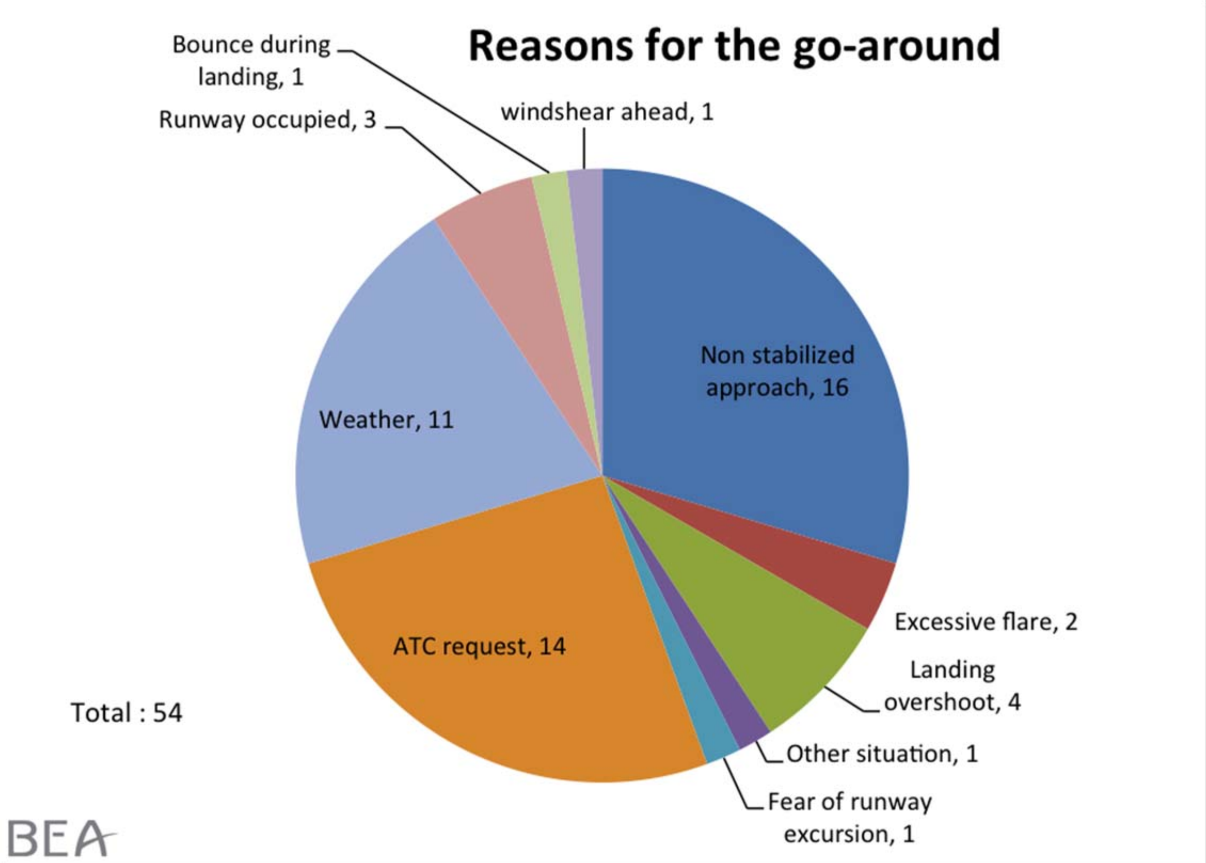


Figure 4 : reasons for the go-around

Difficulties expressed

Pilots experience a go-around as being a temporary break in the optimal execution of a mission at the end of the flight. In one sense, they occur at the wrong time.
Certain disruptions can complicate the management of the manoeuvre. Some develop before the go-around, whereas others occur during the manoeuvre. The diagram below details these disruptions:

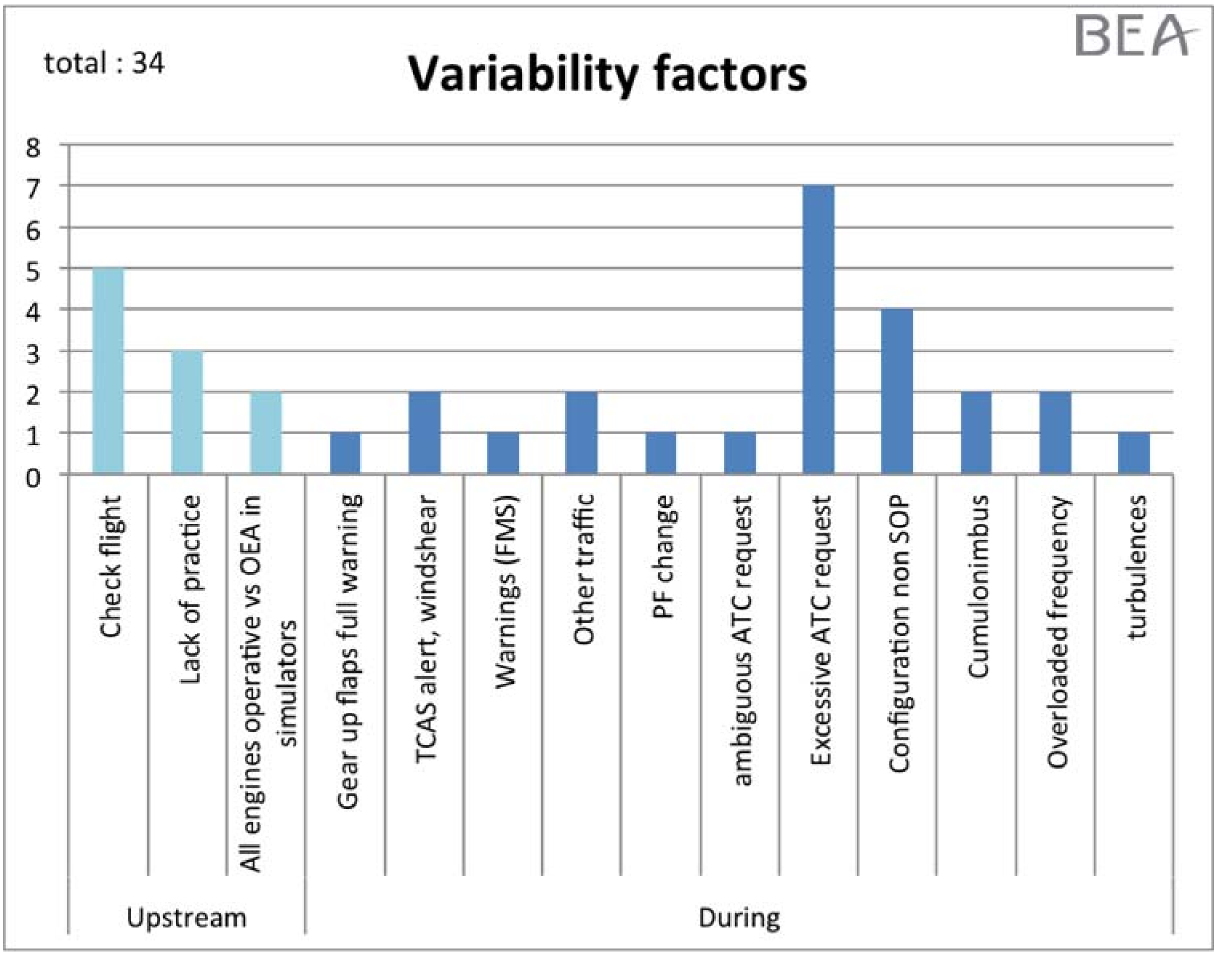


Figure 5 : variability factors reported in the survey (or disrupting elements)

More than one third of the 90 accounts mention disruptive factors. ATC is often mentioned - ambiguous clearances, communication thought to be excessive or a disruptive focus on frequency selection.

The difficulties reported by the pilots can be divided into two main groups. Firstly, to their understanding of the situation and the sharing of this understanding between the flight crew (particularly when the decision is taken to go around). Secondly, the actions to be performed, their sequencing and the management of the automatic systems. The diagram below details all these difficulties.

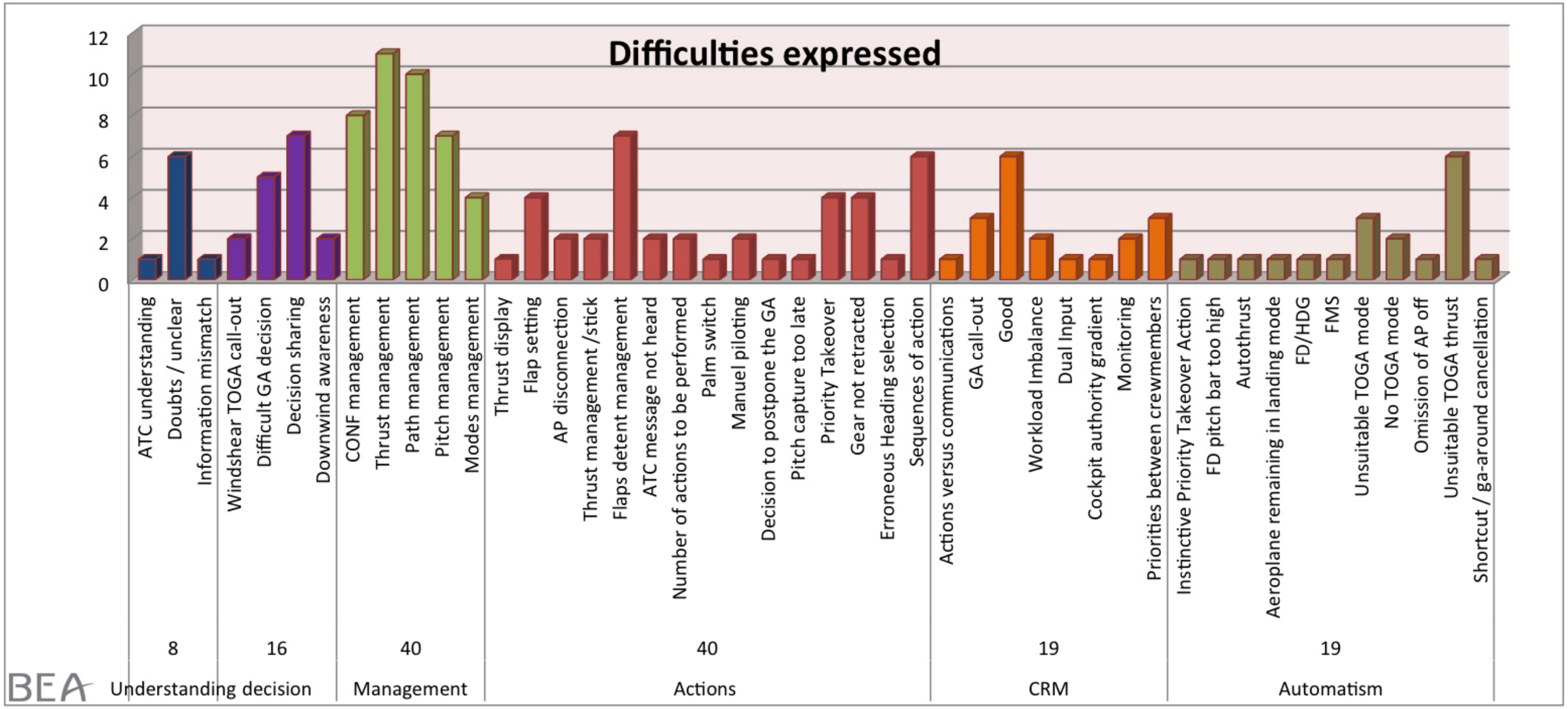


Figure 6 : difficulties expressed by the pilots

The main difficulties reported by the pilots surveyed are:

- An increase in their workload resulting from interactions with ATC and due specifically to:
  - Changes to clearances prompted by specific and unpredictable air traffic situations;
  - Meteorological conditions that prompt unscheduled changes to the flight path (storm, tailwind, etc.,);
  - Communication received during difficult and task-laden phases of the go-around, overloading the pilots' conscious plan of action.
- A reduction in their capacity to cope with the situation, resulting from the momentarily excessive workload induced by the speed at which the situation changes.
- The problems associated with managing a thrust considered by the pilots to be excessive, since it causes very high levels of acceleration and/or vertical speed,
- The rapid changes in configuration (flaps and landing gear), aggravated by the need to make new manual inputs (FCU/FCP), to check them (FMA, PFD), or even to engage certain automatic systems (FD, AP, A/THR).
- The management of the automatic systems, under time pressures, when the go-around does not adhere closely to the intended procedure. In these cases, the automatic systems may no longer be of assistance to the pilot.
- The breakdown of coordinated actions or teamwork in the cockpit.
- The obligation, on certain aircraft, to select full thrust:
  - Which may be excessive, when the stabilisation altitude is too close to the altitude at which the decision to go around was made;
  - Which is illogical when the go-around occurs at or above the stabilisation altitude. In these cases, the thrust levers have to be placed in the TOGA detent and then pulled back which, from a cognitive perspective, complicates the manoeuvres and is time consuming;
  - Which, in two reported events, led to incorrect thrust management, probably combined with an unsuitable pitch attitude, resulting in an excessively low speed (below VLS).
    Which induced disruptions relating to somatogravic illusions.

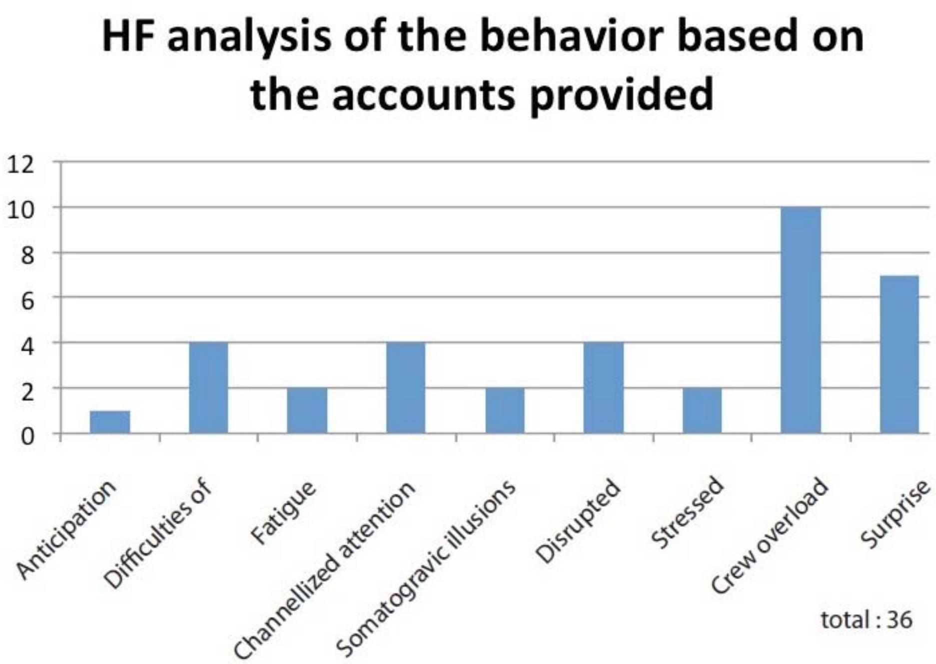


Figure 7 : HF analysis of the behaviour based on the accounts provided

HF analysis of the behaviour based on the accounts provided

The accounts underlined that a go-around introduces a discontinuity in the tasks to be performed and a disruption to their rhythm of execution.

The diverse nature of the tasks and the speed at which they must be performed generate stress, notably when the startle effect is also included in the situation. Since stress reduces our ability to cope with complex actions, performance levels drop during go-arounds. The sudden onset of new tasks, the need to perform vital, rapid and varied manoeuvres, and the rapid changes in the numerous parameters to be managed (controlled) in a limited period of time combine to make it difficult for a crew to perform a go-around that is not controlled right from the start.

The first challenge is to adapt to the new situation, i.e. to control the stress and to manage the "overlaying of tasks". It is not easy to switch quickly to a new mental model. A number of pilots reported confusion and omissions. In some cases, certain actions (or inactions) may be interpreted as resulting from the excessive focussing of attention.

The pilots indicated that because the PNF/PM is overloaded with tasks it prevents him/her from monitoring the PF, which is perceived as hazardous.
Moreover, the lack of opportunities to practice a go-around with all engines in operation, both in training and in line flying, is broadly criticised by the pilots surveyed.

The pilots attempt to lessen these difficulties by looking for ways to simplify the tasks:

- Elimination of actions considered as secondary and time-consuming (e.g. monitoring the FMA, paying attention to instructions from ATC);
- Returning to basic manual aircraft handling.

The following are considered as beneficial:

- Experience acquired in flight and on a simulator;
- Anticipating the manoeuvre, e.g. by a prior briefing during the approach;
- Actions taken calmly;
- And, especially, high levels of coordination within the crew.

Operational consequences reported

The pilots indicated that they quickly assimilated the operational consequences of the go-around, sometimes to the detriment of monitoring the fundamental parameters of the go-around.

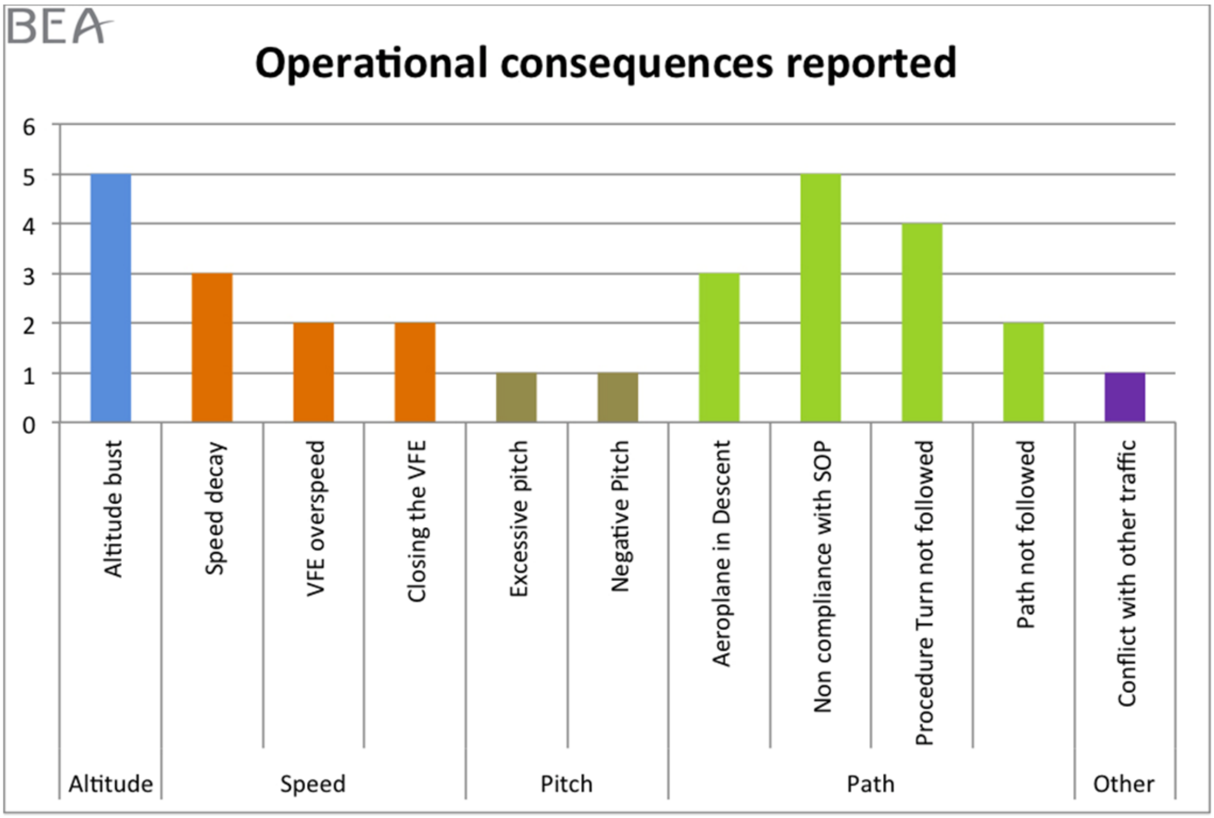


Figure 8 : operational consequences reported

To supplement the above analysis, the accounts below illustrate the elements developed in the previous sections. They are indicative of a possible loss of awareness of the aeroplane's flight path.

Account: *As Captain (PNF/PM) I was flying at about 500 ft during a go-around caused by traffic on the runway. I looked away from the flight path indicators for a few seconds to change the VHF frequency and when I looked back <u>the aeroplane had a nose-down attitude and was descending</u>. <u>There was no reaction from the co-pilot, who was overwhelmed by the events</u>. I took the controls immediately. During the subsequent debrief, my colleague explained that he had "**frozen**" completely when faced with the situation.*

Account: *It was the first LOFT flight for a young pilot as co-pilot in an Airbus A320. The Captain (TRI) was in the left seat, another co-pilot, also in LOFT, was in the central jump seat and I (a co-pilot with more seniority providing a "safety pilot" function) was in the left JPS, behind the Captain's seat. The co-pilot (PF) was flying back to Paris CDG after a long return trip under instruction after an early start. We followed standard ATC instructions behind a BAE-146, which was much slower than us. Due to poor anticipation of the reduction in speed, the separation became too small, so ATC ordered a go-around at about 2,000 ft AGL. Although it had already been discussed during the briefing, the pilots in the control seats quickly re-briefed the go-around to reduce the stress felt quite naturally by the co-pilot under instruction. Just as the go-around was being performed, ATC changed the clearance totally: an altitude lower than normal, right bank right instead of climbing on the runway extended centreline and request for a rapid change of frequency. The Captain entered the changes in the FCU since AP was OFF at this time, and responded to ATC, attempting to perform all the actions required for the go-around. The co-pilot captured a satisfactory pitch attitude and banked the aeroplane to the right. During the bank, while the Captain was in communication with ATC, the pitch attitude suddenly increased to about 23° nose-up (a normal pitch attitude would be about 17.5°*

nose-up, and the maximum permissible pitch attitude is 20°) but was not detected by the two pilots in the control seats. From my position in the JPS, I brought this issue to my colleagues' attention by making the specified technical callout, "PITCH". The co-pilot reduced the pitch attitude, monitored by the Captain. The rest of the flight and the second approach completed without incident. The late change of clearance given by ATC and the request to switch quickly to a new frequency (on which the controller subsequently gave a new clearance, different from the first) significantly disrupted a cockpit the nature of which was already slightly unusual due to the instruction underway. This contributed towards overloading the Captain (PNF/PM) who had less time to monitor the flight path I don't remember if an ASR was submitted or not.

Account: *LOFT flight, about 10 years ago, fast approach to Zurich. The instructor let me take control so that I could appreciate the aeroplane preparation times. With the runway in sight at 1,000 ft he asked me to "set off" I had been expecting a clear "go around" callout, which I did not get, since the instructor thought that his instruction had been clear. Straight away I was not focussed on the go-around procedure, and I didn't get a grip on what we were doing (insufficient availability of mental resources). As a result, I wasn't able to fix onto a familiar pattern. Consequently, I flew the aeroplane but forgot the palm switch, the configuration, etc.*

Account: *During a "high energy" go-around, the PF accidentally failed to select TOGA, the speed dropped to below VLS, and the situation was recovered by the PNF/PM calling out "Speed" and the PF resetting the A/THR to the TOGA detent.*

Account: *It was my first flight as Captain. During a manual ILS approach without FD, I was PF, with a TRI as co-pilot (PNF/PM/PF) who was not very familiar with the cockpit. During the GA at Paris CDG, the flight path and altitude were totally different from the standard values. The co-pilot had a lot of radio work to do and completely overwhelmed, made two mistakes when retracting the flaps. We ended up at the limits of the true airspeed in a bank, so we temporarily abandoned the turn to give the aeroplane some time to accelerate. As a result we deviated from the radar vectoring.*

Account: *On another occasion, we were destabilised by a wing down due to a wind gradient (we were close to a downburst) when under the decision height, so I decided to perform a go-around as co-pilot (PF). The pitch attitude captured should have been OK, but I paused fleetingly in the IDLE detent before applying TOGA thrust. This event was the subject of an ASR for weather reasons and an analysis of the parameters, which did not reveal any loss of thrust. My explanation for this action was a mental anticipation of the next phase of the landing, which is to reduce the thrust when you reach the runway threshold. I needed 5 seconds, and callouts from the Captain to get back on track for a normal go-around. Clearances from ATC (altitude and heading) that deviate from the published values for go-arounds sometimes overload the crew.*

3.2.3 Accounts from instructors

Seventy-two instructors described the difficulties encountered by pilots during training sessions, usually in a simulator. Their accounts provide an external assessment of the behaviour of the pilots, in contrast to the personal and internal assessment provided by the pilots. There is, nonetheless a clear convergence of opinion between instructors and pilots.

Problems observed and positive points

The main difficulties observed were:

- The incompatibility between TOGA thrust and a low stabilisation altitude;
- Disruptions caused by the failure to engage TOGA;
- The concurrent management of configurations and thrust to adhere to the VFE limitations;
- Confusion regarding the choice of and sequencing of the control of the configurations (landing gear and flaps);
- The unnoticed disengagement of the automatic systems during a go-around;
- Forgetting to engage an automatic system;
- The difficulty in returning to basic aircraft handling when an automatic system fault occurs;
- The difficulty in adhering strictly to the published procedures;
- The management of the pitch attitude, sometimes neglected in favour of other actions (e.g. monitoring the speed);
- Additional problems caused by the obligation to follow complex flight paths;
- The startle effect and high workloads, that can lead to a drop in performance;
- The loss of the ability to anticipate;
- The increase in workload caused by unexpected ATC interventions;
- The infrequent opportunities to practice go-arounds under instruction with all engines in operation;
- The lack of monitoring of the PF by the PNF/PM, since the latter has a high workload of tasks.

However, the following were considered as factors which could deliver improvements:

- Preparing for go-arounds via practice flights or on a simulator, and via prior briefing;
- Resorting to basic manual aircraft handling when the management of the automatic systems becomes complex or requires too much deliberation;
- Automatic engagement of NAV mode;
- A lower level of thrust.

3.3 Summary and interpretation of the results

Analysis of the accounts submitted by pilots and instructors provided a clearer understanding of the operational behaviour of the crews during a go-around.

Most of the accounts related to twin-engine aircraft. The pilots who indicated having encountered difficulties during go-arounds often had to cope with a combination of two key factors:

- Limited time;
- The management, often under stressful circumstances, of numerous elements in a rapidly-changing situation.

The pilots suggested the following avenues:

<u>From a crew's perspective:</u> improve the performance of the individuals involved.

- Learn, through practice under instruction, about how to cope with a go-around with all engines in operation;
- Anticipate the likely manoeuvres by conducting a prior briefing;
- Receive instruction on coordination of cockpit resources;
- Avoid hasty actions;

- Revert to basic aircraft handling practices when the management of the situation is complex.

From an external perspective: reduce the time constraints.

- Reduce the thrust (to lower the acceleration and the vertical speed);
- Avoid or postpone tasks not immediately necessary (FMA monitoring, ATC interventions);
- Avoid overloading the PNF/PM by reducing the number of tasks to be performed.

The pilots surveyed generally expressed a negative assessment of the way in which automatic systems are made available to the crew during a go-around. Some pilots declared that they were not confident that the autosystems could handle the vertical control of the flight path, although they appreciated the lateral control. The reservations regarding automatic systems are due to a perception by those asked of:

- Their unsuitability for non-standard go-arounds;
- The complex nature of their control of the aircraft, and the difficulties in interpreting or understanding them when the situation is changing quickly;
- A risk of non-engagement of modes that are difficult to detect and on which the crew is relying;
- The danger associated with not noticing untimely disengagements in high-stress situations, with or without warnings;
- The difficulty in regaining manual control.

The accounts clearly identified cognitive limitations and their consequences in a context of time pressure and high workload.

Many accounts reiterated the factors and precursors highlighted by the investigation of ASAGA-type events. However, investigations into accidents found it difficult to prove these limitations due to a lack of factual data.

4 - SIMULATOR SESSIONS

The BEA conducted a series of simulator sessions to:

- Validate the hypotheses established from the factual data collated during the study;
- Increase the size of the data sample and obtain additional data that cannot be provided by incident reports or interviews[8].
- Understand the process involved when malfunctions are triggered, notably by studying the visual scan of the two flight crew members.

All the sessions were filmed.

Constructing the scenarios/hypotheses
The scenarios were developed based on actual incidents and accounts reported. They included 3 go-arounds, for which the following were studied:

- Application of SOP;
- Startle effect;
- Increase in workload and the task sharing;
- Monitoring performed by the PNF/PM;
- Influence of ATC;
- Management of automatic systems;
- Results of a high energy/low energy go-around
- Visual scan.

4.1 Setting-up the sessions

4.1.1 Simulation environment

The simulations were performed on B777 and A330 training FFS. In order to reproduce the operational context, it was necessary to:

- Construct realistic scenarios;
- Provide the crews with documents representative of those actually used;
- Recreate the usual composition of a crew (co-pilot, Captain);
- Ask the crews to make cabin announcements..

The main limitation of simulators is that they cannot correctly reproduce somatogravic illusions.

4.1.2 Data collected and methods

The main categories of data collected were:

- The point of gaze (fixations);
- Communication between crew members and/or with ATC;
- Observable facts in terms of actions or assimilated information;
- Observable facts relating to the technical system and the context;
- The conversations during the session;
- The pilots' subsequent accounts of their actions and of their perception of the events.

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[8] In order to fully understand an activity, when this understanding cannot be obtained by study of the partial accounts provided by the various individuals involved, information must be collected during the actual execution of this activity (Guérin et al, 1997).

Data was collected both during the session (direct observation, eye tracking, video recording) and afterwards (questionnaires, debriefs).

A HD camera fitted in the cockpit, with an extension link for images and sound, allowed specialists not present in the simulator to observe the sessions live. The rapid sequence of events specific to a go-around could be studied by analysing the video recording.

To supplement the video recording, direct observations were made in the cockpit to pick up any elements not recorded and to identify specific issues to be addressed during debriefing.

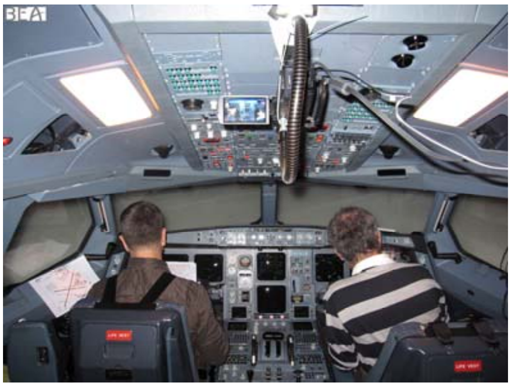

Figure 9 :
The camera installed in the A330 simulator

Figure 10 :
The camera installed in the A330 simulator

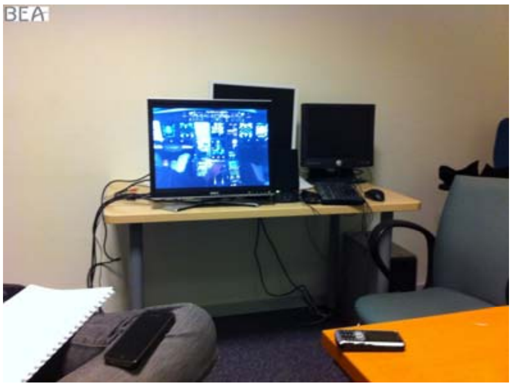

Figure 11 : Video extension link

The study of the visual scan required an eye-tracking system to be installed on each member of the crew. The system consisted of a camera focused on the eye which detected the position of the pilot's pupil (50 Hz) and a head-mounted camera which filmed straight ahead. By correlating the measured position of the pupil with the point focused on by the head-mounted camera, the system identified the point of gaze. Software tools were used to characterise the pilots' fixations on the various zones in their field of vision, called zones of interest. Consequently, it is possible to determine the time spent looking at a particular zone (instrument, control, etc.). Other data can be generated by these tools.

The data required for this study is:

- Heat maps, which provide a qualitative representation of the points of gaze during a specified period of time (take-off, approach, etc.)
- The number of times the gaze focused on a zone of interest
- The average and minimum durations of the fixations on a zone of interest.

Figure 12 : System installed on a flight crew

Figure 13 : Eye tracking image

During the sessions, five people were present in the simulator: the two pilots, the instructor, an eye-tracking system specialist and an HF specialist. Moreover, BEA investigators participated and interacted with the cockpit from outside the simulator via an external link to the HD camera.

Figure 14 : General view of the simulator

Figure 15 : Heat map

A written mini-questionnaire was completed as soon as each session ended to obtain feedback from pilots that was minimally influenced by post-session discussions or other communication with the other pilot and with the other participants. A little later, the pilots were debriefed, which involved systematic questioning and self-confrontation using the various video recordings.

4.1.3 Scenarios

The scenarios were drawn up in conjunction with the following organisations or individuals: OCV, Air France (AF), Dédale, BEA, AIRBUS, ISAE, Jean Pinet, CORSAIR, XL.

<u>Scenario presented to the crews by the BEA before the flight</u>

So as not to influence the results, the crews were told that the sessions were being held to study the visual scan system during a standard flight unaffected by technical anomalies. The scenario presented did not let the crews guess that a go-around was intended. The crews participated voluntarily, and had been contacted directly by the BEA.

The general scenario was as follows: a flight lasting for about forty minutes, taking off from Bordeaux and heading to Lyon. The aircraft has several hours of endurance. No particular meteorological phenomenon occurs. The cruising level is FL 260. The flight must end with a VOR DME approach to runway 18 R at Lyon with the Captain as PF

Scenario actually planned for the simulation sessions

The scenario described above is modified when the crew begins its approach to runway 18 R at Lyon.

ATC announces a change of runway and asks the crew to perform an ILS approach, under radar vectoring, to runway 36 L. This change to the scenario was included to increase the workload during the approach. Without advance notice, a go-around is ordered by ATC, at a height of below 200 feet, caused by traffic on the runway. Unlike the published go-around, which requires the crew to climb in the runway's axis on a magnetic heading of 350° to an altitude of 5,000 feet, ATC instructs the crew to turn left on a heading of 340° and to climb initially to an altitude of 2,500 feet. This change therefore introduces a go-around performed at low altitude with a disruption induced by an altitude limitation imposed by ATC.

The crew diverts to Marseille, in accordance with the options envisaged in the flight dossier. They perform a standard ILS approach to runway 31 R Z, during which the simulated wind gradually swings round to become a tailwind of 15 to 20 kt. ATC does not announce this change in wind direction until the aircraft is on short final. In theory, the crew should decide to perform the go-around. During this manoeuvre, ATC will limit the altitude to 2,000 ft instead of the 3,500 ft published.

On completion of this second go-around, the role of PF will be switched to the other pilot and the crew will then perform a LOC DME approach to runway 13 L under radar vectoring. The actual visibility then falls to zero, obliging the crew to perform a third and final go-around. Unlike the first two, this is a standard go-around. This go-around is often performed during recurrent training.

The actual flight time for the scenario is about 2 h 15.

The following are provided in the appendix:
- Example of a B777 flight dossier. The A330 dossier is similar.
- Approach maps for Lyon and Marseille,
- A detailed script written for the instructor handling the simulator.

4.1.4 Crew sessions on the simulator

Thirteen simulator sessions were performed: 7 sessions on the B777 simulator on the AF site, and 6 on the A330 simulator on the Airbus Training site. The first two sessions on the B777 simulator were used to validate the equipment used and the scenario: thus only 5 sessions were analysed fully.

Consequently, 11 sessions, each consisting of 3 go-arounds (GA1, GA2 and GA3) were accepted for analysis, and thus a total of 33 go-arounds were studied.

The selected simulation programme was as follows:

	Aircraft type	GA1 (go-around requested by ATC)	GA2 (go-around initiated by the crew)	GA3 (go-around initiated by the crew)
Crews 1-6 (1 airline)	Boeing	Captain (PF) and co-pilot (PM)		Captain (PM) and co-pilot (PF)
Crews 7-11 (3 airlines)	Airbus	Captain (PF) and co-pilot (PM)		Captain (PM) and co-pilot (PF)

A typical simulator session was composed of four main parts:

- Welcoming the participants, a brief presentation of the objective and a flight briefing, lasting for 15 to 30 minutes;
- Settling into the cockpit and preparing for the flight, combined with setting up the various data collection equipment (particularly the eye tracker), lasting for 40 minutes;
- Control of the flight, lasting for 2 h 15;
- Debrief, lasting for 1 h 30.

4.2 Results

The 11 GA1 were studied in depth, and the 22 others were studied in more general terms.
All the video recordings can be viewed at: http://www.bea.aero/etudes/parg/parg.php.
The anonymity of the participants has been protected.

4.2.1 Duration of the go-arounds

The first 11 GA'S were timed from receiving ATC clearance to go around up until stabilisation at the heading of 340° and at an altitude of 2,500 ft. The default was that the timer was stopped when clearance was given to climb to 5,000 ft.

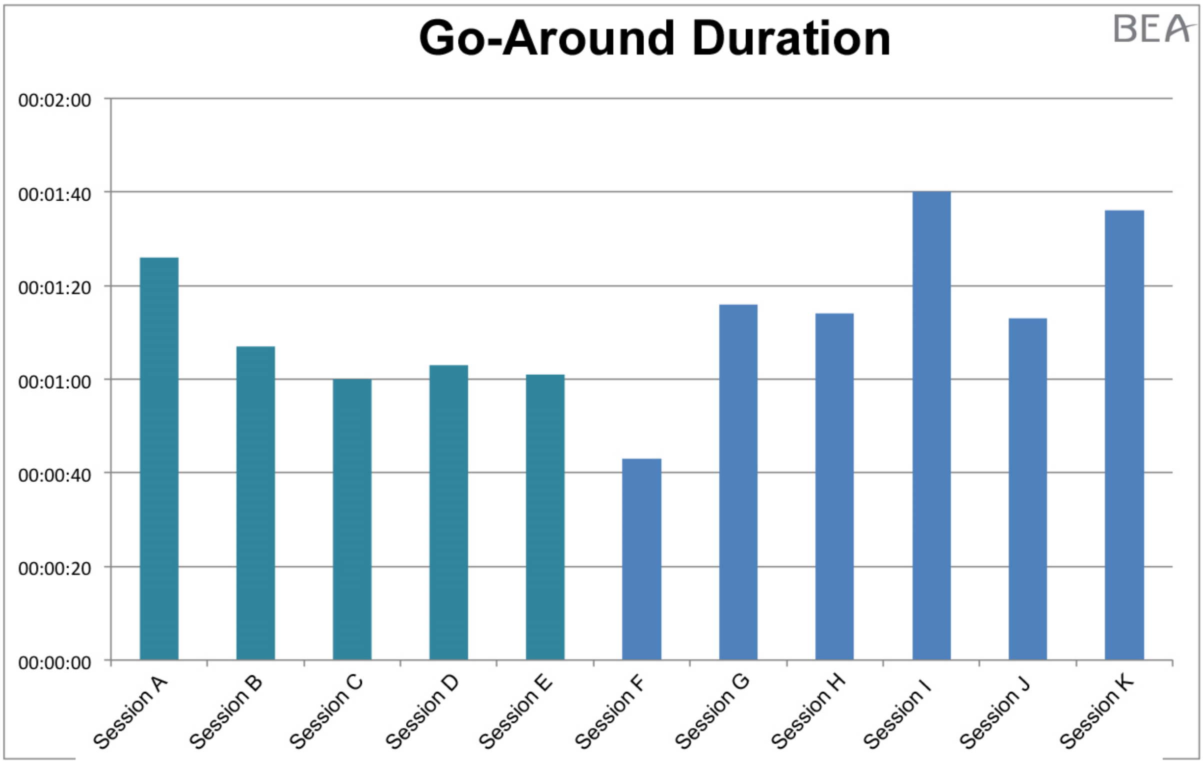

Figure 16 : go-around duration

For the 11 GA1, the durations ranged from 01 min to 01 min 40; with an average of 01 min 07 on the B777 simulator and 01 min 30 on the A330 simulator.

4.2.2 Adherence to the procedures

- Boeing B777 sessions:

The table below presents the actions performed by the crew members during the B777 sessions. It indicates the order in which the actions are listed in the airline's procedure

(SOP) and the order in which the actions were actually performed during the sessions. It also indicates the role of the crew member who performed the action. The grey-shaded lines correspond to actions specified explicitly by the manufacturer and not specified in the airline's procedure.

	Order in procedure	Session A	Session B	Session C	Session D	Session E
PF: Call out GA	1	2	-	1	1	2
PF: Push the TO/GA switch	2	1	1	2	2	1
PF: Call "Flaps 20"	3	4	3	3	3	3
PM: Position the flaps lever to 20	4	5	4	4	4	4
PF/PM: Check rotation and thrust increase	5	3 (PF)	2 (PF)	5 + *(read FMA)*	5 (+ *read FMA*)	5 (read FMA)
PM: Check thrust is sufficient, adjust as needed		9		6		6
PM: Positive climb	6	6	8	7 (PF instead of PM)	6 (PF)	9
PF: Call "Gear up"	7	7	9	8	7	7
PM: Set landing gear lever to up	8	8 + FMA (PF)	10	9	8	10
PF: Limit bank angle to 15° if V<minimum manoeuvre speed						
PF: Select or check a roll mode (>400 ft)	9	11	6	10 PM + PF ask ATC for heading and altitude	9	11
PM: Check that the go-around alt is set (on MCP)	10	10 (PF)	7 (PF)	11	10	
PM/PF: Check that the go-around route is tracked		12 (heading of 240 instead of 340)	5 (error when selecting the altitude)	12	11	8 (PM)
* acceleration height						
PF: set speed to the manoeuvre speed for the planned flap setting	11	14	11 (PM)	performed beforehand	12	performed beforehand

	Order in procedure	Session A	Session B	Session C	Session D	Session E
PF/PM: Retract flaps according to the flap retraction schedule	12	15	12	14	13 flaps UP -> flaps 1	13
* flaps retracted						
PF: select FLCH or VNAV	13	-	13			14
PF/PM: check that CLB thrust is set	14	-	-			
PF/PM: check that GA altitude is captured		13	14	15		15
PM/PF: Call (PF) and do (PM) the "After take-off C/L"	15	16	At level 70	16 (2,500 feet	14 (5,000 ft)	16

- Airbus A330 sessions:

The table below presents the actions performed by the flight crew during sessions on the A330 simulator. Three different airlines participated in the sessions.
Airlines 1 and 3 use their own SOP. These differ slightly from those for airline 2, which uses the manufacturer's procedure (see § 5.2.1 – Manufacturers' Procedures). The differences between the procedures of 1 and 3 are noted in relation to those of airline 2.

The table below presents the order in which the actions should be performed by each member of the flight crew as described in the SOP for their airline, and the order in which they were actually performed during the sessions. Each vertical section of the table relates to one airline.

The indication Y (yes) or N (no) indicates that the action specified in the SOP was, or was not, performed.

Sessions Actions		F	G
PF: Announce GA	1	1	1
PF: Thrust levers to TOGA	2	2	2
PF: Rotation Set pitch attitude to 15 ° then as directed by the FD (SRS)	3	3	3
PF: Call “Flaps”	4	4 + FMA without A/THR in blue	4
PM: Retract flaps 1 notch	5	5	5
PM: Positive climb	6	6	6
PF: Call “Gear up”	7	7	7
PM: Position gear lever to up	8	8	8
PF: NAV mode		9	
PM: Advise ATC	9		9
LVR CLB flashing PF: Thrust levers to CLB	10	10	10
PM: Retract flaps on schedule	11	11	11
PM: Lights off	12	12	

Sessions Actions		H	I
PF: Thrust levers to TOGA	1	1+ verbal call out	1+ verbal call out
PF: Rotation as directed by FD (SRS)	2	2	2
Call out GA	3		
PM: Retract flaps 1 notch	4	4	3
PM: Check and announce FMA	5	3	4
MAN TOGA	Y	Y	Y
SRS	Y	Y	Y
GA TRK	Y	Y	Y
A/THR in blue	Y	Y	N
PM: Positive climb	6	5	5
PF: Order “LDG GEAR UP”	7	6	6
PM: Select landing gear up	8	7	7
PM: NAV or HDG mode	9	8	8

Sessions Actions (no allocation to PF/PM)		J	K
Thrust levers to TOGA	1	1+ verbal call out	1+call out
Announce GA	2	2 at same time as 1	2
Rotation	3		
Set pitch attitude as directed by the FD (SRS)	4	3	
Check and announce FMA	5		3
TOGA	Y	N	4
SRS	Y	N	Y
GA TRK	Y	N	Y
Retract flaps 1 notch	Y	N	Y
Positive climb	6	N	N
Call “LDG GEAR UP”	7	4	6
Select landing gear up	8	5	5
NAV or HDG mode	9	6 (called out but not checke d)	7

Sessions Actions		F	G
PF/PM: ECAM MEMO checked	15	N	N
After take-off C/L	16	14	12

Sessions Actions		H	I
LVR CLB flashing PF: Thrust levers to CLB	10	9 then engage AP	9
Retract flaps on schedule	11	*10*	*10*

Sessions Actions (no allocation to PF/PM)		J	K
When acceleration altitude reached	11		
Check that the target speed increases to green dot if not: select ALT on the FCU			10

- Summary:

No flight crew applied strictly the go-around specified go-around. Deviations were noted with regards to:

- Who (PF or PNF/PM) performed the actions in the gear and flap retraction sequence;
- The PF's callout of the go-around;
- Reading the FMA modes (incomplete or non-existent);
- Monitoring the flight path;
- Cross-checks;
- Reducing the thrust (deliberate disengagement of the autothrust);
- Technical callouts;
- Teamwork (significantly disrupted).

The table below describes the most significant deviations. The sessions performed on the Boeing simulator appear in blue.

	Callouts and management of the clearances	*Mode management*	*Thrust management*	*Aircraft configuration management*	*Management of manual control*	*Trajectory management*
A	100-degree error in heading detected by ATC (240 instead of 340)					Deviation from the correct heading, a heading of 300 degrees at one point
B	No callout of GA	Partial callout of the FMA modes	Non-verbalised verification of the thrust by the PM	“Flaps 20” maintained up until change of mode to SPD mode Flaps 5 maintained until cleared to climb to 5,000 ft the max. speed for this configuration is 173 kt		
C				Rapid sequence of flap retraction as the speed approached VFE	The pitch attitude for level flight was slightly greater than that indicated on the FD	Altitude slightly exceeded, by 40 ft, then by 140 ft subsequently
D	Read back of 5,000 ft rectified by ATC which specified 2,500 ft	A heading of 340 set HDG SEL mode not selected by PNF/PM Detected by PF who requested a correction		Speed approached VFE before the flaps were retracted		
E				The PF gestured with his finger to indicate that the landing gear should be retracted; no verbal indication	AP engaged after retracting the flaps to position 5 and before capturing 2,500 ft	Altitude exceed by 120 ft
F	Read back, but no selection of an altitude of 2,500 ft Confirmation of 5,000 ft requested once the aircraft had climbed to 3,000 ft				2,500 ft not selected on FCU 3,000 ft selected on FCU	Altitude exceeded by 500 ft Vzmax greater than 4,000 ft/min
	Callouts and	*Mode management*	*Thrust management*	*Aircraft configuration*	*Management of*	*Trajectory*

	management of the clearances			*management*	*manual control*	*management*
G			Thrust reduced when altitude of 2,500 ft captured without verbal announcement	Flaps 3 then directly flaps UP	Bank to the left without tracking the FD which moved to the right	Heading reduced to a heading of 315
H		2,500 ft selected on the FCU when climbing through 3,000 ft Mode changed to OP DES				Altitude exceeded by 600 ft Activation of C-chord warning
I	The response to ATC's clearance was "Stand-by"	AP engaged as the aeroplane climbed through 1,200 ft 2,500 ft displayed but not selected on the FCU as the aeroplane climbed through 3,300 ft Mode changed to VS+3800 V/S+3800 maintained for 10 s Mode changed to OP DES to regain the selected altitude of 2,500 ft The initial heading selected when engaging HDG mode was 351, followed by the selection of a heading of 340	LVR CLIMB flashed for 10 s while the PF was selecting the heading and the altitude		AP engaged for 16 s after the go-around FCU manipulated by the PF	The altitude was exceeded by 1,400 ft. This overshoot can be broken down into three components: - 400 ft before asking ATC to confirm the altitude - 600 ft in VS+3800 mode - 400 ft due to the aeroplane's inertia Vzmax greater than 3,800 ft/min C-chord warning triggered (for 40 seconds)
	Callouts and	*Mode management*	*Thrust management*	*Aircraft configuration*	*Management of*	*Trajectory*

	management of the clearances			*management*	*manual control*	*management*
J	ATC advised of the go-around 52 s after its initiation	Few callouts of FMA modes, with the exception of ALT* A heading of 340 set NAV mode engaged (120 s)	Thrust lever positioned back from the CLIMB detent to limit the thrust (message: A/THR *limited*) A/THR disengaged manually		FD not initially tracked, so that a heading to the left could be followed FD then tracked in NAV mode	The bank to the left to a heading of 325 was executed without tracking the FD The FD was then followed, which indicated the orders for applying the FMS's go-around procedure (NAV mode) Heading increased to a heading of 030 Altitude exceeded by 200 ft No cross-check performed by PNF/PM
K		A few FMA modes read after reading the initial go-around modes	Thrust lever positioned back from the CLB detent (OP CLB mode) A/THR disengaged when at 2,500 ft with speed trend positive to the VFE and selection of ALT HOLD on the FCU. A/THR disengagement actions not verbalised	Landing gear retracted by the PNF/PM before the callout from the PF		

4.2.3 Mode management

In general, the changes of FMA mode were called out and checked almost systematically by the crews during the phases preceding the go-around. During the go-around, the first FMA mode was often called out. The subsequent changes were rarely called out.

On average, five to six mode changes occurred during a go-around on the A330 simulator, and two to three on the Boeing simulator. The table below, which is not exhaustive, indicates the significant changes.

Session	Change of mode that actually occurred	Requested change of mode	Mode change called out “Called out” indicates that all the modes were called out	Verified change of mode “verified” = fixation of gaze on the FMA “called out” = verbal call out	Comments
A	THR LNAV TO/GA		Called out	"verified" by the PNF/PM	
	SPEED HDG SEL ALT		Called out	not verified but called out by the PF prompted by the PNF/PM changing the heading and altitude on the FCP → this failure to check is not a deviation	Heading error: selection of a heading of 240 instead of 340
B	THR LNAV TO/GA		*	*	
	THR HDG SEL TO/GA		HDG SEL	verification of HDG SEL mode only, 18 s later	HDG SEL mode called out when it becomes active ("deboxed")
	SPEED HDG SEL ALT		*	*	SPD ("Speed bug") mode assimilated but not called out
C	THR LNAV TO/GA		*	verified and called out	
	THR HDG SEL TO/GA	HDG SEL	HDG SEL	verified	Reminder given by PF to select HDG SEL mode: the pressing of the button was forgotten when selecting the heading – no change of mode
	SPD HDG SEL ALT		SPD ALT	verified and called out	
D	THR LNAV TO/GA		Called out	*	
	THR HDG SEL TO/GA	HDG SEL	*	probably verified*	
	SPD HDG SEL ALT	*	*	probably verified*	
E	THR LNAV TO/GA		*	called out	
	THR HDG SEL TO/GA	*	HDG SEL	*	
	SPD HDG SEL ALT	*	SPD ALT	verified	

Session	Change of mode that actually occurred	Requested change of mode	Mode change called out "Called out" indicates that all the modes were called out	Verified change of mode "verified" = fixation of gaze on the FMA "called out" = verbal call out	Comments
F	MAN SRS GA TRK TOGA	Not analysed. The ATC sequence does not conform with the specified scenario			
G	MAN SRS GA TRK TOGA		Called out	verified	
	MAN SRS HDG TOGA	*	*	*	
	THR CLB OP CLB HDG	*	*	*	thrust levers moved to the CLB detent as the aeroplane approached 2,500 ft LVR CLB flashed for less than 1 s
	SPEED ALT HDG		SPD	SPD ALT	
H	MAN SRS GA TRK TOGA ALT		Called out	*	
	MAN OP CLB HDG TOGA LVR CLB	*	LVR CLB	*	Thrust lever moved without a callout other than of the mode
	THR CLB OP CLB HDG	*	*	*	
	SPD V/S +3700 HDG		SPD pull ALT	*	
	THR CLB OP DES HDG		OP DES OP DES HDG	*	OP DES mode prompted by the selection of an altitude of 2,500 ft when the aeroplane was at 3,000 ft
	THR CLB ALT* HDG				

Session	Change of mode that actually occurred	Requested change of mode	Mode change called out "Called out" indicates that all the modes were called out	Verified change of mode "verified" = fixation of gaze on the FMA "called out" = verbal call out	Comments
I	MAN SRS GA TRK TOGA ALT		Called out	called out	Call out when the modes are no longer boxed
	MAN SRS HDG TOGA OP CLB		HDG	*	Movement on the FCU to the left to engage HDG mode (initial heading of 351) pending confirmation of the actual heading from ATC
	SPEED V/S +3800 HDG		SPEED	verified	
	THR IDLE OP DES HDG ALT		THR IDLE OP DES THR IDLE OP DES ALT	verified	The ALT button on the FCU was pulled in response to the C-chord warning
	SPEED ALT* HDG		*	*	Immediately before the climb to 5,000 ft Note: new mode reversion to V/S which increased to -1700 ft/min despite being in ALT* and changing ALT from 2,500 to 5,000.
J	MAN SRS GA TRK TOGA ALT		*	*	
	MAN SRS GA TRK TOGA OP CLB	Request from PF to select heading	*	*	
	MAN SRS HDG TOGA OP CLB	Request from PF to "pull" "pull"	*	*	
	MAN ALT * NAV TOGA LVR CLB		ALT *	* *	
	SPEED ALT* NAV LVR CLB		*	*	

Session	Change of mode that actually occurred	Requested change of mode	Mode change called out "Called out" indicates that all the modes were called out	Verified change of mode "verified" = fixation of gaze on the FMA "called out" = verbal call out	Comments
	SPEED ALT NAV LVR CLB		*	*	
	THR CLB OP CLB NAV		*	*	
K	MAN SRS GA TRK TOGA ALT		*	*	
	MAN SRS GA TRK TOGA OP CLB		Called out	*	
	THR CLB SRS HDG OP CLB	HDG 340	HDG THR CLB	*	
	THR CLB OP CLB HDG ALT		*	*	
	SPEED VS+3500 HDG		*	*	
	THR CLB OP CLB HDG		*	*	
	SPEED V/S + 1500 HDG		*	*	Altitude selected when the aeroplane passed through 2,500 ft
	SPEED ALT HDG	ALT HOLD pressed (maintain at 2,700 ft) at the request of the PF	*	*	
	ALT HDG		*	*	A/THR disengaged
	OP DES HDG ALT	Pull ALT	OPEN DES	*	ALT button pulled at 2,500 ft
	ALT* HDG		ALT* (at same time as OPEN DES)	OP DES ALT* check	
	SPEED ALT HDG		*	*	AP and A/THR re-engaged

Note: an asterisk in a box indicates that the condition was not met.

4.2.4 Interactions with ATC

The table below summarises the time taken by the crew to assimilate the clearance indicated by ATC and provides key extracts from the dialogue.

Note: during session F, ATC's clearance was transmitted as two separate messages: initial instruction to go around, followed by an instruction to capture a heading of 340 and an altitude of 2,500 ft. The interaction between the crew and ATC was not therefore compared with those recorded for the other sessions.

Sessions	ATC	Time to select the altitude on the FCU	Time to select the heading on the FCU	Dialogue extract PF	Dialogue extract PM	Comments
A	*" [airline 1] go-around due to traffic on runway, maintain 2,500 feet turn left heading 340"*	24 s	32 s (heading of 240 selected)	*10 s: "he said 2,500, 2,500 straight away, but what was the heading?"*	*19 s: "[airline 1] please confirm the clearance"*	No read back from the PM The PF repeats the altitude and requests confirmation of the heading The PM asks ATC to repeat the clearance before selecting the heading and altitude on the FCU Error when selecting the heading
B	*" [airline 1] go-around, turn left heading 340 maintain 2,500 feet"*	27 s	16 s	*9s : "Heading 340"* *15 s: "2500 ft"*		The PF repeats the heading and the altitude to the PM
C	*"[airline 1] go-around to left heading 3-4-0, climb to 2,500 ft"*	29 s	22 s (heading selected) 29 s mode selected	*15 s: "What did he say for the heading?"*	*19 s "[airline 1]…we are going around, can you confirm the heading?"*	ATC replies with the heading and altitude Heading displayed but not selected

Sessions	ATC	Time to select the altitude on the FCU	Time to select the heading on the FCU	Dialogue extract PF	Dialogue extract PM	Comments
D	*"[airline 1] traffic on runway, go-around to the left heading 340 climb to 2,500 feet"*	20 s	12 s (heading selected) 23 s mode selected		*8 s: going around to left, heading 340 climbing to 5,000 feet"*	Immediate but incorrect read back of the altitude Corrected by ATC with repetition of 2,500 feet Heading displayed but not selected
E	*" [airline 1] go-around due to traffic on runway, maintain 2,500 feet turn left heading 340"*	31 s	25 s	*10 s: (...) to the left, I don't know what else"*	*17 s: "er...going around to 2,500 feet, but what is the heading?"*	
F	*2-message request*					
G	*"[airline 1] traffic on runway, go-around turn left heading 3-40, climb to 2,500 feet"*	36 s	31 s	*17 s: "what did he say after left?"*	*19 s: "Please say again, we are going around"*	
H	*"[airline 2] traffic on runway, go-around, turn left heading 340 climb to 2,500 feet"*	40 s	33 s		*20 s "Going around, please again the heading."*	

Sessions	ATC	Time to select the altitude on the FCU	Time to select the heading on the FCU	Dialogue extract PF	Dialogue extract PM	Comments
I	*"[airline 2] traffic on runway, go-around, go-around turn left heading 340, climb to 2,500 feet"*	41 s (altitude selected on FCU) 51 s mode selected	26 s: Assimilation of a heading to the left (HDG mode with heading of 351) 37 s		*3 s: "we're going around [airline 2]* *8 s: "Standby [airline 2] we're going around"* *26 s: "Can you say again for [airline 2]"*	AP engaged after 16 s Action on the FCU by the PF
J	*"[airline 3] runway occupied, go-around turn left heading 340, climb to 2,500 feet"*	32 s	27 s 27 s (heading set on FCU) Then NAV mode engaged	*9 s: "Select heading 340"* *22 s: "Select 2,500"*	*52 s: "[airline 3] we are going around to a heading of 340, 2,500 feet"*	The PF requested the selection of a heading of 340 and an altitude of 2,500 ft, and made his point by pulling the corresponding buttons on the FCU
K	*[airline 3] traffic on runway, go-around* *…* *I confirm, go-around to left, heading 340 climb to 2,500 feet"*	36 s	31 s	*13 s: "…What heading did he say?"*	*14 s: "Err… I don't know"* *15 s: "airline 3] going around, can you repeat the heading and altitude please"*	

- Summary:

Ten of the eleven GA1 were requested by ATC. The instruction to go around was combined with a heading (340) and an altitude (2,500 feet). For the ten crews concerned, the ATC request was assimilated in different ways:

- One PM asked ATC to repeat the clearance within 15 s of the initial request.
- Five PF asked the PM to ask for the heading again, within 20-25 seconds. For these crews, the heading and altitude were selected within 30 seconds.
- One crew included the word “standby” when reading back the go-around, and contacted ATC again 30 seconds later.
- Three crews assimilated the heading and altitude from the first ATC clearance instruction. Note that, for these crews:
    - One error was made reading back the altitude and one error was made selecting the mode for the altitude (detected directly by the PF);
    - In one case, an immediate read back was followed by an error when selecting the roll mode;

In one case, the PF immediately selected the clearances given, which were read back one minute later by the PNF/PM.

4.2.5 Summary of the post-simulation interviews

	Difficulties expressed by the PF	Difficulties expressed by the PM	Priorities expressed by the PF	Priorities expressed by the PM
A	*I feel bad about the deviation from the heading, it felt like it went on forever, we didn't share the same priorities, the PM didn't see that I was holding back the levers*	*when ATC intervened the stress level increased managing the various priorities - thrust, flight path, FMA and listening to what's going on*	**Pitch, thrust**	**Make sure the aeroplane is climbing**, thrust, pitch attitude, FMA, VFE, altitude
B	*the FD led us off in one direction; these are the limitations of the automatic systems - in these cases, it's all down to their logic*	*requests from ATC to reduce altitude and to follow a heading, I couldn't respond to ATC*	Go back to the basics, **pitch, thrust,** heading, altitude, we stayed on flaps 20 and managed the speed	I thought of **positive climb,** pitch attitude, thrust I focused on the speed because the speed can rise very quickly
C	*The overshoot*	*I was slow to respond, I didn't call out the rate of climb when setting the landing gear to up ... Yes, I heard him give a heading and an altitude, but with all the noise in the cockpit and the callouts from the Captain I didn't copy*	**Pitch, thrust**, read the FMA	Role of the PM --> monitor the parameters, **pitch**, thrust, flight path
D	*PM-->concern about the altitude*	*handling bursts of information from my colleague and from ATC all at the same time is difficult and tiring*	**Pitch, thrust** everything else is a lower priority	Flight path
E	*Heading, go-around + altitude, all 3 is too much It's impossible to process all the information*	*I tried to listen to ATC and at the same time the callouts from the Captain - I forgot the ATC clearance and the positive climb. I was confused because of the disruption from ATC*	palm switch **Pitch, Thrust**, climb, FMA	I **called out the modes** since often they are not called out and doing this gets me back on track The FMA is vital on the A320, the FMA modes sequences the whole go-around
F*	*Simple decision, no difficulties*	*Textbook stuff, sequence-based management*	Pitch attitude	**Pitch, thrust** in sequence after
G	*No difficulties, but lots of information*	*I remember a low altitude, a heading to the left, but that's about it*	**Pitch, thrust**	**Pitch attitude, thrust**

	Difficulties expressed by the PF	Difficulties expressed by the PM	Priorities expressed by the PF	Priorities expressed by the PM
H	*Workload a bit heavy, a bit overloaded*	*I was disturbed by the changes (compared with what I expected)*	My actions, i.e. **call out the go-around, flaps and read the FMA**, then select the pitch attitude you follow the FD which displays the SRS, afterwards you engage AP	My priorities are flight path, flight control, **positive climb**, retracting the gear and flaps
I	*I wasn't overloaded at all, no difficulties*	*The requests from the Captain on top of those from ATC was a lot to deal with*	the PM was occupied, me I had to **manage the flight path**	**For a go-around** there are **call outs to make**, the top priorities are safety and flight path
J	*The aeroplane accelerated very quickly and captured the altitude. We had flaps extended. My actions are debatable, but I disengaged the thrust levers so as not to exceed the VFEs. Yes, I exceeded the heading as well because the FD wasn't correct*	*At that point I didn't catch everything, fortunately the Captain did*	**Control the flight path** and the speed	**The right callouts** at the right time
K	*A workload that wasn't too high*	*Surprise generated by the high pitch attitude*	**Pitch, thrust** at the go-around altitude	**Ensure that the aeroplane is climbing**, thrust, pitch attitude, FMA, VFE, altitude At the go-around speed

Note: words in bold type represent a theme that was highlighted significantly in the interview.

At least one member of ten of the eleven crews reported having experienced some difficulties. The eleventh crew is the crew that received the ATC request as two messages.
The PMs reported difficulties in managing the communications with ATC at the same time as responding to the requests from the PF, notably the reading back of heading and altitude. The difficulties described by the PFs relate to the management of the flight path.

4.2.6 Overall summary of go-around 1

The GA1 scenario required the crew to climb rapidly from a position at or below the minimums. The crew then had to adapt the expected go-around flight path to accommodate a very restrictive limiting altitude and a heading to the left.

In accordance with the airlines' SOP, all the go-arounds were preceded by a briefing, generally performed half-an-hour beforehand. Some crews conducted an additional mini-briefing during the final approach, to review the key points of the GA.

A go-around is initiated by the activation of TOGA mode, an increase in thrust, and retracting the flaps by one notch.

For all eleven sessions, this initiation was performed without difficulty or major failings by the crews: all performed the go-around upon receiving the instruction from ATC, all engaged TOGA mode and all retracted the flaps by one notch. There was, however, some variability: no clear callout of the go-around (1 case), no initial callout of the FMA modes by the PF (2 cases) or by any member of the flight crew (2 cases), incorrect flap retraction position request (deviation detected and corrected by the PNF/PM). The crew compensated for all these "approximate responses".

Immediately, or a few seconds after the initiation of the go-around, the tasks allocated to the PNF/PM were multiple and diverse (callouts, communications, inputs, monitoring):

- Callout of "Positive rate (or Positive climb)" and of "Gear up";
- Read back of ATC's instruction and assimilation of the clearances (selection of the heading and altitude);
- Verification of the initiation of the go-around (pitch attitude and thrust);
- Monitoring of the PF's flight control, verification of the FMA modes.

During debriefing, almost all the PNF/PMs reported that they encountered difficulties in managing all these actions simultaneously. These difficulties related to:

- The reading back and assimilation of ATC's initial instruction: *"At that point I didn't catch everything, fortunately the Captain did"; "a heading to the left, but that's about all I can remember"; "I couldn't respond to ATC";*
- The overloading, notably auditory, and to the prioritisation of the actions: *"handling bursts of information from my colleague and from ATC all at the same time is difficult and tiring", "the management of the priority between thrust, trajectory, FMA and the listening";*
- The impacts of the overloading on the actions or callouts to be performed: *"I was slow to respond, I didn't call out the rate of climb when setting the landing gear to up"; "I was confused".*

To cope with the task overload, the flight crew had to prioritise their actions. When questioned on this subject during debriefing, the PFs were almost unanimous regarding their priorities: *"pitch, thrust or management of the flight path".* The replies from the PNF/PMs were more complex and varied. They referred to the *"callouts"* to be made and to the various "*monitoring tasks"* such as *"positive (rate of) climb, ensure that the aeroplane is climbing, flight path, pitch attitude and thrust".*

The crews that experienced difficulties made adaptations to the procedure. Some adaptations had positive effects (approach to interception altitude); others led to deviations from the expected result (flight path, for example).

Assimilation of instructions from ATC

The nominal operation expected during the scenario was the execution of the following actions in the correct sequence: (1) instruction from ATC to perform a go-around with limitations on heading and altitude; (2) read back from the PNF/PM; (3) selection of the heading requested plus selection of HDG mode, selection of the altitude restriction plus selection of ALT mode.

Ten of the eleven GA1 were requested by ATC, with the initial instruction including, right from the start, limitations regarding the heading (340) and the altitude (2,500 feet). For the ten crews concerned, this instruction from ATC was assimilated in different ways.

No crew read back immediately the go-around, the clearances and the limitations requested. Only two crews replied to ATC immediately to confirm that they were going round.

Seven crews requested confirmation of the altitude and/or of the heading. The instruction was therefore managed in two stages: the initiation of the go-around, and then the assimilation of the ATC limitations. Responsibility for asking ATC to repeat the constraints was taken by the PNF/PMs (two PNF/PMs asked ATC to repeat clearance details within 15 s of the initial instruction) or by the PFs (five PFs asked the PNF/PM to request again the heading from ATC, within 20-25s). For these crews, the heading and altitude were selected within 30 to 40 seconds.
Three crews assimilated the heading and altitude from the first ATC clearance instruction. Note that, for these crews:

- The PF assimilated the clearances immediately, repeated the clearances to the PNF/PM, who read back this information one minute later (2 crews);
- One crew read back an incorrect altitude, which was corrected immediately by the ATC.

Overall, in 7 cases out of 10, the assimilation of the ATC limitation, or the request for confirmation, was initiated by the PF.

Callout of positive climb and of gear up

The sequence expected was as follows: as soon as the vertical speed is positive, the PNF/PM calls out “Positive rate” (Boeing) or “Positive climb” (Airbus), the PF replies “Gear up” and the PNF/PM activates the retraction of the landing gear.

In all eleven simulator sessions, the crews retracted the landing gear within seconds of the start of the go-around.

Note that:

- Seven crews followed the specified sequence precisely;
- In two cases, “positive climb” was called out by the PF only just before the PF’s request for landing gear up;
- In one case, the PF's request for gear up consisted solely of a gesture with his finger;
- In one case, the PNF/PM retracted the landing gear after his callout of “positive climb” without waiting for confirmation from the PF.

Management and monitoring of thrust

All the crews applied TOGA thrust immediately upon receiving the go-around instruction. Pushing the thrust lever forwards was the first action performed by the PF, at the same time or before the PNF/PM's callout of the go-around.

There are several indicators that the crew can consult to check that TOGA thrust had been applied: the position of the thrust levers, the mode displayed on the FMA, the actual thrust delivered by the engines. One of the pilots expressed this very clearly during debriefing *"you push the levers forward to the TOGA detent, you check this on the FMA, then, on your way to checking the gear you check your N1".*

Among the 22 pilots, seven of the eleven PFs and six of the eleven PNF/PMs mentioned thrust as one of their priorities. However, there was very little communication between the pilots regarding the thrust. Most of the actions following the application of the thrust were limited to reading the corresponding FMA mode. Only one PNF/PM effectively called out his verification of the thrust: *"we have thrust".* Moreover, one PF disengaged autothrust without calling this out (PNF/PM*"have we disengaged autothrust?"* PF *"yes, it's disengaged"*). As a more general comment, most of the crews relied on the automatic systems to manage the thrust ("*autothrust should know what to do*").

During the eleven go-arounds, the expected operation was adapted on four occasions:

- In one case, the thrust was reduced when the go-around altitude was intercepted, without a callout from the PF;
- Full thrust was maintained for 10 s, even though the LVR CLIMB message was flashing, AP was engaged and the PF was busy selecting a heading and an altitude;
- Manual disengagement of the A/THR (2 cases).

Management of modes (and automatic systems), their callout and monitoring

The initial go-around mode is initiated differently on different aeroplanes:

- By pressing on the "palm switches" on Boeing,
- Automatically when the thrust lever is pushed forward to the TOGA position on Airbus.

As stated previously, all the crews triggered this initial mode.

- The initial modes were called out by 8 PF (out of 11) and verified (with callout) by 5 PNF/PM;
- One PNF/PM called out the initial modes;
- Two crews did not call out the initial modes.

One of the PF explained during debriefing why he didn't call out the go-around: "*I didn't call it out on this occasion because I didn't want to interrupt the PNF/PM's execution of his sequence of actions; he was retracting the flaps*". One PNF/PM explained his callout as follows: "*I called out the modes since often they are not called out and doing this gets me back on track, because I'm used to the A320 and the FMA is vital, the FMA modes sequence the whole go-around*". However, reading this information appears to be costly in terms of time and mental resources.

The second action required is to change the flight path in accordance with the instruction from ATC. The crews selected a heading and an altitude, and thus "heading" and "altitude" modes.

The following selection difficulties were observed:

- HDG mode not selected by the PNF/PM, detected immediately by the PF: “*heading sel”*;
- HDG mode not selected by the PNF/PM, detected immediately by the PF: *“can you put me in HDG please”*;
- HDG mode set briefly, but modified at the request of the PF “pull” and the PNF/PM “push”, NAV mode not detected.

The number of mode changes varied from 3 (the minimum possible) to about ten. This variation was primarily due to the aeroplane’s altitude at the instant when the altitude constraint was assimilated.

On the Boeing simulator, three mode changes were made in sequence: go-around mode, then a change in roll mode (HDG SEL) and finally a change in the vertical mode (ALT).

On the Airbus simulator, the number of mode changes varied from 4 to more than 10. The expected go-around sequence was disrupted by having to assimilate the limitations imposed by ATC, and by the various strategies that the crew had to employ to comply with them._Indeed, the change in the interception altitude (from 5,000 ft to 2,500 ft) may result in mode changes and reversions to the basic V/S mode. This may have resulted, in certain cases, in a high number of mode changes over a very short period of time.

Consequently, during one of the go-arounds, there were nine mode changes. These changes were rarely called out. Most of them were not detected. The airline’s procedures were those of the manufacturer.

MAN TOGA	SRS	GA TRK
MAN TOGA	OP CLB	HDG
SPEED	V/S + 3700	HDG
THR IDLE	OP DES	HDG
SPEED	ALT*	HDG
THR CLB	OP CLB	HDG

Figure 17 : FMA mode

The delay in assimilating the altitude limitation prompted several crews to activate the “open descent” (OP DES) mode in situations where the aeroplane’s actual altitude was higher than the recovery altitude selected by the crew on the FCU.

These mode reversions and changes may result in the aeroplane continuing to climb with a very high vertical speed, irrespective of the altitude constraint. Some crews found it difficult to detect this situation since they expected that the altitude selected on the FCU would be taken into consideration by the aeroplane’s automatic systems. As a result, the only indication that allowed the crew to realise that this reversion had occurred was the consequence (i.e. the appearance of V/S mode); the altitude of 2,500 ft was still displayed. In all the cases, the detection of a reversion prompted an immediate action from the crew.

Consequently, the monitoring of the FMA modes is difficult, but crucial, in terms of understanding the aeroplane’s behaviour.

Management and monitoring of the flight path, calling out deviations

The changes, imposed by ATC, to the go-around procedure also placed significant constraints on the crew.
The task of following the flight path is subject to variability that is an inherent consequence of the significant ATC limitation. The principal manifestations of this variability were minor altitude overshoots due, in part, to the inertia of the aeroplane or to imprecise vertical tracking of the FD (deviations of about 100 to 200 feet).

In the vertical plane, more significant altitude deviations were also recorded:

- Realising that the limit was 2,500 ft when the aeroplane was at about 3,000 ft. Two different circumstances were observed: in the first case, an altitude of 3,000 ft was selected on the FCU, combined with a request for confirmation from ATC, and in the second case, 2,500 ft was selected combined with a transition to OP DES mode;
- An overshoot of 1,400 ft was recorded, due primarily to an altitude overshoot before the crew assimilated ATC's altitude constraint, then an undetected transition to VS mode.

Some crews managed to avoid excessive altitude overshoots by using thrust limitation, achieved either via the automatic limitation of the vertical speed or via manual thrust management.

In the lateral plane, deviations from the specified heading also occurred. For example, some crews immediately assimilated the instruction from ATC by anticipating the selection of a specific heading.

More significant deviations also occurred:

- Due to a heading selection error: during one go-around, the PNF/PM read back 340 but selected 240 on the FCU. The PF verified that HDG mode was selected and tracked the FD to control the lateral flight path. The deviation from the requested flight path could not be detected by comparing the PF's inputs with those indicated by the FD. The only resource in the cockpit which could have indicated the heading actually requested was the pilots' memory. It was ATC which "detected" and notified the crew of the deviation from the heading.
- Due to crew uncertainty about the selected value: the heading of 340 was correctly selected by the PNF/PM; the PF copied the ATC's requests "to the left, 2,500 feet". He reported, during debriefing, that while he was certain about the altitude, he was unsure about the heading. He initially banked to the left, without tracking the FD. When he reached a heading of 320, he asked the PNF/PM to repeat the heading, who then confirmed that he had overshot the requested heading. The PF explained during debriefing: *"yes, all of a sudden I realised, he had selected 340. I saw the roll bar on the right of the screen despite the fact that we should have been going to the left, so I had overshot – the altitude and speed were OK though".* The PNF/PM reported, during debriefing, that he had been monitoring the speed and the altitude: "*I hadn't noticed the FD roll bar*".
- Due to a mode selection error: the heading of 340 was selected correctly, but the heading mode was not selected. The PF banked to the left until he reached a heading of 325 without tracking the FD. At this point he noticed that he had overshot the heading ("*I've overshot the 340 heading*"). This was the first phase of the overshoot. He then tracked the FD which gave him orders that followed the FMS's go-around procedure (NAV mode). The heading reached 030. The PF then noticed that the AP had re-engaged and that the aeroplane was beginning a bank to the right, as

provided for in the initial flight path. The PNF/PM had very little experience on the aircraft.

These deviations highlight the multiplicity of information that the crew must assimilate to follow a lateral flight path:

- The ATC's initial request for clearance "to turn left";
- The ATC's heading clearance of "340"
- The heading of "340" selected on the FCU;
- Checking the PFD and the associated callouts;
- The FD's roll bar;
- The heading information under the horizon line;
- Tracking the flight path indicated on the ND.

In a nominal situation, all this information is consistent, and in some cases redundant. In a critical situation, the accuracy and validity of the data may vary; the PF does not necessarily have the resources necessary for making sense of the various sources. In this context the monitoring performed by the PNF/PM is extremely important. Moreover, this monitoring may prove to be incomplete if an error is made when selecting the mode or the heading itself.

Maintaining the aeroplane in its operational flight envelope and monitoring this

The go-around procedures specify that the flaps should be retracted one notch and, once a positive vertical speed has been called out, that the landing gear should be retracted when requested by the PF. These tasks require the attention of both the PF and the PNF/PM.

Subsequently, the PF's primary role is to control the flight path and to request the retraction of the flaps on schedule until the aircraft's configuration becomes clean. The PNF/PM must monitor the flight path, as well as perform the scheduled flap retractions sufficiently quickly to prevent a VFE overspeed, and also to obtain an additional margin in terms of speed

During the simulations, it was noted that, during this phase:

- The FMA modes were almost never read by the two crew members after the initial verification of the go-around mode;
- There were very few verbal exchanges;
- The monitoring of the actions of the PF (pitch attitude/tracking the FD) by the PNF/PM in particular, but also the monitoring of the PNF/PM (selection of heading/altitude) by the PF was sub-optimal;
- The errors made (heading/speed/mode etc.) were not detected immediately, but often only after the excursions had become large.

Cross-checks, callouts and teamwork are thus difficult to perform if the go-around requested does not comply with the published procedures.
In this context, and without compromising flight safety, the two members of the crew often implemented successful adaptations that, strictly-speaking, deviated from the correct application of the procedure. However, some of these adaptations led to deviations from the flight path.

4.3 PF / PNF-PM's visual scan

4.3.1 Measurements

The eye-tracking technique is often used to measure the point of gaze in the fields of physiology and behavioural analysis. This study focussed on an analysis of the points of fixation in order to contribute towards understanding what the pilot was focussing his attention on, and for how long, during the go-around. Note that a particular limitation of this approach should be borne in mind: the fact that the gaze fixates on a particular display of information (e.g. speed) does not necessarily mean that the pilot has concentrated on it, or that s/he has actually processed the value of this information. However, it is accepted that there is a positive correlation between the duration and frequency of the fixations and the probability that the information viewed has been processed. Thus, a statistical approach is valuable in helping to make a link between point of fixation and distribution of attention.

The results of the processing of eye tracking data can be expressed in different ways, qualitatively and quantitatively:

- Heat maps;
- Graphical representations of the chronological order of gaze fixations;
- The percentage of the total time spent looking at certain zones in the cockpit.

Heat map

Heat maps reflect the "density" of gaze fixations[9] in the cockpit during the go-around period. The colour gradient of the heat map produced by each pilot is deliberately different, and the region with the highest gaze density is systematically shown in red.
It is therefore important not to compare one heat map with another based on the colour of a zone.

Figure 18 : Heat map for a PNF/PM during a go-around

Note: the colour gradient from blue (cold) to red (hot) represents the "degree" of interest on a display of information. The longer the fixation on a display, the more the colour changes towards red, and the greater the probability that the pilot has paid attention to

[9] This density is defined as being the number of fixations per unit surface area.

it. This type of representation can demonstrate, for example, that a pilot has particularly focussed his attention on the artificial horizon, speed and FMA.

As a prerequisite to a quantitative analysis of the point of gaze on different zones in the cockpit, these zones must be defined.

Definition of the zones of interest

The Zones of Interest (ZI) in the cockpit may be defined as being a single value (e.g. speed) or a set of information presented within a display (e.g. the ND). Once the ZI have been defined, data detailing the order and duration of the fixations within each ZI can be generated over a specified period (e.g. at time t0, the pilot fixated the speed for 120 ms). This approach can also be used to determine the fixation duration for each ZI as a percentage of the total duration of the go-around (e.g. the pilot spent 30% of the total duration of the go-around fixated on the speed).

The ZI were selected based on the requirements of the study, on the initial observations and on the limitations of the Eye Tracker tool. The ZI are the framed areas indicated in the photos below.

Figure 19 : definition of the zones of interest in the cockpit

Figure 20 : definition of the zones of interest on the PFD

A zone designated as an "Outside Identified Zones (OIZ)" ZI was also defined. This ZI covers all the viewed areas that are not included in one of the ZI mentioned above. In practice, this ZI primarily includes fixations associated with aircraft configuration management. The OIZ also includes head movements, as well as measurement noise (fixations on the edge of a ZI). The latter was minimised during the various analyses and does not have an impact on the trends identified.

Graphic representations of the chronological sequence of gaze fixations

This representation reveals both the sequence of gaze fixation and the durations.

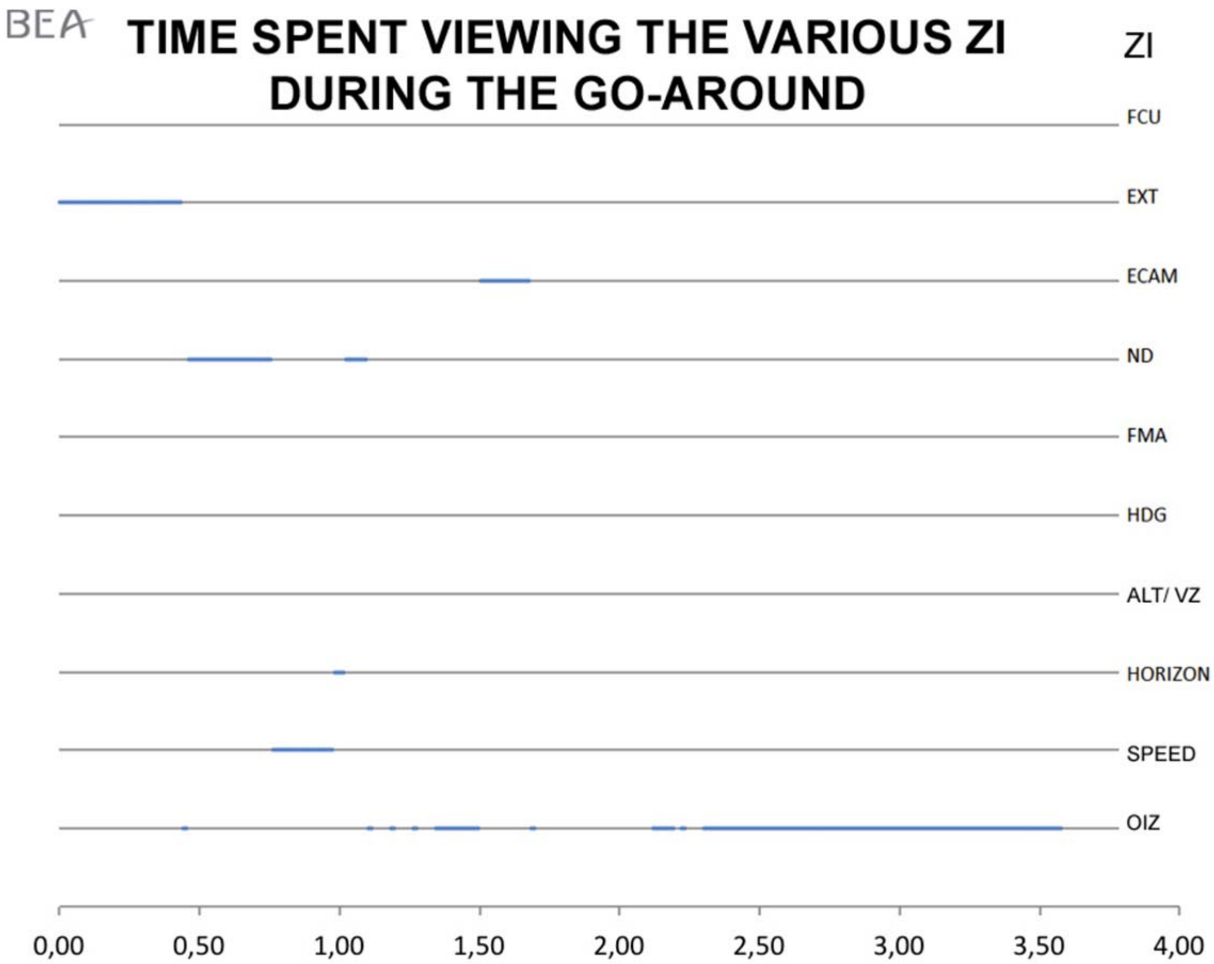

Figure 21 : Graphical representation of the ZI viewed as a function of time. For the first milliseconds, the pilot looked outside, and then fixated on the ND for about 30 milliseconds.

Time spent viewing the various ZI (as a percentage) during the go-around

The table below provides an example of the time spent viewing each ZI (as a percentage) during a go-around: it indicates the distribution of visual attention during the go-around. For example, the pilot spent 8.3% of the time looking at the altitude.

Name	Description	Duration (%)
Outside identified zones		20.6
SPEED	Speed tape	15.5
HORIZON	Artificial horizon/FD	20.5
ALT	Altitude tape	8.3
HDG	Heading indicator on the PFD	2.0
FMA		18.7
ND		9.3
ECAM		0.6
EXT	Windscreens	1.7
FCU	Flight control panel	2.8

4.3.2 Results

During the simulator sessions, all the go-arounds were performed in the order specified by the scenario. The results for GA1 were analysed in more detail since the startle effect was at its greatest for the crew for this go-around. A learning bias and, in principle, a diminished startle effect were suspected for the subsequent go-arounds. However, the results for GA2 agree with those for GA1. The results for GA3 provide information about the viewing behaviour and attention availability when the go-around is performed with AP engaged.

Go-around 1: comparison of the PF's viewing behaviour with that of the PNF/PM

The figure below shows the average time, as a percentage, that the PF and PNF/PM spent viewing each ZI. Two participants were excluded from the statistical analyses: The PF for session I (insufficient measurement reliability) and the PNF/PM for session E (unusable measured data).

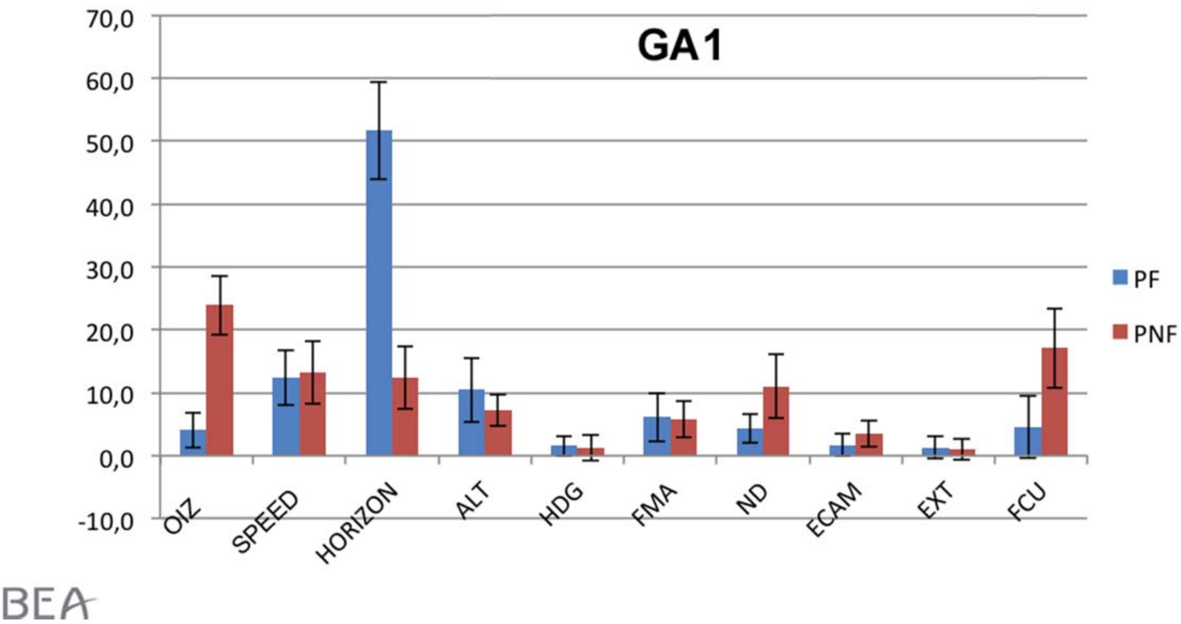

Figure 22 : Time spent viewing each ZI (as a percentage) during GA 1. The error bars show the standard deviations.

Figure 23 : *Representative heat maps for GA1* PF

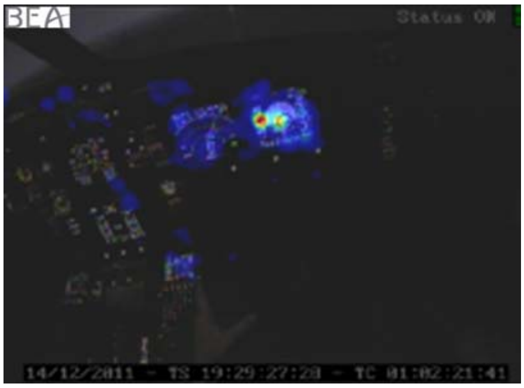

Figure 24 : *Representative heat maps for GA1* PNF

The above heat maps are representative for GA1, PF& PNF/PM. The figure 23 show that the PF's attention is generally focused on the basic flight control information displayed on the PFD whereas the PNF/PM's attention is more varied and widespread compared with the PF on the figure 24.

The statistical analyses reveal that the PF's viewing behaviour differs from that of the PNF/PM. The HORIZON ZI, fixated greatly by the PF (more than 50 % on average) is fixated much less by the PNF/PM (12.5 %). In contrast, on average the PNF/PM spends more time viewing: the OIZ (Outside Identified Zones - 23.9% compared with 4.1% for the PF); the FCU (17.1% compared with 4.6%) and the ND (11% compared with 4.4%). The statistical study confirms that these four ZI are those which reveal the greatest difference between the PF and the PNF/PM during GA1.

A statistical analysis was performed (on the PF separately from the PNF/PM) to identify more precisely the quantitative distribution of the time spent viewing the various instruments in the cockpit. This analysis identified homogeneous groups that were, in statistical terms, very distinct from each other. These groups consisted of one or more ZI (i.e. ZI that were not statistically dissociable from other ZI). This analysis formally established hierarchical relationships between these groups of ZI in terms of the amount of time spent viewing these groups (as a %). These groups of ZI are presented in the tables below.

Thus, for the PF, the time spent viewing the ARTIFICIAL HORIZON, as a percentage, is statistically much greater than those for the other ZI (Group 1). The next most viewed ZI's after the artificial horizons are the zones that display the speed (to the right of the horizon) and the zone that displays the altitude and rate of climb (to the left of the horizon).

For the PNF/PM, the main ZI viewed is OIZ (group 1), followed by the FCU (group 2), and then a group of ZI consisting of SPEED, ND and HORIZON. Finally, the ZI viewed the least was group 4 consisting of ALT, FMA, ECAM, HDG and EXT.

Group	Zones of interest	Viewing time as a %
Group 1	HORIZON	51.7%
Group 2	SPEED	12.3%
	ALT	10.5%
Group 3	FMA	6,1%
	FCU	4.6%
	ND	4.3%
	OIZ	5.9%
	ECAM	1.7%
	HDG	1.6%
	EXT	1.3%

Groups of ZI for the PF during GA1

Group	Zones of interest	Viewing time as a %
Group 1	OIZ	25.7%
Group 2	FCU	17.1%
Group 3	SPEED	13.2%
	HORIZON	12.4%
	ND	11.0%
Group 4	ALT	7.2%
	FMA	5.8%
	ECAM	3.4%
	HDG	1.3%
	EXT	1.0%

Groups of ZI for the PNF/PM during GA1

Summary of GA1

The statistical results reveal that the PF's viewing behaviour differs from that of the PNF/PM. Overall, the PF and the PNF/PM both spent the same amount of time viewing the ZI during the GA1 However, for the PNF/PM, the paths of the visual scans were not homogeneous. Even though, in general terms, the PNF/PM view the same zones, they do not fixate in the same way, or with the same sequencing.

The results suggest that the principal information viewed by the PF (HORIZON, SPEED and ALT) reflects the fact that the PF is primarily focused on controlling the flight path. It is interesting to note that all this information can be obtained from a relatively small zone (i.e. the PFD) and that viewing this information occupies more than 70% of the PF's total visual attention. Results such as this appear to suggest that controlling the flight path is an exclusive activity which generates a high workload for the PF.

In contrast, the PNF/PM's visual attention is spread more broadly, which is consistent with this pilot's role, i.e. programming the flight path, managing the aircraft configuration and monitoring the various parameters. Indeed, the ZI viewed most often by the PNF/PM is "Outside Identified Zones" which corresponds to the management of the configuration (landing gear, flaps, radio panel or overhead panel). The aircraft configuration management also requires regular monitoring of the speeds (VFE). This observation is reinforced by the verbal communications from some PNF/PM that focus the PF's attention, on a number of occasions, on the retraction of the flaps. It is interesting to note that, statistically-speaking, the PNF/PM spent more time viewing speed information than altitude information. Finally, it appears that the management of the flight path, via the MCP/FCU, occupies a great deal of the PNF/PM/PF's attention: the FCU ZI is the second most frequently viewed zone. In total, actions on the interfaces appear to take up more than 55% of the gaze fixations. Analysis of this data, and the viewing of the eye-tracking videos, appears to support the notion that the PNF/PM must handle a large amount of data during a very short period of time. The workload also appears to be high for the PF.

Study of GA2

Although performed manually, GA2 differed in a number of respects from GA1. Firstly, the go-around was initiated by the crew, and was not the response to an ATC instruction. Secondly, the route clearance given by ATC only contained one item of information (a change to the published altitude) unlike the instruction for GA1 which obliged the crews to change both their heading and their go-around altitude. Finally, the fact that the crew had performed a go-around a short time previously may have had an influence on its reaction.

The figure below shows the time spent viewing each ZI (as a percentage) during GA2 for the PF and PNF/PM with error bars to indicate the standard deviation. For the study of GA2, sessions D and I were excluded for the PF (measurements not sufficiently reliable for a statistical study) and sessions A, B, F and I for the PNF/PM (measurements unreliable or unusable).

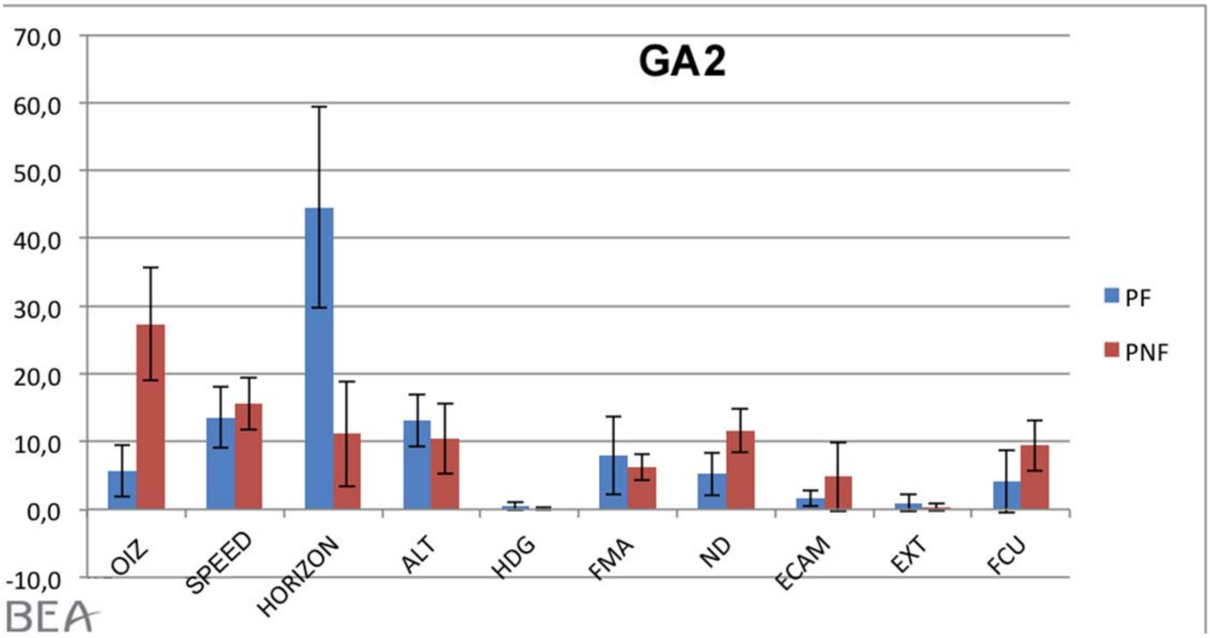

Figure 25 : Time spent viewing each ZI (as a percentage) during GA2.

Figure 26 : *Representative heat maps for GA2* PF

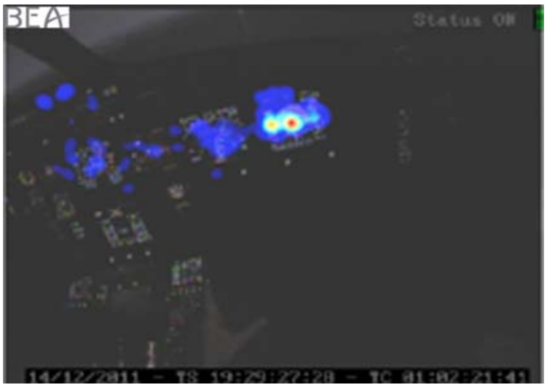

Figure 27 : *Representative heat maps for GA2* PNF

Although the statistical analysis was not performed on GA2, the viewing behaviour of the pilots is similar to that for GA1, with the exception of the time spent viewing the FCU (lower for GA2). This difference may be explained by the absence of a heading limitation in the initial clearance, unlike the clearance given in GA1 which contained an altitude and a heading.

Study of GA3

GA3 differed from the two other go-arounds since it was performed with AP engaged, and after the pilots had swapped roles (PF/PNF/PM). Moreover, ATC did not add clearance limitations and thus the go-around flight path was as published.

The figure below shows the time spent viewing each ZI (as a percentage) during GA3 for the PF and PNF/PM with error bars to indicate the standard deviation. Some participants were excluded from the analyses due to insufficient eye tracking precision: the PF for sessions A, E, H and I and the PNF/PM for sessions A, E, F and H

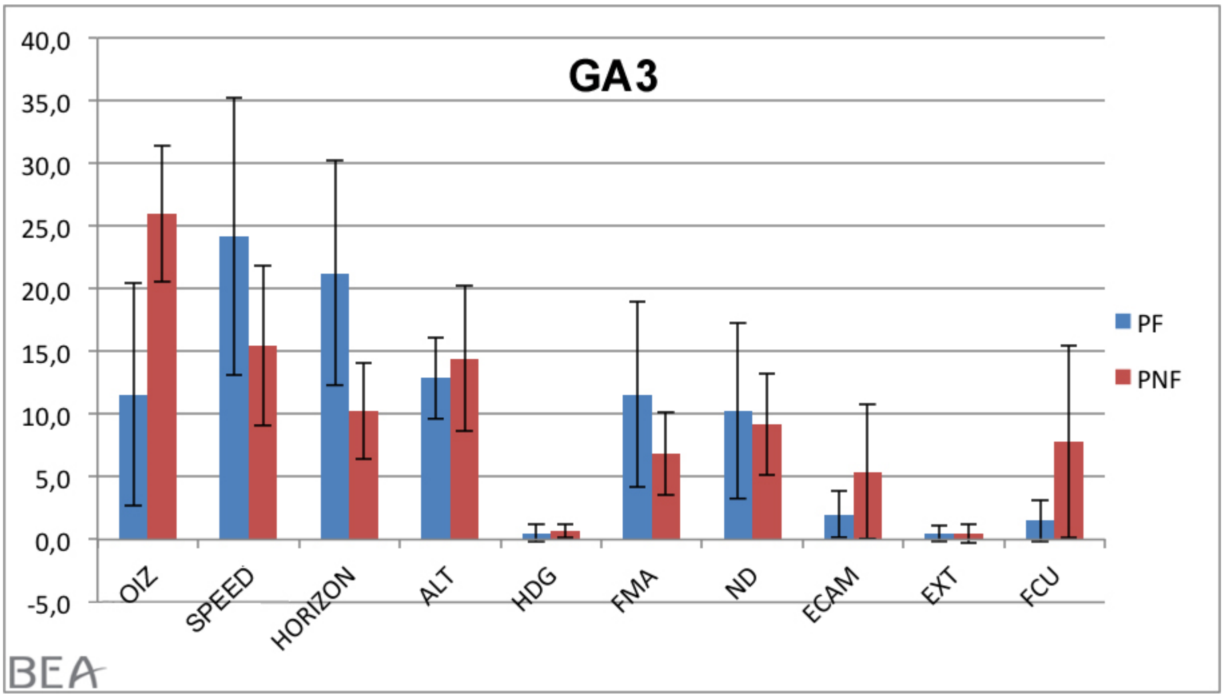

Figure 28 : Time spent viewing each ZI (as a percentage) during GA3

Figure 29 : Representative heat maps for GA3 PNF/PM

Figure 30 : Representative heat maps for GA3 PF

The statistical analyses revealed that the PF and the PNF/PM were dissociable, as for GA1. The ZI for which a difference was recorded are OIZ (PF: 25.95%; PNF/PM: 11.55%) and HORIZON (PF: 10.23%; PNF/PM: 21.25%). Groups of ZI were identified. The statistical analysis isolated the SPEED (24.1%) and HORIZON (21.3%) zones of interest as the dominant group for the PF. The prominent position of “SPEED” was probably due, as with GA1, to the monitoring of VFE.

For the PNF/PM, the OIZ zone of interest (26%) constitutes the dominant group

Summary of GA3

The analysis of GA3 reveals that the viewing behaviour of the pilots differed from that observed for the previous two go-arounds. This was particularly significant with regards to the distribution of the PF's visual attention. The percentage of time spent on the HORIZON ZI fell and was picked up by SPEED, FMA and ND. This more homogeneous distribution (compared with GA1 and GA2) was probably a result of the PF being less overloaded, due to the fact that the go-around was performed with AP engaged. The PF no longer performed a handling role, but instead a checking role. Moreover, no clearance limitations were added to the published flight path which further reduced the workload on the crew.
The time spent by the PNF/PM (as a percentage) on the FCU appears to be high, especially since this pilot is not supposed to operate this interface during a go-around with AP engaged. An explanation for this result may be provided by the fact that some crews (two at least) did not respect this task sharing. Indeed, for these two crews, the time spent on the FCU was relatively long. Note that for this go-around the PNF/PM was the Captain.

Comparison of GA1 and GA3: time spent by the PF viewing the FMA (as a percentage)

The results show that the FMA was viewed more often by the PF during GA3 (11.6%) than during GA1 (6.1%). The percentages are low in both cases. This result may be explained by the fact that GA3 was performed with autopilot engaged, and required a high level of monitoring by the pilots to check the correct activation of the automatic modes. Moreover, the PF had a much higher level of attention availability, since he did not have to control the flight path, which was the case for GA1.

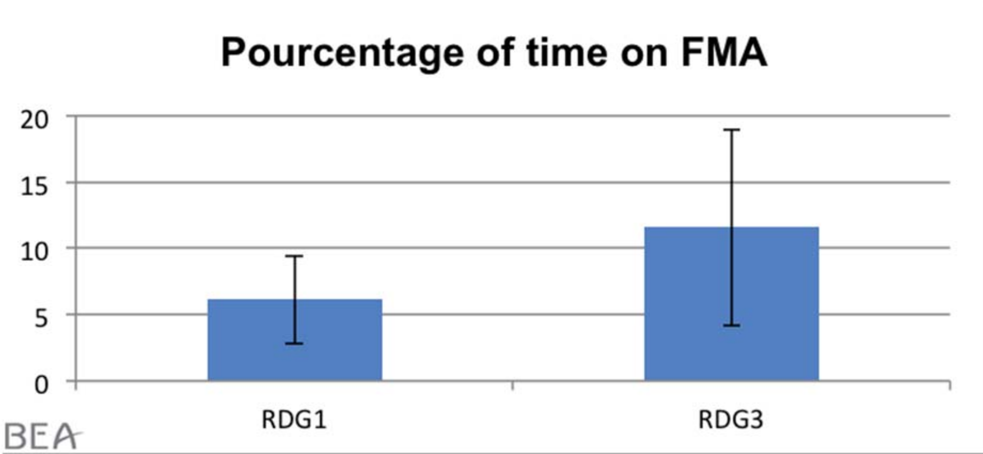

Figure 31 : Comparison of the time spent by the PF viewing the FMA ZI (as a percentage) during GA1 and GA3

The PF spent almost twice as long monitoring the FMA when the go-around was performed in automatic mode (GA3) compared with when it was performed manually.

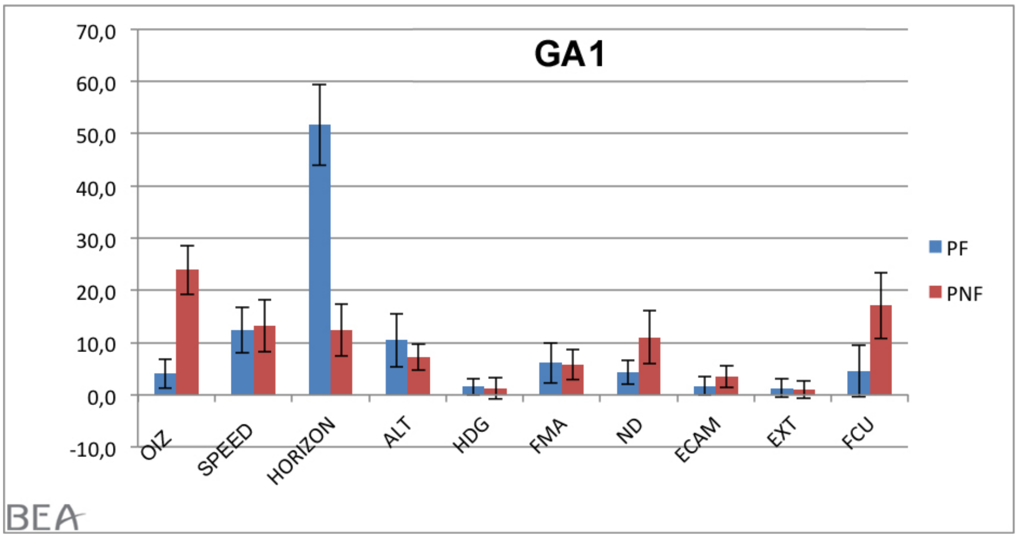

Figure 32 : *Time spent viewing each ZI (as a percentage) during GA1*

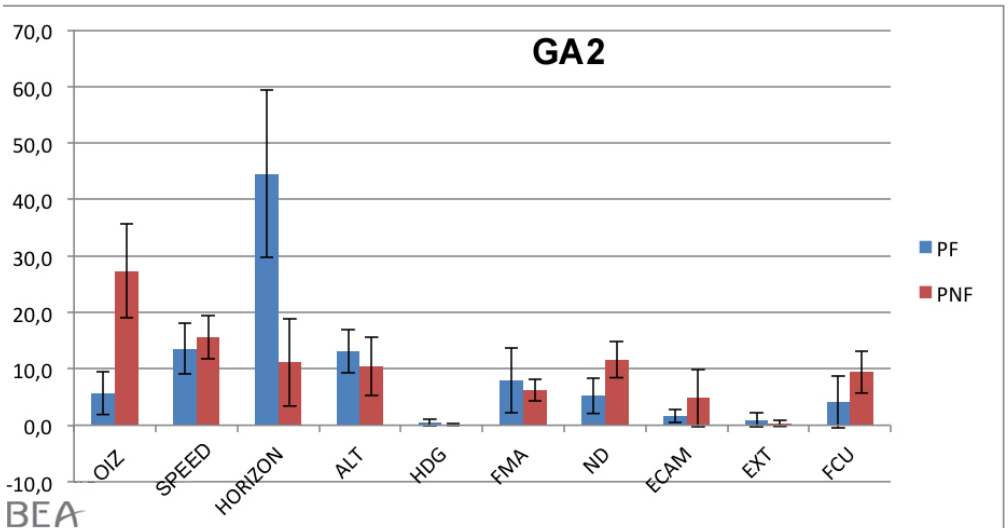

Figure 33 : *Time spent viewing each ZI (as a percentage) during GA2*

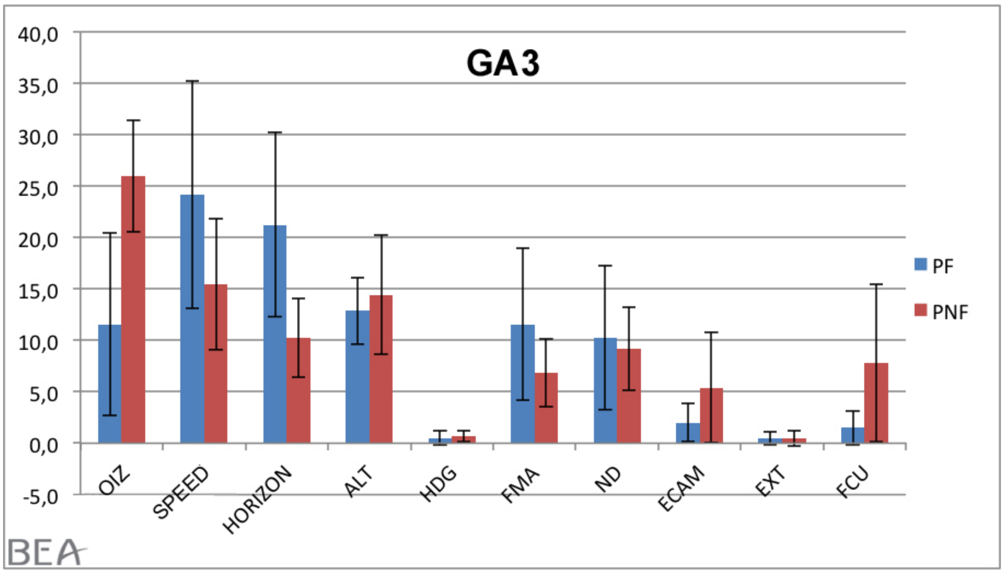

Figure 34 : *Time spent viewing each ZI (as a percentage) during GA3*

Temporal analysis of the fixations during GA1

A graphical representation of the zones of interest viewed as a function of time was produced for GA1. This representation reveals the pattern of ZI viewing in a timeline format. The figures below are examples of this form of data representation. The full set of these diagrams can be found in the appendix.

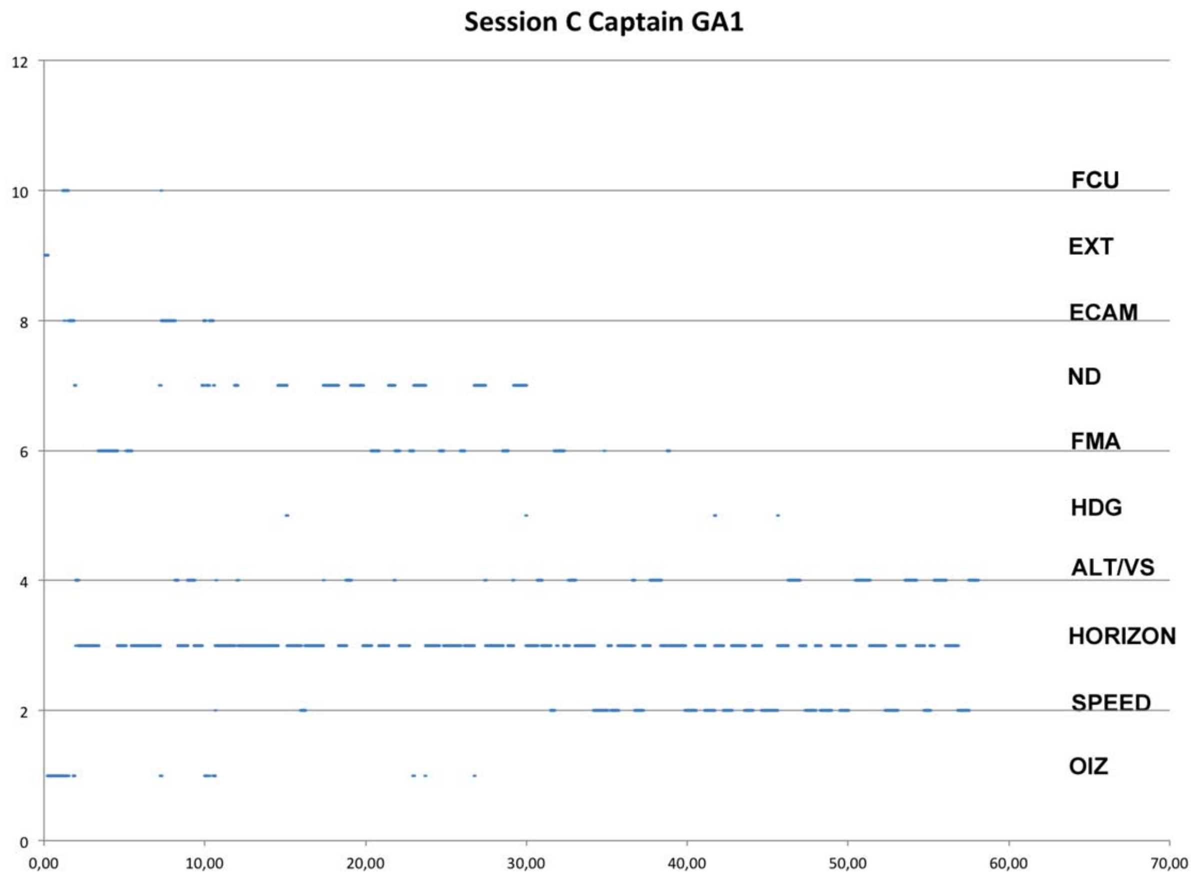

Figure 35 : ZI viewed as a function of time

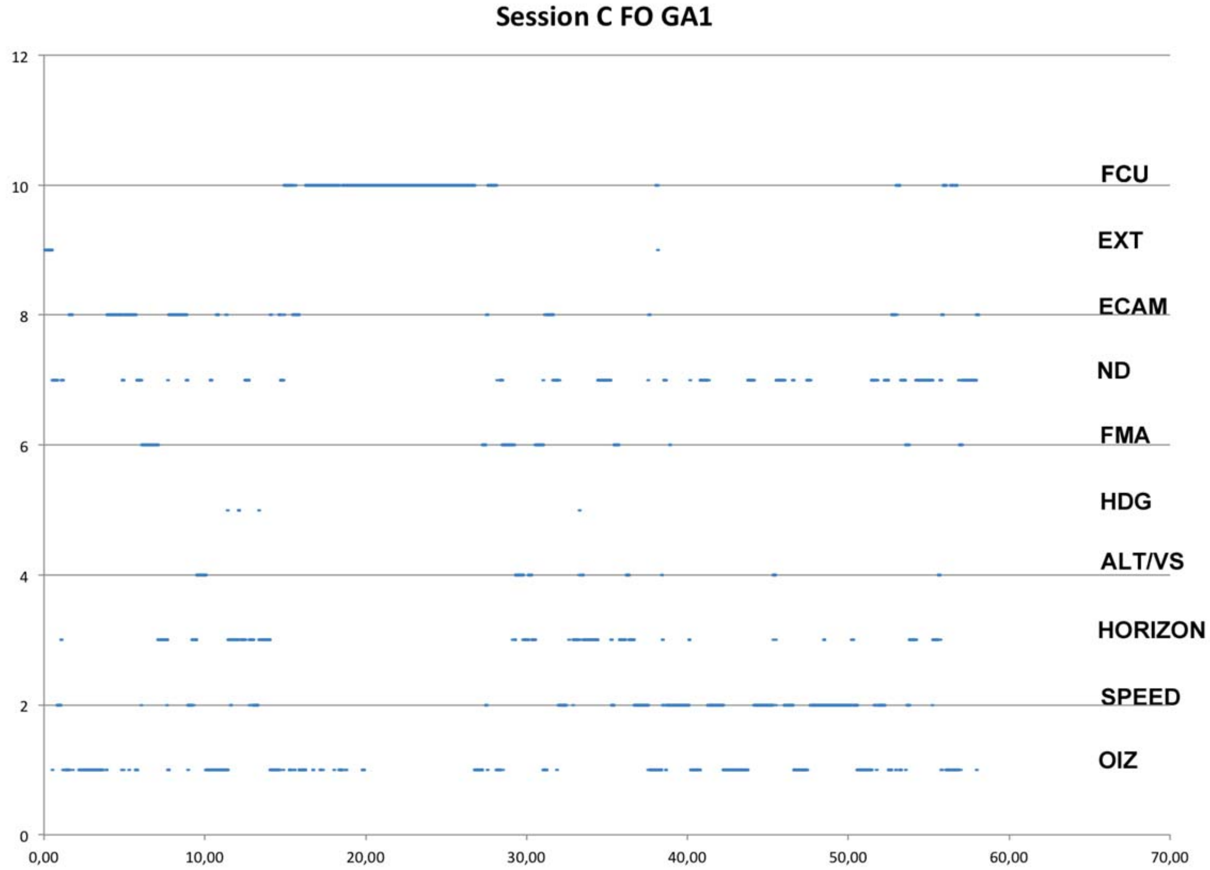

Figure 36 : ZI viewed as a function of time

Results

A case-by-case, analysis was performed with a view to identifying any notable viewing behaviour. The time spent on each ZI (as a percentage) is not commented on in this part.

The table below collates, for each pilot in each session, the observations derived from the analysis of the representations produced for GA1.

Session	PF	PNF/PM
A	Initial viewing mainly of FMA Heading viewed after 40 s (deviation from the heading) Scanning of HORIZON, SPEED and ALT primarily	A long fixation on the FCU (>10 s) ND frequently monitored between 34 and 58 s
B	Scanning of HORIZON, SPEED and ALT primarily (uninterrupted between 25 and 55 s).	Wide ranging ALT/VERTICAL SPEED infrequently viewed up until 25 s.
C	ND frequently viewed up until 30 s. SPEED infrequently observed before 30 or 40 s	A long fixation on the FCU (>12 s) Altitude and speed infrequently viewed initially, up until the change of configuration.
D	ND frequently viewed from 10 to 20 s. ALT/VERTICAL SPEED infrequently viewed before 10 s.	Long fixations on the FCU before 20 s Wide-ranging viewing after 20 s Long fixations (> 1 s) on the SPEED

	SPEED infrequently observed before 25 s	after 30 s.
E	SPEED infrequently observed before 30 s Infrequent fixations on the FMA	SPEED infrequently viewed before 30 s ALT/VERTICAL SPEED infrequently viewed before 23 s. Long fixations (> 1 s) on the FMA before 40 s.
F	Long fixations (>5 s) on the HORIZON ZI before 10 s. ALT/VERTICAL SPEED infrequently viewed before 10 s. SPEED infrequently viewed HDG frequently viewed between 21 and 32 s.	NO DATA
G	SPEED infrequently observed before 37 s HORIZON and FMA the most viewed overall	A long fixation on the FCU (>8 s) Frequent fixations on ND before 24 and after 49 s. HORIZON viewed a great deal
H	Long fixations (>5 s) on the HORIZON ZI before 20 s. SPEED infrequently observed before 30 s	A long fixation on the FCU (>8 / 6 s) ND frequently observed before 22 and after 43 s.
I	Long fixations on the FMA (>1 s) FCU viewed frequently SPEED infrequently viewed between 30 and 50 s	ALT/VERTICAL SPEED infrequently viewed before 40 s.
J	Long fixations (>5 s) on the HORIZON ZI, especially before 12 s. SPEED infrequently viewed before 30 s Infrequent fixations on the FMA	ALT/VERTICAL SPEED infrequently viewed before 30 s. FMA infrequently viewed before 30 s. Long fixations on the FCU before 30 s
K	Long fixations (>5 s) on the HORIZON ZI before 20 s.	A long fixation on the FCU (9 s) Infrequent fixations on the ALT/VERTICAL SPEED ZI Infrequent fixations on the FMA Speed during a second phase

Summary of the viewing behaviour observed during the temporal analysis

These observations identified a number of tendencies:

- Long fixations on the FCU by the PNF/PM
- Long fixations by the PF on the HORIZON ZI at the start of the go-around (the first 20 seconds).

4.3.3 Summary

The MCP/FCU was the focus of long fixations by the PNF/PM. This is a consequence of the changes requested by ATC to the heading and altitude compared with the published flight path initially expected. However, fixation times of more than 10 seconds were measured, which would appear to be unusually long insofar as selecting the modes and entering the target values on the MCP/FCU are actions performed to the detriment of the monitoring of all the other parameters.

The PF's long fixations on the HORIZON ZI at the start of the go-around are probably related to the execution of the flight control tasks (tracking the bars on the FD). Some of the PF's fixations on the FD do, however, appear to be particularly long (session J).

At the start of the go-around, there are often a low number of fixations on the speed by the PF, and sometimes by the PNF/PM. This may be explained by the fact that, since thrust is very high, the speed is not considered as an immediate concern.

Later on, during a second phase, SPEED is viewed more frequently, and becomes a ZI that is viewed at least as much as the ALT/VERTICAL SPEED ZI for the go-around overall. This second phase appears to correspond to the retraction of the flaps, after the assimilation of the clearance.

4.3.4 Precursors of attentional tunnelling

Pilots' ability to be attentive to numerous items of information in the cockpit is a significant factor.

However, the analysis of accidents and numerous scientific publications have demonstrated that operational stress and fatigue can result in pilots neglecting crucial information, such as visual and aural warnings. This phenomenon, called channelized attention is defined as being "the allocation of attention to a particular channel of information, diagnostic hypothesis or task goal, for a duration that is longer than optimal, given the expected cost of neglecting events on other channels, failing to consider other hypotheses, or failing to perform other tasks" (Wickens, 2005). It seems possible that this phenomenon might occur during the go-around phase which is often unexpected, uncertain and of sudden onset, and may take place after many hours of flight.

Moreover, the analysis of ASAGA-type events, presented in the first part of this report, identified elements that are compatible with this hypothesis (e.g. the inability of pilots to detect the non-engagement of automatic systems during go-arounds, the lack of a response to aural warnings, etc.)

During the simulator sessions, analysis of the eye-tracking data identified a number of precursors of attention tunnelling:

- Crew 1, first go-around. During this go-around, the PNF/PM set a heading of 240° instead of 340° into the MCP. The PF tracked the flight director to the incorrect heading for 11 s until the controller reminded the crew of the correct heading to advise it of its error. The PF realised immediately that he should have flown the aeroplane in the lateral plane directly to the heading of 340, without using the flight director ("*I should have flown to the heading myself*");
- Crew 7, first go-around. During this go-around, the PF focussed for 22 s on the vertical flight path to capture the target altitude, to the detriment of his monitoring of the horizontal flight path from which the aeroplane was deviating. Indeed, analysis of the eye-tracking data revealed that the PF's gaze switched exclusively between the altimeter, the pitch bar on the flight director and the FMA. This type of preoccupation with one axis to the detriment of another is well known in accidentology, and has caused several accidents or serious incidents during the approach phase (e.g. the accident to a CRJ100 at Brest Guipavas on 22/06/2003, and the incident involving an MD83 at Nantes on 21/03/2004). Moreover, it is interesting to note that the PNF/PM neither detected nor notified the PF of the deviation from the lateral flight path. The PNF/PM's attention was taken up by the management of the configuration of the flaps and by the management of the speeds, as indicated by his viewing behaviour (exclusive switching between the flaps and the speed indicator). This was not the only case of a go-around on the simulator during which the PNF/PM focussed his attention

excessively on this task to the detriment of his monitoring role, thus preventing him from notifying the PF of his deviations from the flight path. The statistical analyses support this observation since the time spent by the PNF/PM (as a percentage) managing the speeds and the configuration exceeds 40%;

- Crew 9, first go-around. During this go-around, the PF took responsibility for setting the altitude and heading values on the FCU. As a consequence of focussing on this instrument he failed to see, on his own PFD, that the aeroplane was significantly overshooting the altitude specified (i.e. 2,500 feet). The indicators of the PF displaying some level of attention tunnelling are his inability to anticipate this altitude overshoot, despite having fixated on the altimeter for a long time before entering data into the FCU, and despite his co-pilot calling out this deviation ("*We're climbing through 3,000 [feet]*"). Moreover, he did appear to notice the mode reversion "Open Climb to Vertical Speed + 3,800 feet per minute" displayed on the FMA and also visible on the FCU. If it was the altitude warning that made him aware of the overshoot, he, like the PNF/PM, allowed it to sound in the cockpit for more than 40 s without cancelling it. Furthermore, this warning did not prompt him to take back control of the aircraft or to use vertical speed mode to descend as quickly as possible down to 2,500 feet;
- Crew 10, first go-around. During this go-around, the PF concentrated exclusively on the flight director for 11 seconds. He never looked at the FMA, did not notice that "Heading" mode had been engaged by the PNF/PM, and was not aware of the mode transition to "Navigation". As a result, he tracked the flight director in the lateral plane, despite being in "Navigation" mode (heading 330) or in "Heading" mode (heading 340), even though he had called out that the heading was 340.

4.4 Simulator fidelity

General

Simulator manufacturers design their simulators based on a set of data provided by the aircraft manufacturers called a "Data Package" (DP). These DP cover the aeroplane's entire known flight envelope and are compiled from flight test data. The main public transport aircraft manufacturers conduct qualification tests on the DP to ensure their consistency with actual flight data.

In general, all simulator operators use the same DP.

Simulator qualification

Simulators must be qualified by the national aviation authority concerned, which carries out:

- A conformity check: an in-depth check to demonstrate the consistency between the DP and the flight test data. This evaluation is objective.
- A subjective evaluation (performed by an experienced pilot) of handling and fidelity.

Note that the objective evaluation of a simulator outweighs the subjective evaluation. However, an important subjective evaluation is performed to assess the "motion" (displacement/travel/movements) generated by the simulator, based on an assessment by pilots.

Each simulator is qualified individually (since there are settings unique to each simulator). Thus, for the same type of aeroplane simulator, operated by the same airline, it is possible to have different settings. Differences in settings are, however, becoming less frequent.

Regulatory framework

In Europe, the regulation derives from JAR-STD 1A: AEROPLANE FLIGHT SIMULATORS since August 01, 2008. Work is on-going to harmonise European and American regulations. In practice, the European and American regulations derive from the advisory document issued by ICAO (DOC 9625. issue 2), although this is very similar to JAR-STD 1A with regards to FFS.

Issue of simulators and go-arounds

According to the survey conducted by the BEA and to the experts who participated in the study, during an in-flight go-around, the longitudinal acceleration combined with the nose-up pitching moment of underwing engines generates a powerful perceptual illusion of a nose-up attitude.
Somatogravic illusions such as this are not accurately represented in FFS.

The regulatory requirements regarding the simulation of a go-around are primarily concerned with the admissible deviations from actual go-around data, as indicated in the example below:

Test	Tolerance	Flight Condition	Comments	Level			
				A	B	C	D
(7) One-Engine-inoperative Go-around	± 3 kts airspeed ±1·5° pitch angle ±1·5° AOA ± 2° bank angle ± 2° sideslip angle	As per AFM	Engine inoperative go-around required near maximum certificated landing weight with critical engine(s) inoperative. Provide one test with autopilot (if applicable) and one without autopilot. CCA: Non-autopilot test to be conducted in Non-normal mode.		✓	✓	✓

Extract of ICAO DOC 9625

These objective tests make no provision for the simulator's movements ("motion cues"). Moreover, no requirement specifies that the simulator should simulate the somatogravic illusion during the go-around.

Tests of the capabilities of the simulator's motion platform, such as the response frequency, are required for the qualification of the simulator. However, there is no test of the ability of the simulator's motion platform to represent in-flight accelerations. Accelerometers are, however, installed behind the pilot's seat in level D-qualified FFS.

Accelerations are not measured in the simulator. Another reason why simulator accelerations tend not to be compared with those in the aeroplane is because of the difficulties in defining acceptability criteria for the fidelity of simulators in relation to this parameter.

Although no objective standard exists for somatogravic illusions, the major simulator manufacturer indicated that this issue has been studied, but never implemented. However, it seems possible to tailor the "motion cues" to the specific context of a go-around. This customisation should be required for manoeuvres classified as "unusual".

Specifically, and if the requirement is specified, it is technically possible to increase the simulated pitch attitude. Moreover, during a simulation of a go-around, there is still a margin between the attitude of the simulator and its physical limitations. According to the manufacturer, the pitch attitude generated by the simulator's platform ranges between 10 and 15 degrees nose-up and nose-down, although it is possible to reach a maximum of 20 to 25 degrees. The manufacturer stated, however, that research and in-depth analyses should be conducted to ensure that the end result is not the delivery of "negative training". The impact on training would also have to be evaluated.

In conclusion, there is some scope for progress in the simulation of somatogravic illusions. This should be researched so that illusions can be simulated more accurately and to define the associated regulatory criteria for the qualification of simulators.

In addition, some American airlines are putting pressure on the FAA to authorise the training of pilots on FBS simulators only, for cost reasons. In view of the simulator fidelity issues discussed above during go-arounds, this would appear to be inappropriate for this flight phase.

4.5 Somatogravic illusions

Spatial disorientation represents a human being's inability to correctly sense his/her position, attitude or motion with respect to the earth's surface and the gravitational vertical plane. In flight, it may take different forms depending on the flight phase and the pilot's response to the situation. Spatial disorientation results from gaps in interpreting and integrating the information, sometimes altered under certain conditions, from sensory receptors (mainly the eyes, vestibular system and proprioceptive receptors) by the central nervous system that provides situational awareness. The responses to these perceptions depend on the personality, physical and mental condition and experience of each individual. These are limited by the characteristics of the tasks to be performed by pilots, as well as by the environment in which these tasks must be performed.

Somatogravic-type illusions

On the surface of the earth, humans are accustomed to living in the earth's field of gravity, which is always constant, and represents a stable reference of verticality. During a flight, because of the movements of the aircraft, the body is subjected to inertial and gravitational forces, which combine into a gravity-inertial resultant equivalent to a variation in intensity and/or direction of the gravity field vector. This set of forces can change the perception of the body's orientation relative to the gravitational vertical. For example, an acceleration of the aircraft can give the same impression as a backward tilt, i.e. the perception of a climbing aircraft. The reference of verticality taken into account by the pilot's central nervous system is no longer the earth's gravity but the resulting gravity-inertial force, which is the sum of the earth's gravity and the inertial forces. The somatogravic illusion therefore leads to a misperception of the body's orientation in space.

During go-around or takeoff phases in low visibility conditions, while the aircraft is accelerating, pilots may try to counteract this perception of climb by pitching down the aircraft's nose until the dive counterbalances the apparent backward tilt caused by acceleration, which may end in impact with the ground. Furthermore, if this false-climb illusion is reinforced by the presence of a false visible horizon (such as a shoreline or a string of lights with the ocean or unlit background terrain), a pilots' desire to push the stick more may become difficult to control.

The conditions required for the occurrence of a somatogravic illusion can be described as:

- Degraded external visual reference points
- Sufficient linear acceleration experienced between the moment when the pilot begins to perceive an acceleration and the moment when he/she stops pulling on the sidestick;
- Acceleration maintained so that the illusion persists and the pilot always feels nose up in spite of an actual descending flight path;
- No correction by the pilot by collecting information on the actual position of the aircraft, failure to monitor basic instruments.

The state of awareness and experience (training and actual experience of go-around) may be factors favouring the occurrence of this type of illusion.

Model for estimating the perceived orientation

Certain existing models can be used to calculate an estimate of the orientation perceived by the pilot based on different accelerations. These models, of course, cannot predict the perception of a given pilot but do provide an estimate of the influence of inertial forces and rotational movements on the orientation perceived by a pilot during flight. The estimate calculated by these models assumes that pilots have no external visual information, and that they do not monitor their instruments attentively, especially the artificial horizon, during the flight phase studied. It is precisely in such circumstances that spatial disorientation occurs most often.

A simulation model was developed by the BEA. It was based on a theory for estimating the spatial orientation using filters or constant gain estimators for the vestibular organs (Merfeld, 2001). This model uses the parameters recorded by the flight data recorder from the physical characteristics of the vestibular organs (equivalent to three accelerometers and three gyroscopes).

Nevertheless, it is not possible to have knowledge of the pilot's head movements and the influence of proprioceptive receptors. Therefore the estimate does not take these parameters into account. The pilot's head is thus assumed to be fixed, its position corresponding to a position directly related to the seat position. The different axes of the vestibular organs are thus considered parallel to the axes of the aircraft.

Results and Applications

As part of a recent investigation into a fatal accident involving a heavy public transport aircraft, the model for estimating the perceived orientation was used with FDR parameters. The figure below shows that at the time of the missed approach, the attitude perceived by a pilot, provided that his perception is based exclusively on the interpretation of vestibular inputs (without external visual references and without monitoring the artificial horizon), is initially close to the real attitude. It then deviates from the actual attitude from about 11 degrees to increase and remain between 15 and 22 degrees nose up. Nose-down inputs were made by the PF when the real pitch attitude (i.e. the aeroplane's attitude) deviated from the attitude experienced by the PF. The difference observed between the real attitude and the estimation of the perceived attitude may be related to the occurrence of a somatogravic illusion.

The following diagram shows the real aircraft pitch attitude against the perceived pitch estimated by the model.

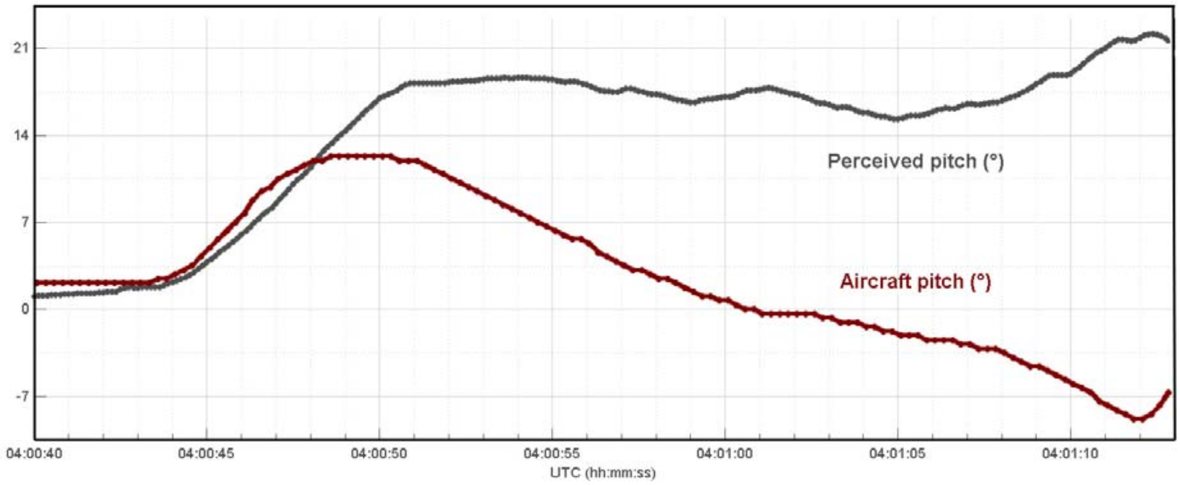

Figure 37 : Real and perceived pitch attitudes during a missed approach

When a somatogravic illusion is present, there is therefore a difference between the attitude experienced and the real pitch attitude. This difference may be as much as 25 degrees.

In the case above, the attitude perceived is similar to that of the go-around, even though the aeroplane's true pitch attitude is negative.

5 - OTHER INFORMATION

5.1 Crew training

The instruction given during the various stages of pilot training in how to manage go-arounds was studied and deviations were noted in terms of the method for managing pitch attitude and power.

Three phases were studied:

- Phase 1: initial and advanced training During this phase, student pilots become pilots who hold a commercial pilot licence. They may apply, once they have accumulated a minimum number of flying hours, to join an airline. In addition, instrument rating and Multi Crew Cooperation (MCC) are included in this phase. Two FTO's participated in the study of this phase.
- Phase 2: Type rating. This phase is associated with the commercial pilot license. A manufacturer and two airlines with the accreditation needed to issue type ratings participated in the study of this phase. This made it possible to study the go-around procedure for aeroplanes manufactured by two different manufacturers: Airbus (A320 and A330/A340 family) and Embraer (EMB145. 170, 190)
- Phase 3: Recurrent training and checking and scheduled skills maintenance within the airline. An aircraft operator participated in the study of this phase. This cooperation made it possible to obtain information about training on go-arounds for two families of aeroplane, Airbus (A320) and Boeing (B777).

From a regulatory point of view, the integrated course for airline pilots is detailed in the Joint Aviation Requirements document JAR-FCL 1 (1.160 and 1.165)[10]. It specifies five stages. During stage 1 (before solo) in dual instruction (10 h) no mention is made of a go-around. Neither does it appear in the second stage (before solo cross-country navigation).

The FCL concentrates on instrument flight training. The course does not therefore make explicit provision for the execution of certain manoeuvres, including the go-around.

Phase 1: Initial and advanced training up to MCC

CPL training

The FTO's consulted comply with the regulatory programme, although they think that at times the workload is high. There are a few disparities between the scheduling of the flying hours and the stage of progress through the course at which the go-around must be covered. However, the principles of the manoeuvre appear to be well taught, validated and checked, notably before solo flight.

The pilot trainees fly in the airspace at a busy airport. They therefore have opportunities to perform go-arounds, either on their own initiative, or on that of the instructor, or when instructed by ATC.

One of the FTO's consulted assesses the decision-making ability of certain student pilots in relation to performing a go-around (at the airline's request).
In addition, the FTO's teach the students how to deal with all the possible situations in which a go-around is necessary (e.g. low energy, high energy, bounce, flare-out, too high).

[10]Phase 1 does not include the European PART FCL, which has been in force in France since April 2013.

During other “solo” phases, the student pilots perform several navigation flights. During this phase, they appear to forget aspects of their initial training and are less comfortable making a go-around decision and executing the manoeuvre.

Single-engine IFR training
During this phase, the emphasis is on stabilising the approach. Several go-arounds are performed since the approaches are performed by simulating a lack of visual references at the minimums. Generally-speaking, the student pilot learns to better anticipate the next sequence. When flying solo, the clearances and radio communications spread the pilot’s resources more thinly: decision-making is not as good, and go-arounds are not executed as well (e.g. deviations in heading and pitch attitude).

Twin-engine IFR training
During this phase, the focus of the training is on passing the final test, which includes a go-around with one engine inoperative. The manoeuvre is generally executed well.

In conclusion, the principles of performing a go-around around are well taught and checked by instructors during the CPL and IFR single and twin-engine training courses. However, student pilots appear to consider that the various phases of the integrated course (PPL, CPL, IR, Single, Twin) are independent. According to the FTO’s, this sometimes results in “omissions” in the execution of certain manoeuvres, such as the go-around. The omissions sometimes relate to pitch during a go-around

The application of thrust is a tool used to initiate a missed approach procedure or an aborted landing procedure. The “apply thrust” aspect of the procedure is never omitted. This is probably due to the limited performance of the aeroplanes used in training (piston engines) that are very different from the aeroplanes flown in airline duty (turboprops or turbofans).

MCC training
During this specific training that develops teamwork, several types of go-arounds are performed (at the minimums, on instruction from ATC, initiated by the instructor, incapacity of the PF). Several go-arounds are performed during each flight.

A varied range of aircraft simulators are used: twin piston engines (Piper PA 34), single-pilot turboprop (Beech 200), multi-pilot (ATR 42) and turbofan (Airbus A320).

The theory taught is that the PNF/PM monitors the flight path (pitch attitude – effective thrust, but not the vertical speed).

When the simulator represents a type of single-engine aeroplane, it does not provide the pilot in the right seat with all the flight control tools and the information needed for correct monitoring of the flight path.

Phase 2: Type rating

Three different types of TRTO were visited.

TRTO 1

The first TRTO was that of a manufacturer. The A320 type rating (TR) course lasts for five weeks. It provides the trainees with all the technical and operational information needed to operate the aeroplane and its systems.

The go-around with all engines in operation appears to be just one of many exercises. The programme includes 13 go-arounds, 9 of which with all engines in operation and 4 with one engine inoperative. One of these go-arounds is performed during the test on a simulator.

The emphasis is on the first three items of the FCOM procedure: Announce *Go around* – *Pitch*/TOGA simultaneously – *Flaps*, check and announcing the modes displayed on the FMA.

The go-around training takes place in an environment that imposes very few constraints (no or limited interaction with ATC, no major system malfunctions, no flight paths[11] with constraints related to environmental issues). There are therefore no surprises compared with the published procedure.

The issues of spatial disorientation and/or somatogravic illusions are not covered during this training, even though some of the trainees have been flying in fleets whose aeroplanes (e.g. turboprops) do not achieve the high performance levels of the A320, and the trainees are thus less likely to confronted by the phenomenon.

At the request of the BEA, this organisation provided feedback from its instructors. In response to the question: “does the trainee experience difficulties?” 22% of the answers were positive. The main reasons given were insufficient familiarisation with the procedure and problems handling the aeroplane. The possible consequences are not achieving a correct pitch attitude, generating additional workload and even spatial disorientation. However, in 85% of cases, the FMA was read in accordance with the SOP.

TRTO 2

The second TRTO visited was an organisation operated by a regional airline accredited to deliver type ratings for Embraer (145, 170, 190). Theory is taught at the airline’s headquarters. The simulator training component of the course is provided at Flight Safety, Le Bourget. The entire phase lasts for two and a half months (including LOFT). This course is longer than that specified by the manufacturer because the airline has found, from experience, that trainees who have only completed the manufacturer’s programme require additional sessions.

The airline adheres strictly to the manufacturer’s go-around procedure.

Aside from adapting pilots to the new systems included in the EMB170, the procedure and its application are simple, and do not generate any problems during operation.

The TR programme includes 10 simulator sessions. One go-around, as a minimum, is performed during each session. Moreover, the pilots have the opportunity to practice the procedures on a GFS (Ground Flight Simulator) and can thus develop an effective mechanised approach to the tasks.

The emphasis is on the callout, selection and verification (via the FMA) of the annunciations of the modes: “GA – Track – GA”. The FMA displays a clear and legible indication of the modes during a GA (green labels on the FMA boxed).

[11] An environmentally sensitive flight path is one that is constrained by environmental considerations: e.g. zones that cannot be flown over, or altitude restrictions for noise reasons.

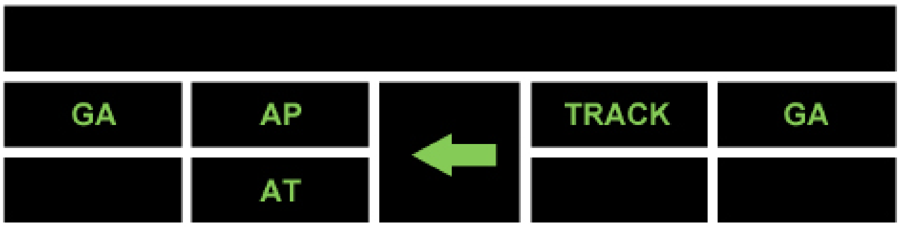

Figure 38 : FMA mode on EMB170

The option to go around with the AP is conditional on this display. If the display is not correct, the pilot must disengage the automatic systems and perform a manual go-around (based on the usual parameters: pitch attitude and thrust). The “bird” provides information about the energy status and indicates the climbing flight path with a pitch attitude which is 8° in manual. As in a final approach, the pitch attitude is close to 5°; the risks of somatogravic illusions are thus limited.

Moreover, the PNF/PM must check the thrust on the EICAS, after checking the vertical speed indicator and that the gear is retracted.

Note that a go-around with one engine inoperative is performed during the test.

Two problems were raised by the training manager:

- The go-around procedure is not adapted to “high energy” situations for technical reasons relating to the aeroplane (performance version pilot actions and time limitation).[12]
- The go-around altitudes are often too low and thus incompatible with the performance of the aeroplane.

<u>TRTO 3</u>

The third TRTO visited was an airline accredited to deliver type ratings for the Airbus fleet (A318, A319, A320, A321, A330, A340). The A320 training phase lasts for eight weeks (note that most A330/A340 pilots are already familiar with Airbus systems).

320 series

The training includes 13 go-arounds, 4 of which are with one engine inoperative. The go-arounds are taught in manual mode in order to learn the gestures involved. Gradually, through their understanding of the automatic systems and by developing flight control skills and techniques, the pilots learn to apply the application optimally.
During this phase, the emphasis is on the role of the PNF/PM, notably in monitoring the pitch.

The pilots receive information continuously via the flight training log and incident prevention messages.

330 series

The training programme includes at least 19 go-arounds with all engines in operation, 5 with one engine inoperative and 2 aborted landings. All types of go-around are taught (high energy, low energy). The causes of go-arounds are varied (failure to stabilise,

[12] A high-energy go around is a go-around manoeuvre performed at an altitude close to or higher than the go-around altitude.

instrument failure, no visual references acquired at the minimums, windshear, ATC, etc.). During this phase, the concern is to comply with the obligatory programme

In conclusion, according to the three TRTO's and during type rating, go-around training takes place in an environment that imposes very few constraints (no or limited interaction with ATC due to the role played by the instructor in the simulator, no major system malfunctions, no environmentally sensitive flight paths).

The risks associated with somatogravic illusions are not generally covered. In any case, they could not be reproduced faithfully due to the performance capabilities of the simulator and the nature of the flight path followed by the aeroplane in these situations.

There appears to be a mismatch between the performance of modern aeroplanes and high-energy go-arounds.

The stabilisation altitudes associated with the go-around are often too low and thus incompatible with the performance of the aeroplane.

Type rating and aeroplane training

Paragraph FCL.725 (subpart H of PART FCL on class and type ratings[13]) lays down the requirements for the delivery of class and type ratings.

Specifically, article c requires that "an applicant for a class or type rating shall pass a skill test to demonstrate the skill required for the safe operation of the applicable class or type of aircraft".

Appendix 9 details the requirements for this skill test. It states that: "When the type rating course has included less than 2 hours flight training on the aircraft, the skill test may be conducted in an FFS and may be completed before the flight training on the aircraft. In that case, a certification of completion of the type rating course including the flight training on the aircraft shall be forwarded to the competent authority before the new type rating is entered in the applicant's licence."

This requirement was already present in JAR-FCL 1 (and in the French ruling, FCL-1)

Moreover, paragraph FCL 730.A of PART FCL states that a school can offer a ZFTT course (*Zero Flight Time Training*) which does not include any flight time in an actual aeroplane. However, a pilot undertaking instruction on a ZFTT course must have accumulated a certain amount of practical experience beforehand on a multi-pilot turbo-jet aeroplane, certificated to the standards of CS-25, or on a multi-pilot turbo-prop aeroplane having a maximum certificated take-off weight of not less than 10 tonnes or a certificated passenger seating configuration of more than 19 seats.

EU-OPS does, however, require that line flying (LOFT) shall be commenced as soon as possible within 21 days after the end of TR.

Moreover, the AMC for PART ORA (*Organisation Requirement for Aircrew*), in paragraph AMC2 ORA.ATO.125 Training Programme - (k) Aeroplane training with FFS, requires that:

[13] PART-FCL (Commission Regulation 1178/2011 – Annex 1) :
http://eur-lex.europa.eu/LexUriServ/LexUriServ.do?uri=OJ:L:2011:311:0001:0193:EN:PDF
AMC and GM to PART FCL:
https://easa.europa.eu/agency-measures/docs/agency-decisions/2011/2011-016-R/AMC%20and%20GM%20to%20Part-FCL.pdf

(1) with the exception of courses approved for ZFTT, certain training exercises normally involving take-off and landing in various configurations should be completed in the aeroplane rather than an FFS. For MPAs where the student pilot has more than 500 hours of MPA experience in aeroplanes of similar size and performance, these should include at least four landings of which at least one should be a full-stop landing, unless otherwise specified in the OSD established in accordance with Regulation (EC) 1702/2003 when available. In all other cases the student should complete at least six landings. This aeroplane training may be completed after the student pilot has completed the FSTD training and has successfully undertaken the type rating skill test, provided it does not exceed 2 hours of the flight training course.

To summarise, aeroplane training is mandatory after passing the test on a simulator. There is no specific programme for this flight, and there is no specified requirement for a go-around. The only requirement is for 4 or 6 landings to be completed.
When the training is provided in the form of a ZFTT course, the check flight is not mandatory, although experience-based conditions apply.

However, the FAA informed the BEA that, in the USA, it was possible to transport passengers without having performed aeroplane training after obtaining type rating on a simulator.

Phase 3: Recurrent training and checks

Recurrent training and checking is a regulatory requirement (EU OPS 1.965). The training programmes are established by the operators so as to ensure that all major failures to aircraft systems and the associated procedures are covered over a period not exceeding three years. The minimum regulatory requirements, which already consume a great deal of resources, are nonetheless also applicable to the TRTO visited with regards to the go-around. Consequently, one or more manoeuvres are carried out, in the context of an appropriate scenario.
The programme (2011) established by one of the French airlines visited, included, for the "A320 family" pilots, a campaign of go-arounds whose purpose was the development of an individual strategy.

This programme included an additional go-around with one engine inoperative and a high-energy go-around.

For the "A330 family" pilots, the annual programme includes a LOFT mission, incorporating two scenarios. However, since there are an insufficient number of scenarios, the startle effect is eliminated once a few sessions have been performed (due to communication between the trainees).

The instructors noticed that the go-around procedure, when performed in manual mode, was carried out by applying strictly the same procedure as that executed during a go-around in automatic mode: TOGA, nose-up input. On some occasions the pitch attitude is insufficient (between 5 and 10° nose-up), or even non-existent, which causes the aeroplane to accelerate along its flight path, and to approach the limit speeds rapidly.

During LOFT, instructor captains are asked to perform a go-around for the benefit of the inexperienced co-pilots.

Moreover, during line flying, a short/medium or long-haul pilot will only rarely perform go-arounds. For Air France, the rate is about one a year for short and medium-haul, and one every 5 to 10 years for long-haul pilots.

Summary

As a pilot progresses through his or her training, he/she may be faced with the following realities:

- Fewer and fewer "real" go-around procedures are carried out in an aeroplane.
- The execution of a go-around may be thought of as the application of a new procedure, rather than the need to clear the ground rapidly and safely.
- The primary principle of managing "pitch/thrust" may be forgotten as the pilot progresses through the various training courses.
- The training in MCC may be conducted on aeroplanes whose performance is very different from that of modern aircraft.
- Somatogravic illusions are not systematically covered during the training. They are not reproduced.
- Aeroplane training is not mandatory. When aeroplane training is performed, a go-around is not mandatory.
- The go-around is often performed with one engine inoperative after the type rating.
- The go-arounds performed under instruction do not feature a scenario which includes a disruption or an element of surprise.

5.2 Go-around procedures published by the operators and manufacturers

Operators establish procedures which may differ from those of the manufacturer since they are allowed to adapt them to their fleet and/or to their corporate culture. The procedures established by some manufacturers and operators are presented below.

5.2.1 Manufacturer's procedure

In general, a go-around procedure consists of the following:
- Calling out the go-around and calling out flap retraction by one notch
- Engaging (and checking) the go-around mode
- Selecting an initial pitch attitude and thrust, without readjusting them regularly thereafter.
- Retract the flaps one notch then the landing gear
- Monitoring deviations and the associated callouts and stabilising the flight path, assisted notably by the FD
- Finish retracting the landing gear and flaps
- Performing the after take-off check-list.

The manufacturer's go-around procedures for B777, A330 and EMB170 are presented below.

Manufacturer's procedure for Boeing 777

777 Flight Crew Operations Manual

Go–Around and Missed Approach Procedure

Pilot Flying	Pilot Monitoring
At the same time: • push the TO/GA switch • call "FLAPS 20"	
	Position the flap lever to 20.
Verify: • the rotation to go–around attitude • that the thrust increases	
	Verify that the thrust is sufficient for the go-around or adjust as needed.
	Verify a positive rate of climb on the altimeter and call "POSITIVE RATE."
Verify a positive rate of climb on the altimeter and call "GEAR UP."	
	Set the landing gear lever to UP.
Limit bank angle to 15 degrees if airspeed is below minimum maneuver speed.	
Above 400 feet radio altitude, select or verify a roll mode.	Verify that the missed approach altitude is set.
Verify that the missed approach route is tracked.	
At acceleration height, set speed to the maneuver speed for the planned flap setting.	
Call "FLAPS___" according to the flap retraction schedule.	Set the flap lever as directed.
After flap retraction to the planned flap setting, select FLCH or VNAV as needed.	
Verify that climb thrust is set.	
Verify that the missed approach altitude is captured.	
Pilot Flying	**Pilot Monitoring**
Call "AFTER TAKEOFF CHECKLIST."	Do the AFTER TAKEOFF checklist.

Manufacturer’s procedure for Airbus A330

A330 FLIGHT CREW OPERATING MANUAL	STANDARD OPERATING PROCEDURES	3.03.23	P 1
	GO AROUND	SEQ 001	REV 26

GO AROUND

Apply the following three actions simultaneously :

– **THRUST LEVERS . . . . TOGA**

– **ROTATION . . . . PERFORM**
· Rotate the aircraft to achieve a positive rate of climb, and establish the required pitch attitude, as directed by SRS pitch command bar.

– **GO AROUND . . . . ANNOUNCE**

Note : The MCDU PERF page automatically switches to the GO AROUND phase.

– **FLAPS . . . . RETRACT ONE STEP**

– **FMA . . . . CHECK AND ANNOUNCE**
Check the FMA on the PFD. The following modes are displayed : MAN TOGA/SRS/GA TRK/A/THR (in blue).

– **POSITIVE CLIMB . . . . ANNOUNCE**

– **LDG GEAR UP . . . . ORDER**

– **LDG GEAR . . . . SELECT UP**

R – **NAV or HDG mode . . . . AS RQRD**

Note : Go-around may be achieved with both AP engaged. Whenever any other mode engages AP 2 disengages.

● **At go-around thrust reduction altitude (LVR CLB flashing on FMA) :**

– **THRUST LEVERS . . . . CL**

A330 FLIGHT CREW OPERATING MANUAL	STANDARD OPERATING PROCEDURES	3.03.23	P 2
	GO AROUND	SEQ 001	REV 20

● **At go-around acceleration altitude :**

– **Monitor that the target speed increases to green dot.**

● **If the target speed does not increase to green dot :**

– **FCU ALT . . . . CHECK and PULL**

– **Retract flaps on schedule.**

Note : Consider the next step :
– Engage NAV mode, to follow the published missed approach procedure, or
– Prepare for a second approach by selecting the ACTIVATE APP PHASE, and CONFIRM on the PERF page.

GO-AROUND FROM AN INTERMEDIATE APPROACH ALTITUDE

To interrupt the approach, or to perform a go-around, from an intermediate altitude in the approach, and if TOGA thrust is not required, proceed as follows :

– **SET the thrust levers to TOGA detent, then retard the thrust levers as required.**
This enables to engage the GO AROUND phase, with associated AP/FD modes.

– **SELECT the applicable AP/FD and A/THR modes on the FCU.**

Note : If the thrust levers are not set briefly to TOGA detent, the FMS does not engage the GO AROUND phase, and flying over, or close to the airport (less than 7 NM) will sequence the Destination waypoint in the F-PLN.

Manufacturer's procedure for EMB170

EMBRAER 170 175 190 195 STANDARD OPERATING PROCEDURES

PROCEDURES AND TECHNIQUES APPROACH

NORMAL GO-AROUND - ACTIONS and CALLOUTS		
	PF	PNF
Go-around	**"GO-AROUND".** • Press either TOGA buttons. • Verify or move thrust levers to TO/GA detent. • With the airspeed greater than V_{REF}. **"FLAPS__".** • Verifies rotation or rotates towards GA initial pitch attitude (8°).	• Verify GA annunciations. • Verify engine at go-around thrust. • Selects GA flaps.
Positive Rate of Climb	• Confirm positive rate of climb. **"GEAR UP".**	• Verify positive rate of climb. **"POSITIVE RATE".** • Position gear lever up. • Selects V_{FS}. • Advises ATC.

EMBRAER 170 175 190 195 STANDARD OPERATING PROCEDURES

PROCEDURES AND TECHNIQUES APPROACH

NORMAL GO-AROUND - ACTIONS and CALLOUTS		
	PF	PNF
Go-around	**"GO-AROUND".** • Press either TOGA buttons. • Verify or move thrust levers to TO/GA detent. • With the airspeed greater than V_{REF}. **"FLAPS__".** • Verifies rotation or rotates towards GA initial pitch attitude (8°).	• Verify GA annunciations. • Verify engine at go-around thrust. • Selects GA flaps.
Positive Rate of Climb	• Confirm positive rate of climb. **"GEAR UP".**	• Verify positive rate of climb. **"POSITIVE RATE".** • Position gear lever up. • Selects V_{FS}. • Advises ATC.

PROCEDURES AND TECHNIQUES APPROACH

STANDARD OPERATING PROCEDURES

EMBRAER 170 175 190 195

NORMAL GO-AROUND - ACTIONS and CALLOUTS		
	PF	PNF
400 ft AGL	**"SELECT FMS AND HEADING (NAV)".**	• Selects appropriate navigation primary source. • Selects Lateral Mode.
Acceleration Altitude	**"CLIMB SEQUENCE".** • Executes published missed approach or proceed as instructed by ATC.	• Selects FLCH. • Retracts flaps on schedule. • At flap zero calls: **"FLAP ZERO".** • Monitor missed approach procedures.

NOTE: Callouts are shown in bold text.

5.2.2 Examples of operator's procedures

The procedures established by Air France (B777 and A330) and XL Airways France (A330) are presented below. Corsair uses the manufacturer's procedure. The airline's procedures may differ from those of the manufacturer. Pilots must apply the procedures established by their airline.

Procedure established by XL Airways France for the Airbus A330

XL Airways France

NORMAL PROCEDURES
STANDARD OPERATING PROCEDURES
Go Around

PRN 02-02-23
Page 1
Rev 00 / 25th Mar 2008

GO AROUND

(Reference FCOM 3.03.23)

GO AROUND

- **Apply the following three actions simultaneously :**
  - **THRUST LEVERS** .... **TOGA**
  - **ANNOUNCE** .... **< GO AROUND - FLAPS >**
  - **ROTATION** .... **PERFORM**

    Rotate the aircraft to achieve a positive rate of climb, and establish the required pitch attitude, as directed by SRS pitch command bar.

    Check and announce FMA : TOGA, SRS, GA TRK.

    NOTE
    The MCDU PERF page automatically switches to the GO AROUND phase.

  - **FLAPS** .... **RETRACT ONE STEP**
  - **ANNOUNCE** .... **< POSITIVE CLIMB >**
  - **ORDER** .... **< GEAR UP >**
  - **L/G UP** .... **SELECT**
  - **CONFIRM/ANNOUNCE** .... **< GEAR UP/FLAPS ___ >**

    NOTE
    Consider retarding to CL detent, if TOGA thrust is not required.

  - **NAV or HDG mode** .... **SELECT**

    NOTE
    Go-around may be achieved with both AP engaged. Whenever any other mode engages AP 2 disengages.

- **At go-around thrust reduction altitude ("LVR CLB" flashing on FMA).**
  - **THRUST LEVERS** .... **CL**

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NORMAL PROCEDURES
STANDARD OPERATING PROCEDURES
Go Around

XL Airways France

- **At go-around acceleration altitude :**
  - **Monitor that the target speed increases to green dot.**
  - **If the target speed does not increase to green dot :**
    - **FCU ALT** .... **CHECK and PULL**
  - **Retract flaps on schedule**

    NOTE
    1. *Consider the next step :*
       - engage NAV mode, to foloow the published missed approach procedure, or
       - prepare for a second approach by selecting the ACTIVATE APP PHASE and CONFIRM on the PERF page.
    2. *If a go-around must be performed for ATC reason, systematically fill a Captain Report with all possible details to allow the airlines to sue the relevant services..*

GO AROUND FROM AN INTERMEDIATE APPROACH ALTITUDE

To interrupt the approach, or to perform a go-around, from an intermediate altitude in the approach, and if TOGA thrust is not required, proceed as follow :

- **SET the thrust levers to TOGA detent, then retard the thrust levers as required.**

  This enables to engage the GO AROUND phase, with associated AP/FD modes.
- **SELECT the applicable AP/FD and A/THR modes on the FCU.**

  NOTE
  If the thrust levers are not set briefly to TOGA detent, the FMS does not engage the GO AROUND phase and flying over, or close to the airport (less than 7 NM) will sequence the Destination waypoint in the F-PLN.

Procedure established by Air France for the Airbus A330

REMISE DE GAZ

C-P	"REMISE DE GAZ"	ANNONCEE

Conformément au manuel GEN.OPS.

PF MANETTES DE POUSSEE ...... TOGA

Les modes MAN TOGA, SRS et GA TRACK s'engagent.
Les manettes de poussée peuvent être placées ensuite dans le cran CL si TOGA n'est pas nécessaire pour le gain d'altitude.

PF ASSIETTE ...... 12,5° (***A340***) ou 15° (***A330***) puis SRS

En pilotage automatique, l'AP suit le mode SRS.
*En pilotage manuel, le PF affiche l'assiette **et** applique initialement la poussée TOGA **puis** suit la barre de tendance horizontale si disponible.*
En cas de panne d'un réacteur, le PF affiche une assiette initiale de 12,5° (A340 et A330).

PF "VOLETS X" ...... ANNONCES

PNF VOLETS X

PNF TRAIN ...... RENTRE

Annonce "VARIO POSITIF" lorsque le vario se stabilise à une valeur positive et sur ordre du PF place la manette de train sur UP.

PNF ECARTS ...... ANNONCES

	Seuil	***Annonce***
Assiette longitudinale	>20° ou <10°	"Assiette"
Vitesse	< Vapp - 5 kt	"Vitesse"

PF NAV ...... ENGAGE

L'engagement du mode NAV le plus tôt possible permet de réduire le risque de séquencement F-PLN erroné engendrant des guidages AP/FD avec un virage en sens inversé.
De plus, après une approche RNAV (GNSS), le mode NAV garantit le maintien dans l'aire de protection de la remise de gaz.

PNF ATC ...... INFORME

PF MANETTES DE POUSSEE ...... CLIMB

Placer les manettes de poussée dans le cran CL, à l'altitude de réduction de poussée.

PNF VOLETS ...... RENTRES

-A la vitesse F, les volets sont rentrés à 1.
-A la vitesse S, les volets sont rentrés à 0.

PNF EXT LT : RWY TURN OFF et NOSE ...... OFF

PNF GND SPLRS ...... DESARMES

PNF ENG START ...... NORM ou IGN

1 / 2 - A330/340 TU VOL 1 - REMISE DE GAZ

A330/340 TU VOL 1 (23/09/10)

Mettre le sélecteur sur IGN si de fortes turbulences ou de fortes pluies sont rencontrées.

C-P MEMO ...... VERIFIE

En cas de remise de gaz, si l'avion ne remonte pas au-dessus de 2200 ft, le Memo LDG ne s'affichera qu'à 800 ft RA.

<u>NOTE</u> : Après l'exécution de la remise de gaz, effectuer la check-list "Après décollage".

//FIN

Procedure established by Air France for the Boeing B777

REMISE DE GAZ 2 GTR

La procédure suivante est adaptée à l'utilisation du **pilote automatique** .
En cas de remise de gaz en pilotage manuel le PF demande les sélections et affichages au MCP, le PNF effectue au MCP les sélections et affichages demandés par le PF.
Pendant toute la manoeuvre les pilotes vérifient le suivi de la trajectoire et l'interception de l'altitude de RdG.

PF	PNF
La procédure remise de gaz 2 GTR s'effectue volets 20°. "REMISE DE GAZ" Annoncée	
Simultanément : Poussoir(s) TO-GA Appuyé(s) *Cette action initialise la prise d'assiette et l'affichage de la poussée automatiquement.* "VOLETS 20" Commandé	Levier FLAP Cran 20
Assiette de remise de gaz Vérifiée Poussée de remise de gaz Vérifiée	
NOTE : En cas de remise de gaz en pilotage manuel : ∘ effectuer la rotation manuellement vers l'assiette de remise de gaz, ∘ sélecter et vérifier l'application de la poussée de remise de gaz.	
	Vérifie un vario positif à l'altimètre : "VARIO POSITIF" Annoncé
Vérifie un vario positif à l'altimètre : "TRAIN SUR RENTRÉ" Commandé	
	Manette de train UP
Au-dessus de 400 ft AAL : Sélectionner ou vérifier le mode de guidage latéral.	Vérifier que l'altitude de remise de gaz est affichée au MCP.

1 / 2 - 777 TU - REMISE DE GAZ 2 GTR

777 TU (11/02/10)

PF	PNF
À l'altitude d'accélération : Afficher la vitesse d'évolution pour le cran de volets prévu.	
"VOLETS __" suivant la séquence de rentrée des volets Commandé	Levier FLAP Comme demandé
Volets rentrés au cran prévu : Sélectionner FLCH ou VNAV comme nécessaire.	
Poussée de montée (CLB à l'EICAS) Vérifiée	
Appeler la check-list **"AFTER TAKEOFF"**	Effectuer la check-list **"AFTER TAKEOFF"**

- Les annonces techniques pendant la remise de gaz doivent être faites conformément aux consignes du GEN-OPS.
- L'alarme "DON'T SINK" de l'EGPWS retentit en cas de perte d'altitude pendant la remise de gaz. Elle persiste tant qu'un vario positif n'est pas rétabli.
- Sur les avions équipés de l'engagement automatique du LNAV en remise de gaz, si la procédure de remise de gaz est disponible au FMS :
  - -en pilotage automatique, armement du LNAV puis engagement à 200 ft RA,
  - -en pilotage manuel, armement du LNAV puis

5.3 Air traffic control service and missed approach procedure

The BEA consulted the European Aviation Safety Agency (EASA) whose new prerogatives cover ATC aspects. Although the responsibilities of the Agency and of Eurocontrol have not yet been clearly defined, EASA should harmonise the procedures and regulation governing ATC in Europe. Currently, these procedures are defined nationally in compliance with ICAO's PANS-OPS documents.

Controllers may deviate from the published go-around procedure when giving heading and/or altitude instructions, so long as safety is not compromised, for the purpose of ensuring that the flow of traffic is organised and expedited optimally.

The case studies (section 2), the survey (section 3) and the simulation sessions (section 4) did, however, demonstrate that the ATC environment can disrupt flight crews during a go-around.

Several factors have been identified:

- The startle effect, which is very disruptive for flight crews – causes a high workload, notably when the flight path imposed by ATC differs from that in the published procedure.
- The design of go-around procedures whose go-around stabilisation altitude is low. This is a factor due to the increasing incompatibility between the performance of modern aeroplanes and the low altitude gains.
- Radio communications transmitted to the crew during the go-around, which overloads the PNF/PM.

EASA informed the BEA that amendments to the procedures described at ICAO level should be examined:
The potential recommendation for a standard missed approach procedure (runway heading, 3,000 ft) for all runways (unless geographical constraints exist) should be carefully evaluated, especially in consideration of other airspace design constraints (SID's, STAR's, other runways, airspace reservations, etc.). Such a recommendation should be addressed at ICAO level considering amendment of PANS-OPS. The same is valid also for the recommendation for reduced communication during the missed approach.

ATC procedure as described in ICAO documents

The reference documentation (ICAO PANS OPS derived from DOC 4444 and 8168) stipulates that:

- *During a missed approach, the pilot is faced with several tasks such as changing the aircraft configuration, attitude and altitude. For this reason, the design of the missed approach has been kept as simple as possible and consists of three phases (initial, intermediate and final). It has a beginning and end characterised by a sufficient altitude/height".*
- *"Only one missed approach procedure is published for each approach procedure".*
- *"The missed approach procedure must not be initiated below the decision height/altitude. If the procedure is engaged before the missed approach point, the pilot should normally continue to the MAPt or to the Middle marker or at the specified DME distance and then follow the missed approach procedure."*
- *"Except for reasons of safety, no transmission shall be directed to an aircraft during take-off, during the last part of the final approach or during the landing roll."*

PANS OPS ATM also indicates in the section on missed approach phraseology and in ICAO document Doc 9432-AN/925 4.8 go-around that:

- *"Instructions to carry out a missed approach may be given to avert an unsafe situation."*
- *"When a missed approach is initiated, cockpit workload is inevitably high. Any transmissions to aircraft going around should be brief and kept to a minimum."*
- *"Unless instructions are issued to the contrary, an aircraft on an instrument approach will carry out the missed approach procedure and an aircraft operating VFR will continue in the normal traffic circuit"*

The design of missed approach procedures does not consider the actual performance of modern aeroplanes.

Design of missed approach procedures

A missed approach may be defined such that the aeroplane continues to fly straight ahead, or with a prescribed turn either at a turning point or at an altitude. There is no standard that specifies a preference for any one of the construction methods.

Missed approach: climb straight ahead
The missed approach is a "straight ahead" manoeuvre when the aeroplane continues to follow the magnetic route that it followed for the final approach, and when no turn is prescribed before the aircraft has reached a safety altitude.

Missed approach with designated turning point
A turn must be performed, regardless of the altitude reached at the turning point (TP) specified on the approach chart. The turn must not be started before or after this point.

Missed approach with turn at a designated altitude
An altitude is designated at which the turn starts to return to the holding fix.
The turn must not be started below or above this altitude; however, in **certain** cases, there is a requirement not to turn until a fix has been reached.

Minimum height for acceleration in level flight
In the event of an engine failure, some aeroplanes have to take time to accelerate in level flight before continuing with the climb A minimum height for the acceleration in level flight is normally calculated, with due consideration for any obstacles.

When there is no specific indication to this effect on the chart, this means that no option to accelerate at level flight has been studied.

In the event of a missed approach with turn at designated altitude/height, the minimum height for acceleration published is at least equal to the turn height.

The minimum acceleration altitude/height for a missed approach, published on the instrument approach chart is provided for information only. An operator may conduct its own study, which would consider the particular characteristics of its aircraft, and specify a value that differs from that published.

Telecommunications during a go-around

Appendix 10 to ICAO document includes no particular requirements for silence from the controller while a crew is performing a go-around.

On the contrary, requirements to this effect are specified in relation to take-off and final approach. Indeed, section 5.2.1.7.3.1.1 of appendix 10 stipulates that:

Except for reasons of safety, no transmission shall be directed to an aircraft during take-off, during the last part of the final approach or during the landing roll.

5.4 Regulatory aspects relating to controllability during go-arounds at low speed

The issue of an excessive nose-up trim position, at low speed and with full thrust, is not at present dealt with precisely in the certification regulations.

The regulations and particularly section CS 25.1329 (h) are primarily concerned with the protections and responses of the flight guidance system (FGS) at low speed. The sections relating to out-of-trim positions do not address the issue either.

In certain aeroplane configurations (notably a forward centre of gravity and high weight), a trim position close to the full nose-up position is possible. For this reason, aircraft manufacturers have not made provision for specific warnings when trim is close to a stop.

During certain ASAGA-type events involving a loss of control associated with a trim close to the full nose-up position, the aeroplane was still controllable when full thrust was initially applied. However, as the thrust increased, the pitch attitude and angle of attack increased to excessive values. Only a very few crews managed to regain control of the aircraft by reducing the thrust, and then by adjusting the position of the trim.

Manufacturers have recently modified their “upset recovery” procedures accordingly.

Currently, the position of the trim is almost never monitored by the crews, particularly during a go-around.

5.5 Tailwind during the approach and final approach phases

Wind information available

Airbus A330

The wind is calculated by each of the 3 ADIRU based on the difference between the ground speed vector (calculated by the inertial unit) and the airspeed vector (calculated by the air data computer, assuming zero side-slip).

The wind speed and direction is indicated on both pilots' navigation displays (ND), in the top left corner, by an arrow accompanied by numerical values in the form DDD/SS (where DDD is the wind direction in magnetic degrees and SS the speed in knots).

Figure 39 : a navigation display on A330

In normal operations, the wind indicated by the left ND is the wind calculated by ADIRU 1 and the wind indicated in the right ND is calculated by ADIRU 2.

Inaccuracies in calculating the ground speed have a significant impact on the accuracy of the calculated wind: assuming zero error in the measurement of the airspeed, the accuracy is ± 8 to 9 kt in terms of speed and ± 10° in direction, so long as the actual wind speed is at least 50 kt. However, there is no indication of the degree of accuracy of the wind in the flight ops manual or FCOM. On the A380 the wind speed and direction can be determined more accurately when GPS information is available: approximately a few degrees in direction and less than 5 kt in terms of speed.

Boeing 777

The wind is calculated in two ways: by the ADIRU and by the FMC. In the ADIRU, the wind vector is calculated as the difference between the ground speed vector calculated by the ADIRU and the airspeed vector, assuming zero side-slip and angle of attack. In the FMC, the ground speed vector used is the FMC's ground speed vector. The side-slip is still assumed to be zero, but the angle of attack is considered in the calculation.

The FMC's ground speed vector is corrected based on the variation in GPS position, which means that it is more accurate than the ADIRU's ground speed vector.

The wind speed and direction is displayed on both pilots' navigation displays (ND), in the top left corner, by an arrow accompanied by numerical values in the form DDD°/SS (where DDD is the wind direction in magnetic degrees and SS the speed in knots).

Figure 40 : a navigation display on B777

In normal operations, the wind indicated by the ND is the wind calculated by the FMC. If it is invalid, the wind calculated by the ADIRU is presented instead. The wind is only indicated if its speed is greater than 5 kt.

The wind values calculated by the FMC are also displayed on the PROG2 page of the FMS:

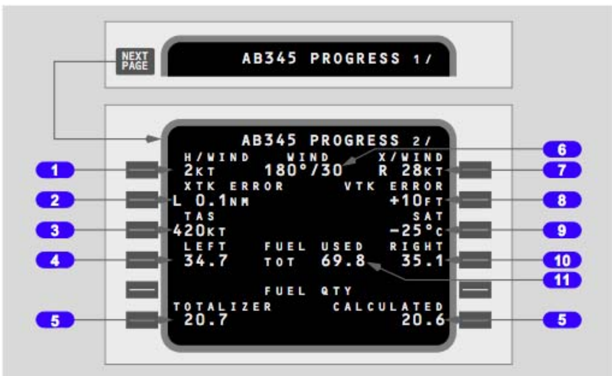

Figure 41 : *PROGRESS 2 page of the FMS on a B777.*
arrow 1: head/tail component; arrow 7: cross-wind component; arrow 6: total wind.

Since the accuracy of the ground speed vector derived by the FMC is much better than that derived by the ADIRU, the accuracy of the wind vector is also much better in the

FMC than in the ADIRU. The accuracy of the wind calculated by the ADIRU is about ± 12 kt in speed and ± 10° in direction. In the FMC, the accuracy is about ± 2 kt in speed and ± 2° in direction. However, there is no indication of the accuracy of the calculated wind displayed by the ND in the flight ops manual or FCOM.

Operational utilisation of the displayed wind

According to the manufacturer

The Airbus and Boeing operating procedures do not envisage that pilots will consider the displayed wind values when making decisions, particularly for landing. The wind values, including gusts) which must be used by the pilots to take the decision as to whether or not to land is the wind information provided by the control tower, which is averaged over a period of two minutes. Ultimately, it is the Captain who makes the decision.
However, Boeing does state that the wind information determined by the FMC is accurate.

According to certain airlines

All the airlines that participated in the study indicated that their pilots use the wind information displayed in the cockpit when making a decision regarding a go-around. Their training teaches them to consider this information qualitatively. The pilots indicated that they usually find this information to be reliable. In contrast, they report that the accuracy of the wind information provided by ATC can vary significantly from one continent to another.

According to research ordered by EASA

EASA ordered a study from a European research laboratory[14] on the subject of detection of gusts of wind near the ground. It specifies, among other things, using an average wind value over 2 minutes and not the current wind supplied by the FMS to detect gusts of wind.

[14] http://www.nlr-atsi.nl/downloads/analysis-of-existing-practices-and-issues-rega.pdf

6 - ANALYSIS

The analysis begins with a description and a summary of the issue of loss of situational awareness on approach during a go-around. Subsequently, each of the factors brought to light by the study is analysed in detail.

6.1 DESCRIPTION OF ASAGA-TYPE SCENARIOS

These scenarios are a synthesis of all the events and statistics presented in the factual part of the report.

General scenario

An ASAGA-type event is a go-around characterized by a loss of control of the flight path during go-around. This loss of control results from a loss of situational awareness by the crew that leads the aeroplane to make significant speed and pitch excursions. The pitch often has significant deviations compared to those recommended by the SOP and the speeds are often close to VFE or even higher.

The initial flight path on the go-around is often a climb then, progressively, and without any clear reaction from the crew, it becomes descending and ends up either as a serious incident or an accident.

It is apparent from the study that most ASAGA-type events involve twin-jet aeroplanes. They are light at the end of the flight because of the fuel burnt and have a very high thrust / weight ratio. In fact, the twin engines powering these aeroplanes develop very high thrust since, in accordance with certification standards, the aeroplane must be able to perform a go-around on a single engine.

ASAGA-type go-arounds are often associated with a disruptive element, before or during the application of thrust, which startles the crew (e.g. unexpected ATC constraints, automatic system inputs not in line with the go-around, unfavourable meteorological environment). Crews find themselves faced with a situation where they have to make a large number of critical actions (landing gear retraction, flight path management) under strong time pressure. These go-arounds are generally performed manually. However, some ASAGA scenarios show that the crew can engage the AP in an inappropriate mode.

Collisions or near collisions with the ground usually occur less than a minute after the beginning of the go-around.

Moreover, in the majority of ASAGA-type accidents, the CRM between crew members – which generally was not the subject of specific comments during the phases before the go-around - becomes inoperative at the time of the go-around. A lack of PM monitoring is another common factor identified.

Specific case of go-arounds with the pitch trim set close to the nose-up stop

Some ASAGA-type serious incidents or accidents are characterized by a loss of control of the aeroplane. Beforehand, the final approach is usually performed under AP. Following a particular event (e.g. disengagement of the autothrottle or auto-thrust, speed or altitude selection error) the speed decreases. The system automatically compensates for this loss of speed by a gradual deflection of the THS to pitch up until the AP disengages and / or the stall warning is triggered.

The crew reacts and performs a low energy go-around. The pitch increases to excessive values due to the application of full thrust while the pitch trim is close to full nose-up position and the aeroplane has a low initial speed. When there is not/is no longer automatic pitch trim management, action on the control column/wheel to the nose-down stop does not counteract the nose-up moment generated by the maximum thrust combined with full nose-up pitch trim. The pitch and the angle of attack then continue to increase up to the stall. Actions that have allowed some crews to regain control of the aeroplane before the stall were a decrease in the thrust during the go-around and then nose-down pitch trim inputs.

Defining the problem

The conditions for ASAGA-type events are difficult for crews to detect and correct. However, there are several common causal and contributing factors. Debriefing sessions on simulators and analysis of the survey show that pilots perform few real go-arounds during their careers. Management of the go-around can thus lead to many errors. During recurrent training, crews are trained on simulators with scenarios that are not representative of the ASAGA phenomenon and often with a single engine (i.e. engine failure). ASAGA-type events have always occurred with all engines running.

The crew starts the go-around with a nose-up pitch followed by the application of full thrust. The acceleration due to this rapid and significant increase in thrust can create the feeling of a too high nose-up pitch. In the absence of external visual references and visual monitoring of instruments, a somatogravic illusion can cause the PF to reduce the aeroplane pitch towards inappropriate values. In practice, these somatogravic illusions are little known to crews and existing simulators do not make it possible to recreate them so as to train pilots to recognize them.

Automatic systems management also poses problems. The initial engagement modes being different from those expected for the go-around, when they are neither called out nor checked, leads the aeroplane to follow an unwanted flight path. Thus, in addition to reading the FMA, the monitoring of primary parameters - pitch and thrust - is a guarantee for the crew to ensure that the automatic systems put the aeroplane on a climbing flight path during the go-around.

The succession of mode changes is difficult to detect, call out and check during the go-around. The time pressure associated with limited human cognitive abilities - and therefore of crews - is the major problem in ASAGA. The crew must perform a number of actions and cross-check them in a short time. The induced cognitive overload may prevent the detection of deviations both by the PF, who is mainly concentrated on the PFD, and by the PM, who undertakes a set of tasks that divert his attention. Thus, a deviation, even in an important parameter or in the flight path, may not be detected by the crew.

In ASAGA-type events, the PM has a primordial role and a sudden, high workload, higher than that of PF. Furthermore, the work is difficult to order and manage. Any deficiencies in his monitoring task can have catastrophic consequences.

In the conclusions of accident reports, the absence of any CRM often appears as a contributing factor. However, CRM often functions nominally and is not subject to major remarks before a disruptive element intervenes during or after the go-around. Similarly, where incidents are concerned, CRM functions again after the crew has regained control of the flight path.

The analysis of incidents and accidents, the results from the simulator sessions and the survey data, show that it is not useful to limit attribution of responsibility to the crew's failure to follow the principles of CRM. It is necessary to find additional ways to help the crew find synergy. This "lack of CRM" now seems to be a normal consequence where there is a situation involving startle effect, cognitive overload, time pressure and high stress. The evaluation of the loss of situational awareness should be the subject of measures both in the field of training and at the level of certification of the aeroplane.

To this should be added the consideration of ATC constraints:

- The flight path may be different from the published procedure prepared during the approach,
- Aeroplane performance may not be compatible with some published go-around procedures.

In all cases, the failure to take into account the notion of stabilization of the go-around flight path may increase the crew's difficulties.

Thus, the main challenge for the performance of a successful go-around remains finding ways of giving the crew time to carry it out and also to simplify their actions.

Moreover, whether it is for determining the circumstances of an accident, for a discussion at the end of a simulator session or for assessing crew members' monitoring abilities, the use of a video recorder is a vital tool to avoid errors in analysis (hindsight bias) during an investigation.

Finally, there is the problem of fatigue at the end of long-haul flights, which may play a role in the decision - the crew has a psychological incentive to want to land and not perform a go-around - and the performance of the go-around.

6.2 PERFORMANCE OF THE GO-AROUND

Monitoring the primary flight parameters

The analysis of ASAGA-type events always reveals pitch/thrust issues and shows that, at one moment, crews are no longer aware of these basic parameters. Even if the pitch and thrust may vary during the go-around (SRS mode / SPD mode), they remain fundamental items to be monitored during the procedure. Their magnitude must also be known. Once the pitch attitude and the thrust are stabilised, the speed is also a parameter that needs monitoring.

Though a majority of pilots say they do not have a problem to maintain pitch during the go-around (more than 66% of the pilots in the survey) or manage thrust (more than 53% of pilots), most instructors emphasize the opposite.

Thus, when a crew is "lost" during a go-around, the pitch attitude/thrust moment then the speed must absolutely become the heart of their strategy.

In addition, in training, pilots are encouraged to disconnect the automatic systems (specifically, the AP, FD, ATHR or AT) when the aeroplane does not react as desired. This principle has rarely been applied by crews involved in the events in this study when they found themselves in a situation where they no longer understood how the automatic systems were operating. Specifically, in case of a rapid increase in speed, they did not realise that it was better to reduce thrust manually, rather than to try to « understand ».

Conversely, flight crews must ensure that that they re-engage automatic systems only once the FD's are centred and the FMA modes perfectly understood and consistent with their plan of action, which is to say once the situation is stabilised. It emerged that this problem also occurred during the incidents in the study: some crews thus used automatic systems without checking, believing that they could help them to stabilise the aircraft. A study on the use and understanding of automatic systems by crews could thus be launched.

Time pressure

Of the two crew members, it's the PM that has the heavier workload, especially when taking into account possible ATC constraints and when retracting the gear and flaps. Pilots confirmed this both during post simulation interviews and in the survey conducted by the BEA.

This excessive workload for the PM leads him/her to prioritize actions to the detriment of monitoring activities. PF's are also obliged to make choices on the parameters to be monitored because of the workload and the rapid evolution of some of these parameters. Reports on accidents or serious incidents showed that time pressure resulted in many errors confirmed by the analysis of simulator sessions and visual scan. The human factors specialists who participated in this study confirmed that the go-around is a heavily loaded flight phase. The study assessed the workload and the associated time pressure.

Factually, the simulator sessions reinforce the evidence from the survey and highlight a heavy workload where the startle effect associated with the required speed of execution creates a stress situation, especially in IMC.

Training and compliance with procedures are important elements, but they do not make it possible to push back these limitations. The use of technology is one possible way of making progress as it allows actions to be simplified and gives pilots time to execute and control them. Manufacturers take into account the cognitive limitations based mainly on their own experience. But the study showed that this was inadequate to correctly to implement required procedures and actions. It is not enough to teach them well for them to be applied well, while requiring discipline and perfect crew coordination at the same time.

In conclusion, the go-around phase is very busy and it is imperative to provide more time so that it is less risky.

Thrust of modern aircraft

Maintaining control of the performance on a go-around demands control of all the actions required in the allotted time, itself a function of the speed at which they evolve. In this context, the primary go-around parameter is thrust, because it directly affects acceleration and vertical speed. The initial main parameter for the conduct of a go-around is pitch which, for a given thrust, determines the split between longitudinal acceleration and vertical speed. Some PF's during sessions input on the thrust by limiting it, which allowed them not to deviate too much from the set instructions, in order to control time management for all their flight parameters. Conversely, in some accidents, the PF no longer managed thrust after the start of the go-around.

The thrust limitation on Boeing 777 or the manual management of thrust on other aeroplanes allowed some crews to avoid altitude busts or overspeed.

Note: Airbus has since certified a reduced thrust on the A380 called "GA SOFT". To select it the throttles must be advanced to the stop at the TOGA detent, then pulled back by a notch to the MCT detent. This function is also currently being certificated on Airbus A330 and A340.

The main objective of this thrust limitation is to limit the effects of somatogravic illusions. But by also inducing a vertical speed limitation, it can give extra time for the completion of the go-around. On B777, the vertical speed is limited by default to[15] 2,000 ft / min while on A330, vertical speeds of up to 4,000 ft / min have been observed. Thus, the use of reduced thrust is a useful tool that it would be good to extend to all manufacturers.

Selection and engagement errors for go-around mode

There may be a conflict between the application of maximum thrust and the operating environment that does not necessarily require it. In fact, when the aeroplane is at an altitude close to or above that of the go-around, full thrust is not required.

As an example, on Airbuses, selecting go-around mode is always performed by pushing forward the thrust levers to the stop. The go-around mode is always associated with the application of full thrust whatever the phase of flight. A detent error, either forward or backward, leads to inappropriate mode selection; the consequences can be either an initial non-engagement of go-around mode, or a subsequent non-reduction of thrust.

There may thus be a natural reluctance to have to push forward the thrust levers to the stop to engage go-around, and also a tendency to rush to return to the CLB detent. All these factors may favour selection errors both during forward movement and aft movement of the levers.

These selection errors were reported in serious incidents and mentioned in the survey. The failure to detect mode changes shows the difficulty in detecting these errors in a very busy phase of flight.

On Boeing, the go-around engagement mode is different. Errors in the initial engagement of the go-around mode were also discovered but were not initially detected.

Studies should be undertaken in order to evaluate errors linked to mode engagement during go-arounds and perhaps propose a simpler way to engage them in correlation with thrust adapted to the flight conditions.

All the events highlight a mismatch between thrust applied and pitch. In fact, whoever the manufacturer may be, cases of full thrust with a downward flight path have been observed. Cases of negative pitch after applying full thrust also exist, and at low altitude. The BEA considers that manufacturers should undertake studies to inform the crew of an inconsistency in the relation between pitch and thrust and help them to rectify the situation.

6.3 VISUAL SCAN MANAGEMENT

PM's Visual scan

The results of eye tracking during the simulations showed that visual scanning by the PM was diffuse in the go-around: although on average each pilot spends the same time on

[15] It is always possible to get maximum thrust by pressing the TOGA switches twice.

each Zone of Interest, the sequencing of items they scan is totally different. This means that the path followed by the gaze of the PM is not standard. The study of visual scan during simulator sessions also showed that pilots have no personalised method.

The survey indicates that many PM's do not know where and when to look during a go-around. Pilots are looking for a way that would help them maximize performance of all the actions required while maintaining a high level of monitoring. Without training on the visual scan to use, it is difficult to imagine that a pilot knows how to organize it for a procedure that is rarely undertaken and which requires a lot of actions.

In conclusion, it is necessary for manufacturers and operators to define together a visual scan that would optimize crew teamwork during a go-around. Similarly, a study should be undertaken on extending the definition of visual scan for standard procedures that require a high workload over a relatively short time frame.

Following the go-around procedure

Analysis of the simulator sessions showed that the procedures developed by the manufacturers and / or operators are, in general, followed by crews. In contrast, the surveys conducted on ASAGA-type accidents showed that, in general, the go-around procedure was not executed in accordance with the published procedure.

The study highlights that respecting all items in the procedure is often done at the expense of monitoring functions, especially flight path tracking. There is a conflict between basic airmanship and the sequence imposed by the go-around procedure. It is therefore essential that manufacturers adjust their procedures in relation to realistic current operational contexts - particularly ATC constraints and aeroplane performance - using appropriate tools with which to assess pilots' workload more thoroughly, via pilots' visual scan.

Go-around and gear and flaps

Go-around procedures were developed based on risk analysis. Today, with modern high-powered aeroplanes that are light at the end of the flight, the risk of an accident is no longer related to configuration management but rather to flight path management.

In some cases, manufacturers already plan that the sequence of flaps retraction can be delayed. The case of the missed ILS PRM Approach [16] procedure or the windshear procedure should be mentioned here. This allows crews to have more resources to perform the procedure. Some manufacturers also plan automatic retraction by one notch when VFE is exceeded.

Since the PNF's configuration management is time-consuming and is done at the expense of monitoring, a study could be launched on the possibility of assisting the PM to monitor the parameters related to the flight path by partially reducing his/her management thereof.

Attentional tunnelling

Analysis of some accidents seems to suggest that the go-around phase leads to the phenomenon of attentional tunnelling where one pilot, or both, focus exclusively on a problem at the expense of general monitoring of the flight parameters. This problem of attentional tunnelling is also apparent from a review of the pilots' accounts from the

[16] The ILS PRM approach principle allows two aircraft to simultaneously make an ILS approach on two close parallel runways.

survey. However, experiments did not show that channelized attention occurred. Detailed analysis of some go-arounds seems nevertheless to reveal precursor behaviour.

In particular, the eye tracking data show that some piloting actions through the use of flight instruments generate strong attention "capture": programming of the flight path from the FCU / MCP, flight path management using the flight director and flap management in relation to speed limits (VFE). The instruments used to perform these actions are those that produce either the longest attentional tunnelling time (i.e. exclusive fixations), or the highest fixation frequency, or both. The specific ergonomics of some of these instruments can contribute to strengthening and maintaining attentional tunnelling. Thus, the position of the FCU / MCP, away from all primary flight instruments, does not allow pilots engaged in fine tuning adjustments, to have access via peripheral vision to the flight path parameters. For example, during a go-around, a copilot focused exclusively on this interface for 10 s without monitoring any other flight information such as the flight path parameters. For information, it is recognized in the automotive field that focus on a secondary interface (e.g., GPS, radio, mirror) must never exceed 2 seconds (source: National Highway Traffic Safety Administration, U.S. Department of Transportation, 2006). With no transposition of this study to the field of aeronautics, it cannot be firmly stated that this length of time is excessive, even if it appears to be.

Flying using a FD also requires intense attention that can cause a state of fascination if primary parameters (heading, target altitude, vertical speed) are incorrectly set (GA session A, for example). This can force the aeroplane off the planned flight path. The ASAGA experiments reinforced the impression of attentional tunnelling related to carrying out these various actions.

Attentional tunnelling phenomena pose three problems:

- They are difficult to predict
- They are difficult to detect and thus prevent
- Once the pilot is drawn in, it is difficult to help him/her get out.

It appears to be necessary to study means of preventing and / or helping pilots escape from attentional tunnelling. The BEA has observed, during recent investigations, that essential information that could help the crew out of an unusual situation was scattered around in a lot of other information of lesser importance. Thus the prominence of essential information (visual and auditory) could be improved in the light of the increasing integration of information on the PFD and the ND.

Research in this direction should be developed, the most promising today being a move towards simplification of the information presented to crews in a unusual situation, or the application of "violent" stimuli to get the crew to react and the help them out of an attentional tunnelling situation.

6.4 COCKPIT ERGONOMICS

FMA

In general, manufacturers rely on reading and a thorough understanding of the modes displayed on the FMA.

The simulations and analysis of events show that most crews neither detect nor check all the mode changes. This may lead the aeroplane into a dangerous situation. Whatever the type of aeroplane, problems related to modes were observed throughout go-arounds.

At the beginning of the go-around, following a single action, crews must read up to four different items of information to check that the go-around mode has been engaged. Two serious incidents illustrate the consequences of a failure in reading: the switch to LAND mode on Airbus, or acceleration at full thrust on the ILS axis on Boeing following the disengagement of A/T. The study does not call into question the necessity of an initial reading of FMA modes, but work could be done by manufacturers in order to simplify their reading and interpretation.

Secondly, the simulations showed that during the go-around, reading the FMA is virtually non-existent. Up to 10 undetected FMA mode changes were observed, while some have a direct consequence on the PF's monitoring of the aeroplane flight path. The non-detection of FMA mode changes by both crew members is mainly related to cognitive saturation, time pressure, lack of defined visual scan and the workload associated with the go-around.

Finally, on interception or selection of go-around altitude, surveys and simulations show that full thrust is sometimes still applied and that mode reversions are not detected.

Crews do not always understand the rapid succession of mode changes and the diversity of possible combinations. This may have consequences on the aeroplane's attitude and on the crew's situational awareness.

The detection, reading and understanding of FMA modes should therefore be facilitated.

FCU / MCP manipulation

Simulations showed that the PM could stay focused on the management of FCU / MCP for periods up to 10 seconds. Manufacturers have indicated that training on manipulation of the FCU / MCP specifies that the selected values should be read on the EFIS and not on the FCU / MCP, in order to maintain the gaze on the PFD. However, modifications in FCU / MCP values are also displayed on the latter and almost all pilots observe them during changes in value.

It seems obvious that human beings will favour observation of the value displayed next to the button that is being manipulated, whatever their level of training, especially in high workload situations.

Operators should again insist on best practices but it is likely that drift occurs. In the medium term, it would be appropriate for aeroplane manufacturers to think about improving FCU / MCP manipulation in order to reduce the time spent on it.

Position of the trimmable horizontal stabilizer

Several events studied were the result of a (quasi) loss of control when the following conditions were met:

- Low speed,
- A horizontal stabilizer trim position close to full nose-up position and / or nose-up trim but outside of the normal operational context,
- The application of high thrust.

When these three factors are present, setting of the elevator on full nose-down position no longer makes it possible, after a certain time, to counter the moment generated by the combined action of the nose-up trim and the thrust. The aeroplane can thus exit the flight envelope and stall. The pilot thus no longer has authority to correct the attitude of the aeroplane when he pitches down.

The information presented to him/her does not thus usually direct him/her towards appropriate solutions, namely a decrease in the thrust and / or a change in position of the trim. The risks identified are a non-recoverable stall at low altitude. The study showed that this risk is not directly taken into account in certification.

Without knowledge of the trim position at very low speed, the only way to get out of this is an immediate reduction in thrust when the aeroplane pitches up excessively. It is easy to understand the difficulty for crews to undertake this little known and unnatural manoeuvre during a go-around. In addition to the known risk of loss of control, the BEA believes that EASA should ensure that the recovery procedure ("upset recovery") is well known to crews, especially with regard to thrust reduction.

Due to the development of autotrim on aeroplanes or the intensive use of autopilot, pilots seldom, if ever, manage the horizontal stabilizer trim position. The trim adjustment being automated in flight, its use becomes transparent to the pilot. In addition, given the uncertainty of the application of the recovery procedure, it is essential for manufacturers to develop a way to make the crew aware, at the earliest possible stage, of an excessive drop in speed, so that they avoid applying full thrust with an unusual nose-up trim position. They also need to think about how to prevent the trim reaching or remaining in an inappropriate position with respect to flight conditions, so that the aeroplane does not become uncontrollable during a low energy go-around.

Wind displayed to crews

Wind information is vital for crews for the conduct of the flight, especially for the decision to perform a go-around, particularly where there is a tailwind.
Two sources of information are used by crews:

- ATC wind provided by the ATC service.
- The aeroplane wind calculated by the ADIRU alone or combined with GPS information.

Statutorily, only ATC wind is valid. However, four issues were highlighted in the study:

- ATC wind is not instantaneous wind but averaged wind.
- The degree of confidence of the crew in ATC wind differs from one continent to another.
- In case of tailwind, the ground wind is usually significantly lower than the wind at altitude encountered during the approach. This can create a conflict for any go-around decision.
- The wind presented to crews and displayed on the ND or the associated FMS page is often used by the crew to make the decision.

However, crews know neither the accuracy of the wind presented, nor its source. For example, on A330, aeroplane wind is calculated only from ADIRU, and is not guaranteed below 50 kt. Conversely, aeroplane wind including GPS information is very accurate (on A380 or B 777 for example).

Whatever the source, crews tend to trust aeroplane wind to the detriment of ATC wind. Unfortunately, many public transport aircraft do not use the GPS source to provide accurate wind to crews. This information is not documented in FCOM's.

The problem of aeroplane wind is outside the scope of this study. Wind is a key parameter taken into account in piloting and the strategies adopted. Without compromising the regulatory aspect of ATC wind, the BEA believes that information on aeroplane wind must be as accurate as possible and that the crew must also know the precision of the information presented.

6.5 SOMATOGRAVIC ILLUSIONS

Somatogravic illusions are a contributing factor to ASAGA-type accidents and serious incidents, mainly in the absence of external visual references. Faced with these illusions, pilots have probably pushed forward on the control column while, during a go-around, the goal is rather to move away from the ground as quickly as possible.

Few pilots are aware of it and do not know that the difference between the pitch perceived during a go-around and the actual pitch of the airplane can sometimes reach values up to 15 degrees, but also that significantly positive pitch may be experienced while true aeroplane pitch is negative.

The difference between the perceived pitch and the true pitch that characterizes somatogravic illusions is not always properly simulated today. The study showed that progress seems possible, however. It is essential that pitch perceived during simulator sessions be representative of those of a flight.

In addition, evaluation of the fidelity of motion simulators is subjective. No regulatory standards exist. As crews do not frequently undertake real go-arounds, the critical nature of this failing should be remedied since, in the case of go-arounds, the simulator is the only source of learning. The investigation into the accident to the aircraft registered F-GZCP on 1st June 2009 has already led the BEA to recommend that regulators *"... modify the basis of the regulations in order to ensure better fidelity for simulators in reproducing realistic scenarios of abnormal situations."*

Some manufacturers have told the BEA that there are already digital representations of terrain in 3 dimensions displayed to crews. Thus, a pilot in IMC may have “artificial” external visual references and react better when the aeroplane is dangerously close to the ground. The majority of ASAGA-type accidents took place at night and / or IMC. The consequences of somatogravic illusions could probably be better compensated for by providing information on the external environment.

Finally, it is now legally possible to undertake passenger transport flights without ever having faced:

- Somatogravic illusions,
- The time pressure associated with changes in procedures and the application of full thrust with all engines operative,
- Performing a high-energy go-around above operational minima.

The survey identified a large number of accounts from pilots expressing significant difficulties in the performance of their first real go-around during a check flight. Thus, one or more go-arounds must be made - in the absence of a better simulator representation - during a check flight. This flight is usually mandatory in Europe after the successful simulator test. No minimum program is provided statutorily. At the world level, ICAO does not mention any obligation to undertake aeroplane training after passing the simulator test. In all cases, it seems to be essential to undertake aeroplane training whose program includes a number of go-arounds with all engines operative before transporting passengers to obtain a first CS 25 TR.

6.6 CREW TRAINING

Initial training

From the beginning of his/her training, the pilot is faced with the go-around procedure. Taught well, it is well reproduced by trainees. Practising the flight and the manoeuvre will contribute to good pilot performance. During advanced stages of training, the procedure being performed infrequently on a day-to-day basis, it is no longer presented among the reflex actions. It is presented in the form of a "piloting tool" that allows for a new circuit or a new instrument procedure.

There may be a kind of semantic confusion between a procedure and a manoeuvre whose basics can be forgotten. As there is no longer a need for a rapid response, strict adherence to the various procedural items can crumble.

The various clearances or radio exchanges involve a greater dispersion of attention: go-around procedures are a little less applied and / or completed. If power setting (General Aviation) is not forgotten (probably due to low performance of the aeroplanes used), the pitch is sometimes variable and inconsistent with that required for the completion of the manoeuvre.

Moreover, in all these phases that bring the pilot to his/her professional license and instrument rating, the pilot is often Captain, the unique pilot on board. Deviations from procedures were marked at the end of this phase by the instructors interviewed during the study.

Crew training and monitoring

After passing this essential stage, the pilot will increase his/her flying experience. In Europe, before being type-rated for the public transport of passengers, he/she will often follow MCC training. This phase is important because it introduces the crew concept, with all the principles of appropriate communication in the cockpit. Beyond basic human factors, technical callouts and their application in the simulator are taught in order to be able to communicate with other pilots and manage an aeroplane in a very standardized framework.

The monitoring of parameters, in terms of tools used, uses techniques learned in the initial course (T-scan, for example) as pilot-in-command, theoretically the only decision-maker. Though this type of monitoring is suitable for older aeroplanes, it is much less so for aeroplanes in service today for which the maximum of information has been placed on the screen at the centre of the pilots’ field of vision. In addition, the more recent the aeroplane is, the more the amount of potential information presented on the PFD increases. Today, however, it’s possible to do MCC on a Beech 200, a single-pilot airplane, whose ergonomics and performance are far removed from a Boeing 737-800 or an Airbus 320.

In terms of tasks, the procedures and in particular the go-around determine the actions to be performed by each crew member. However, piloting factors to be checked are rarely mentioned. Differences to call out are highlighted, but much less is made of the main parameters to be monitored during the go-around, that’s to say the pitch and thrust.

After obtaining an MCC, a pilot can legitimately be a candidate to be an airline pilot for a public transport airline.

Today, operators select their pilots according to their own criteria. Though it is not possible to impose strict standards for airline recruitment on them, it is still desirable to encourage a more thorough evaluation of the candidate's aptitude to undertake monitoring duties. The monitoring function is now absolutely essential.

Type rating

The type rating phase does not pose a particular problem because training is undertaken according to the principles defined by manufacturers with strict application of procedures. It should be noted, however, that some difficulties arise with discovering how a new aeroplane works. In fact, at this stage, insufficient familiarity with the procedures, difficulties in handling the aeroplane and work overload have been observed. This last point is important in view of the conditions for performing the procedure in the simulator, which is not constrained by the environment (little or no interaction with ATC, no major system malfunctions, no flight path changes).

After passing the simulator test during their first CS 25 type rating, aeroplane training is usually performed in Europe, but is not always mandatory elsewhere. However, no real go-around is mandatory. Crews are rarely faced with the real acceleration they will experience, including longitudinal, which cause somatogravic illusions.

Recurrent training

During training and recurrent training stages, following some incidents, some operators have added a go-around with all engines operative in addition to the regulatory program. This addition also allows the performance of the procedure to be adjusted, especially when it is performed manually.

Some instructors noted differences when the pilots followed the manufacturer's proposed procedure in automatic mode: TOGA, nose-up input. The result is either non-compliant pitch (between 5 and 10 ° pitch) or no pitch application at all, an accelerated flight path with a rapid approach to speed limits, etc.

They also noted that automatic system management was not perfect. The events in the study as well as the simulator sessions showed that the FMA mode, at the time of engagement of the automatic systems, in addition to their subsequent changes, are not systematically called out and/or checked.

In addition, the number of scenarios that could contribute to placing the pilot in a varied number of situations is particularly inadequate. Most of the time, a standard go-around is required. The study showed how accident scenarios underline the importance of a disruptive or a startle effect element. Thus, it would be a good idea to train crews to perform, in addition to a standard go-around, a realistic go-around based on a scenario as described in the study.

Finally, there is a paradox in having a mandatory execution of a go-around with one engine inoperative at the expense of a go-around with all engines operative. As there is less thrust, there is more time to execute it. Therefore, there should be a balance between go-arounds with one inoperative engine, mastery of which is essential, and those made with all engines operative. The study did not bring to light any major accidents with "one inoperative engine" configuration – with one exception, that of the Port Sudan accident. .

6.7 AIR TRAFFIC MANAGEMENT (ATM)

Modification of the go-around flight path by ATC

When crews prepare a descent, they perform two main actions:

- They program the published final approach procedure specified by ATC into the FMS. This also includes the go-around;
- They perform a briefing running over the key points of the procedure and of the go-around.

These actions are usually performed half an hour before the estimated landing time. As was noted during simulations, some crews take care to re-do a short briefing on the go-around during the final approach. This "mini-briefing" reactivates the key points of the go-around to help in its performance. Any modification of the planned flight path thus disrupts the crew and its cohesion. Whether or not there is mini-briefing on final, certain memory items can be contradicted by ATC orders. The crew can be surprised and unsettled when changes to the go-around flight path are requested by ATC.

In some accidents or serious incidents investigated, as well as the analysis of many accounts in the survey, controller clearances were found to be disruptive and / or contributing to the increase in the workload.

The simulator experiments showed that instructions given by the controller are not immediately taken into account by the crew at the beginning of the go-around procedure. Of the average of one minute it takes to perform a go-around, 30 seconds on average are necessary for crews for recall. Most crews do not recall the numbered values exactly. This is due to several reasons: on the one hand, crews are taught not to be disrupted by ATC (stand-by or not read-back), on the other hand, the number of actions to perform (retraction of flaps and gear, flight path management) take up all of the crew’s capacities and leave them little availability to perceive and memorise ATC information.

In the majority of GA1 simulations, it was not the PM that remembered the ATC clearance but the PF. This is one of the elements that show that the PM no longer has the resources necessary to carry out the initial go-around actions with an ATC disruption in the sequence. Further, the PF is also disrupted because he/she expects these constraints to be taken into account by the PM.

Moreover, modifications to the flight path do not allow crews to use and activate the go-around flight path inserted in the FMS. Thus, the FD orders displayed on the FD PFD at the beginning of the go-around are not those that the PF should follow as long as the ATC constraints have not been taken into account through the use of the FCU / MCP.

When the PM finally takes into account the ATC constraints, analysis of visual scan during the simulator sessions showed that he/she is preoccupied by managing the heading and altitude at the expense of monitoring the flight path and some primary parameters.

The simulator sessions, evidence from the survey and analysis of events show that communications with ATC have potentially negative consequences such as:

- Excessive verbalization during a phase of flight with a heavy workload
- Disruption in the performance of CRM
- A risk of error in entering clearance values at the FCU / MCP
- Errors in initial flight path with a risk of a mid-air collision or collision with the ground
- Undesirable modification of aeroplane’s FMA modes.

The GA2 simulator sessions showed similar though less severe consequences due to the fact that there was only disruption in altitude, but not heading. The GA3 in automatic and standard showed greater availability of the crew for monitoring aspects and a marked improvement in the application of the procedure. Crews were able to benefit from a learning effect from the second go-around which improved flying performance and mental availability. The fact that GA3 was not disrupted was also a factor in better performance.

Thus, for all the reasons mentioned above, the BEA believes that it is necessary – except where such intervention is deemed essential - for ATC not to give any instructions contrary to the published go-around procedure.

If it proves necessary, however, for ATC to modify the go-around procedure, consideration should be given to studying what means are needed to anticipate it so as to announce it to crews as soon as possible so they can prepare for and reduce the risk associated with any startle effect element.

Controller training and procedures

ICAO provides that, except for safety reasons, no transmission must be made to the aeroplane during takeoff, during the final part of the approach procedure and during the landing roll. These provisions do not take into account the missed approach. However, verbalization by ATC during a go-around is a disruptive factor and in some contexts, a disruptive element that may prove to be a major factor in destabilizing the crew. It would thus be helpful to request that ICAO study the possibility of establishing a standard requiring that no ATC transmission be broadcast as long as the crew does not indicate that the go-around procedure is complete, except for safety reasons.

Finally, it is necessary to ensure that the training of controllers underlines all the risks associated with changes in flight path and communication during the performance of the go-around, in order to better understand their consequences: increasing the workload and time pressure. At the European level, EASA should conduct audits to ensure that the national authorities integrate the above points into controller training programmes.

Published missed approach procedures

It is necessary to give crews time to perform the go-around and disrupt the flight path as little as possible.

Some go-around procedures are designed without taking into account the risks they pose to crews when the level-off altitude is insufficient in terms of the aeroplane's rate of climb. In fact, the survey and the simulations showed that a large proportion of crews experience difficulty when the height gained during the go-around is limited. Two cases may arise:

- A low go-around altitude compared to that of the minima,
- A go-around performed at an altitude close to or above the published go-around altitude.

When the difference between the approach minima and the go-around height is small, crews have insufficient time for the correct performance of manoeuvres. The simulations seemed to suggest that a go-around altitude less than 2,000ft above minima does not allow sufficient time to complete the manoeuvre in good conditions.

The BEA therefore considers that an appropriate difference in height between the minima and that of go-around should be sought. It should take into account, in addition to environmental factors, modern aeroplane performance, in particular their vertical speed.

The time needed to reach the go-around altitude being the determining factor, a minimum height gain should thus be reassessed based on the evolution of aeroplane performance.

When a crew performs a go-around without the help of automatic systems, it initially follows the same heading as the one it had on final. Most of the time, finals are aligned with the runway centreline. A go-around flight path that extends that of the final is thus easier to follow. In ICAO terminology, this possibility is called a straight ahead missed approach. However, ICAO does not indicate that the construction of such a procedure should always be the standard unless there are environmental or other constraints.
The design of go-around procedures in a straight line with a sufficient altitude has the advantage of significantly reducing the crew's workload and optimizing its performance by facilitating the performance of the go-around. This should be the preferred solution.

6.8 ADDITIONAL INFORMATION

Taking into account failings in CRM

The study showed that the implementation of the go-around procedure and the associated workload can dissociate the two crew members' actions for too long. Any deviation from flight path is then difficult to detect by the PM. The same applies to the detection of PM manipulation errors by the PF (flap retraction for example).

Until now, failings in CRM have always been put forward as contributory or even causal factors in go-around accidents. However, the analysis of recent events showed that the concept of CRM is questionable though it functioned correctly before a disruptive factor intervened. The simulator sessions clearly illustrated this. In fact, any startle effect requires the use of resources and the crew is almost systematically de-consolidated. CRM is necessary and fundamental in aviation, and is particularly developed in Europe and North America. However, it is no longer a sufficient barrier to prevent new types of accidents resulting from the loss of situational awareness following a disruptive event. Aspects of CRM become "naturally" inapplicable in accident, and not only within the strict context of ASAGA-type accidents.

We must therefore go beyond the current concept of CRM and develop new means and / or training methods to assist the crew to regain awareness of the situation in which they find themselves.

Image recorders

The study showed that the use of the video was indispensable to conduct a proper analysis of the simulator sessions. Besides non-verbal communication, video recordings make available all the information presented to the crew. Thus, in the context of safety investigations and on many occasions, the BEA and its foreign counterparts have faced technical difficulties understanding the cockpit environment, requiring lengthy, costly and often inconclusive technical examinations. The study showed that video recording of the pilots' workspace brings a considerable improvement in the understanding of events. In addition, installed in a simulator, it was a useful source of information during debriefings.

In addition, the study showed that video recordings, restricted to the external environment and the pilots' workspace, meet the needs of both an investigation and the legitimate concerns for respect of pilots' privacy. For this, the filmed environment should exclude, as far as possible, the pilots' heads when seated in their normal piloting positions.

For the understanding of accidents and improving aviation safety, it is indispensable to make mandatory the installation of an image recorder on board aeroplanes performing public transport passenger flights. The BEA has issued five recommendations since 1994 on this subject, most notably in the context of the investigation into the F-GZCP accident on 1st June 2009, without any concrete results thus far.

With regard to pilot training, the study demonstrated the obvious plus factor in using video recording in a simulator. During the sessions, the pilots wanted to watch the video in order to re-memorize their actions and to learn a maximum number of lessons. During debriefings, they all showed great interest in having this information available, it being understood that it is used and managed by pilots. The investigators did not notice any debate on the subject of the protection of privacy when it came to the installation and use of video recording in simulators for pilot training.

7 - CONCLUSION

ASAGA-type events are due to a combination of the following:

- Time pressure and a high workload.
- The inadequate monitoring of primary flight parameters during go-arounds, especially with a startle effect.
- The difficulty in applying CRM principles in a startle effect situation.
- Inadequate monitoring by the PNF.
- The low number of go-arounds with all engines operating performed by crews, both in flight and in the simulator.
- Inadequate fidelity on flight simulators.
- The non-detection of the position of nose-up trim by the crew during go-arounds.
- Interference from ATC.
- The mismatch between the design of procedures for go-arounds and the performance characteristics of modern public transport aeroplanes.
- Aircrew learning teamwork on unrepresentative aeroplanes before a first CS 25 TR.
- Somatogravic illusions related to excessive thrust on aeroplanes. The lack of evaluation of visual scan during the go-around.
- The channelized attention of a crew member.
- The difficulty of reading and understanding FMA modes.
- Excessive time spent by the PNF on manipulating the FCU / MCP.

8 - SAFETY RECOMMENDATIONS

Note: In accordance with Article 17.3 of European Regulation (EU) 996/2010 of the European Parliament and Council of 20 October 2010 on the investigation and prevention of accidents and incidents in civil aviation, a safety recommendation shall in no case create a presumption of blame or liability for an accident, a serious incident or an incident. The addressee of a safety recommendation shall inform the safety investigation authority which issued the recommendation of the actions taken or under consideration, under the conditions described in Article 18 of the aforementioned Regulation.

8.1 FLIGHT CREW TRAINING

Monitoring primary flight parameters

Analysis of accidents or serious incidents due to go-arounds shows that crews are often no longer aware of the basic parameters – pitch, thrust – and their correlation with changes in calibrated airspeed and vertical speed. Performing the go-around requires a high number of actions. Crews may have difficulty in identifying priorities for their actions and may not continuously monitor these parameters. Neither the procedure nor the training in its use stipulates that the crew should go back to these two fundamental parameters.

Consequently, the BEA recommends that:

- **EASA in coordination with manufacturers, operators and major non-European aviation authorities ensure that go-around training integrates instruction explaining the methodology for monitoring primary flight parameters, in particular pitch, thrust then speed [Recommendation FRAN-2013-017]**

Assessment of the role of the PM

The performance of the monitoring function is essential but insufficient during the go-around. During performance of the go-around studied, the PM's attention was focused on the actions to take and not on their monitoring. It is therefore necessary to focus on this issue in particular during initial training in MCC and then assess the results during on-going and recurrent training.

Consequently, the BEA recommends that:

- **EASA, in cooperation with the national civil aviation authorities and major non-European aviation authorities, ensure that during recurrent and periodic training, training organizations and operators give greater importance to the assessment and maintenance of the monitoring capabilities of public transport pilots. [Recommendation FRAN-2013-018]**

Recommendations on CRM

The ASAGA study highlighted the difficulties of maintaining a good level of CRM throughout a go-around. The priorities of the PF and PM are different. Their respective workloads limit their interaction and mutual monitoring of actions. Although fundamental, current CRM alone cannot constitute a reliable safety barrier in the case of disruptive elements. In general, whatever the type of recent accident, investigative findings often point to shortcomings in CRM.

Consequently, the BEA recommends that:

- **EASA study the additional technical and regulatory means required to mitigate the shortcomings of CRM in high workload and/or unusual conditions. [Recommendation FRAN-2013-019]**

Flight crew training

Today, a go-around is considered as a normal procedure. Nevertheless, the study showed that its rarity, gestures and complexity in terms of workload make the procedure a singular one. A go-around does not often occur during operations – especially on long haul flights – and is one of the manoeuvres that are poorly represented by simulators, in particular due to the absence of a realistic ATC environment. For this reason, in practice, the go-around procedure is not a normal procedure but a specific one.
The study showed that pilot training did not correlate with the scenarios of accidents and serious incidents due to go-arounds, especially during recurrent simulator checks. The number of go-arounds with all engines operating is insufficient and the scenarios used are often predictable. PANS training (PANS-TNG) does not include realistic scenarios during the go-around.

Consequently, the BEA recommends that:

- **ICAO enhance the PANS-TNG by including realistic detailed training scenarios based on current technology and risks. [Recommendation FRAN-2013-020]**
- **ICAO modify the relevant annexes to make mandatory the performance in an aircraft of a go-around with all engines operating for the issuance of the first CS-25 type rating. [Recommendation FRAN-2013-021]**
- **EASA review the regulatory requirements for initial and periodic training in order to ensure that go-arounds with all engines operating are performed sufficiently frequently during training. [Recommendation FRAN-2013-022]**
- **EASA review the regulatory requirements for the first CS-25 type rating in order to make mandatory the performance of a go-around on an aircraft with all engines operating. [Recommendation FRAN-2013-023]**

Recommendations on video recordings

During the study, use of video was essential to carry out a proper analysis of simulator sessions. In addition to the non-verbal communications, the video recordings made it possible to have access to all the information presented to the crew. A video recording of the pilots' workspace is a major improvement. Installed in a simulator, it would be a source of additional information of use during crew debriefing.

Consequently, the BEA recommends that:

- **ICAO make mandatory the installation of an image recorder in all full flight simulators intended for public transport and used in the context of training. [Recommendation FRAN-2013-024]**

8.2 ERGONOMICS AND CERTIFICATION

Limitations on available thrust

When full thrust is used during a go-around, an excessive climb speed can be reached very quickly, and make it difficult to undertake the actions in the go-around procedure. It can, firstly, be incompatible with the time required to perform the go-around and, secondly, be a source of the somatogravic illusions that have led 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 time, to limits excessive sensory illusions and excessive pitch attitudes.

Consequently, the BEA recommends that:

- **EASA, in coordination with major non-European aviation authorities, amend 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 examine, 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]**

Error in go-around engagement modes

The study showed, however, that there is a conflict between the application of maximum thrust and an operating environment that rarely, if ever, requires it. On Airbus aircraft, the thrust lever is primarily a mode selector and is generally not moved, except during take-off and flare. In a phase of flight with a high workload, qualified pilots make mode selection mistakes in go-arounds both when advancing the thrust lever to stop and/or when moving it back to the CLIMB detent. Errors in mode engagement, such as confusion between an input on the palm switch and the AT disconnect button, have been highlighted on Boeing aircraft and have also led to serious incidents.

Consequently, the BEA recommends that:

- **Airbus and Boeing re-evaluate the possibilities of errors linked to the engagement of go-around modes. [Recommendation FRAN-2013-027]**
- **Aircraft manufacturers study the means required to detect and correct erroneous mode selection during a go-around. [Recommendation FRAN-2013-028]**

Management of aircraft configuration

The PM's management of the aircraft configuration is time-consuming during the go-around and is undertaken to the detriment of monitoring the primary flight parameters.

Consequently, the BEA recommends that:

- **Aircraft manufacturers study the feasibility of simplifying the management of the aircraft configuration, during a go-around, in order to increase the PM's monitoring availability. [Recommendation FRAN-2013-029]**

Study of visual scan to develop go-around procedures by manufacturers

The assessment of visual scan is fundamental in developing a procedure. Some devices, such as oculometric systems, exist today so that a detailed study can be made. At present, analysis of visual scan is not formalised, despite the fact that it alone can be used to analyse teamwork shortcomings in detail.

Consequently, the BEA recommends that:

- **Aircraft manufacturers and operators study pilots' visual scan in order to improve and validate their procedures, particularly with regard to go-arounds. [Recommendation FRAN-2013-030]**
- **EASA, in cooperation with the international certification authorities, introduce certification criteria to make mandatory the study of pilots' visual scan in developing procedures defined by manufacturers. [Recommendation FRAN-2013-031]**

Simulated representation of external references

Most ASAGA-type events have occurred at night and/or without visibility. The loss of external visual references certainly contributed to the loss of situational awareness during the go-around. The possibility of seeing or having a representation of the outside environment would probably make it possible to reduce the risks associated with somatogravic illusions. Today, there are systems available that represent the outside environment in 3D.

Consequently, the BEA recommends that:

- **AESA and manufacturers study the implementation of means to allow flight crew to have access to a virtual representation of the outside environment in IMC conditions. [Recommendation FRAN-2013-032]**

8.3 TRAINING AND ERGONOMICS

Channelized attention and dispersion to the detriment of the primary parameters

The study showed the vital importance of monitoring by the PM during the go-around. PM can have great difficulty in monitoring all the parameters required by the procedure. The PM's visual scan during a go-around is not homogeneous for a given procedure. It even reveals a significant dispersion of attention. Training does not adequately address this problem. Phenomena such as channelized attention or attentional tunnelling may well occur during a go-around.

Consequently, the BEA recommends that:

- **EASA, in cooperation with the national civil aviation authorities and major non-European aviation authorities, ensure that the risks associated with dispersion and/or channelized attention during the go-around, to the detriment of the primary flight parameters, be taught to crews. [Recommendation FRAN-2013-033]**

- **In the long term, main civil aviation authorities, in coordination with aircraft manufacturers and operators, define means to counter channelized attention phenomena. [Recommendation FRAN-2013-034]**
- **EASA, in coordination with manufacturers, operators and major non-European aviation authorities, study whether to extend these measures to other procedures requiring a high workload in a short time frame. [Recommendation FRAN-2013-035]**

Engagement of automated systems – monitoring modes displayed on the FMA

The study showed that the number of changes in FMA modes during the go-around can be high. This makes it difficult for crew members to detect and read all these changes. Go-around procedures cannot be evaluated based solely on the assumption that FMA mode changes have been comprehensively read and understood. In addition, the selection of a proper guidance mode, displayed on the FMA, does not in itself guarantee correct tracking of the path. Go-around procedures are not evaluated in a realistic operational context.

Consequently, the BEA recommends that:

- **EASA ensure that national civil aviation authorities check, during in-flight and simulator checks, that monitoring of the engagement modes of automated systems by pilots is correctly executed. [Recommendation FRAN-2013-036]**
- **EASA, in coordination with the major non-European certification authorities, ensure that aircraft manufacturers modify ergonomics so as to simplify the interpretation of FMA modes, and facilitate detection of any changes to them. [Recommendation FRAN-2013-037]**
- **EASA, in coordination with the major non-European certification authorities, ensure that go-around procedures designed by manufacturers and taken up by operators are evaluated in a realistic operational environment. [Recommendation FRAN-2013-038]**

Manipulating the FCU / MCP

During a go-around, the attention given to manipulating the FCU / MCP can take a long time, during which the flight path is no longer monitored. Most crews manipulate the FCU/MCP without observing the result on the EFIS, despite the fact that this does not correspond to recommended practices.

Consequently, the BEA recommends that:

- **EASA in coordination with national civil aviation authorities ensure that airlines under its oversight once again insist during training on the best practices for manipulating the FCU / MCP. [Recommendation FRAN-2013-039]**
- **EASA ensure that aircraft manufacturers improve for new aircraft, the design of the FCU / MCP and decrease the time required for its use during a go-around, while evaluating the impact of the time it is used during other phases of flight with high workloads. [Recommendation FRAN-2013-040]**

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 a loss of control. Before the go-around, the speed drops and the aircraft systems compensate for this loss of speed by pitching up the stabilizer more and more. Consequently, aircraft manufacturers should develop means to prevent this type of excessive trim from occurring and/or to prevent the aircraft stabilizer from being kept in an unusual attitude during a go-around. 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 national civil aviation authorities, major non-European certification authorities and manufacturers, ensure pilots have practical knowledge of the conduct required during a go-around at low speed with pitch trim in an unusual nose-up position, and that they make a competence assessment. [Recommendation FRAN-2013-041]**
- **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]**

8.4 SIMULATORS

Fidelity of simulators and somatogravic illusions

Simulators do not correctly represent the phenomenon of somatogravic illusion during a go-around. The pitch and accelerations present in the simulator are not those felt during a real go-around. There is no objective standard for evaluation of qualification of simulator motion. It appears, however, technically possible to improve simulator fidelity in this respect. In addition, experienced pilots rarely carry out real go-arounds and it is statutorily possible that recently qualified co-pilots have never been subject to somatogravic illusions prior to carrying out scheduled flights during line-oriented flight training. During the investigation into the accident involving F-GZCP on 1 June 2009, the BEA had already recommended to EASA that it

- *Modify the basis of the regulations in order to ensure better fidelity for simulators in reproducing realistic scenarios of abnormal situations.*

Consequently, the BEA completes this recommendation in the context of this study and recommends that:

- **ICAO ensure that manufacturers of simulators in cooperation with aircraft manufacturers improve simulator fidelity with respect to the phenomena of somatogravic illusions, especially during go-arounds. [Recommendation FRAN-2013-043]**

8.5 AIR TRAFFIC MANAGEMENT (ATM)

Modification of go-around flight paths by ATM

ATC can modify the published missed-approach procedure during the go-around manoeuvre. Crews can then be surprised, or even upset, to have to change their plan of action during a go-around. The consequences of these changes can be significant, particularly when they prevent the use of certain automated systems and increase the time pressure. In a flight phase where the workload is already high, additional actions further disrupt teamwork, and monitoring by the PM in particular.

Consequently, the BEA recommends that:

- **ICAO define standards and recommended practices (SARPS) or procedures for air navigation services (PANS) so that air traffic controllers, except where necessary for safety reasons, do not give instructions that are in contradiction with the published missed-approach procedure; and that, when necessary, the instructions are announced to crews as early as possible during the approach. [Recommendation FRAN-2013-044]**
- **EASA, without waiting for possible ICAO actions, in coordination with Eurocontrol and national civil aviation authorities, implement regulatory measures limiting modifications to published missed-approach procedures. [Recommendation FRAN-2013-045]**

Controller training and radiotelephone communications from ATC

The study showed that ATC exchanges between controller and crew during a go-around disrupt the crew and that some dialogues could be delayed. In paragraph 5.2.1.7.3.1.1 of Annex 10, ICAO provides that during certain phases of flight no transmission must be made to an aircraft. This is not the case for missed approaches.

Consequently, the BEA recommends that:

- **ICAO extend the provisions of Annex 10 to include the go-around phase by requiring that, unless required for imperative safety reasons, no transmissions are made to an aircraft during a missed approach manoeuvre, as long as the crew have not indicated that they are available again. [Recommendation FRAN-2013-046]**
- **EASA, in coordination with Eurocontrol and national civil aviation authorities, ensure that the risks associated with the transmission of messages and modifications in the flight path during go-arounds are taken into account by ATM training organizations or air navigation service providers during initial and recurrent training of air traffic controllers. [Recommendation FRAN-2013-047]**

Design of missed approach procedures

Among the various possibilities for designing a missed approach, a straight-ahead missed approach is not given priority, although it could facilitate the control and use of automated systems on aircraft. Furthermore, at present the published go-around altitude is not related to aircraft performance. The rate of climb of most modern aircraft is high and even has to be limited for some. Thus, the BEA has documented cases in which the published go-around altitude does not give crews enough time – about a minute – to carry out the scheduled actions before interception. Yet the study showed that the time available during the go-around was a decisive factor for its success.

Consequently, the BEA recommends that:

- **ICAO indicate, during the design of a missed approach procedure, that a straight-ahead missed approach flight path must be given preference when that is possible. [Recommendation FRAN-2013-048]**
- **ICAO introduce, in SARPS or PANS during the design of a missed approach procedure, that the first vertical constraint be as high as possible, taking into account the high performance of public transport aircraft, to carry out a standard go-around. [Recommendation FRAN-2013-049] EASA, without waiting, in coordination with Eurocontrol, take the necessary steps to propagate the safety benefits from the above recommendations. [Recommendation FRAN-2013-050]**