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Swiss Transportation Safety Investigation Board STSB

Aviation Division

Final Report No. 2244

by the Swiss Transportation Safety Investigation Board STSB

concerning the serious incident (Airprox)

involving an Airbus A319 aircraft, registration G-EZAU
operated by EasyJet with the callsign EZY 899B,

a Boeing 737-800 aircraft, registration D-ABKB
operated by Air Berlin with the callsign BER 17Z

and a Boeing 737-800 aircraft, registration G-TAWF
operated by Thomson Airways with the callsign
TOM 857

on 26 May 2013

10 NM north-north-west of waypoint MOLUS

Cause

L'incident grave est dû à une perte de séparation entre un avion en montée autorisé par erreur au FL 380 et un appareil qui croisait sur une route perpendiculaire au FL 370. La manœuvre d'évitement vers le haut entamée par ce dernier a provoqué une seconde perte de séparation avec un troisième avion qui se trouvait sur une route de sens opposé au FL 380.

General information on this report

This report contains the Swiss Transportation Safety Investigation Board's (STSB) conclusions on the circumstances and causes of the serious incident which is the subject of the investigation.

In accordance with Article 3.1 of the 10th edition, applicable from 18 November 2010, of Annex 13 to the Convention on International Civil Aviation of 7 December 1944 and Article 24 of the Federal Air Navigation Act, the sole purpose of the investigation of an aircraft accident or serious incident is to prevent accidents or serious incidents. The legal assessment of accident/incident causes and circumstances is expressly no concern of the investigation. It is therefore not the purpose of this investigation to determine blame or clarify questions of liability.

If this report is used for purposes other than accident/incident prevention, due consideration shall be given to this circumstance.

The definitive version of this report is the original in the French language.

In order to ensure data protection, it employs the generic masculine.

Unless otherwise indicated, all information in this report refers to the time of the serious incident.

Unless otherwise indicated, all times in this report are stated in coordinated universal time (UTC). At the time of the serious incident, Central European Summer Time (CEST) applied as local time (LT) in Switzerland. The relationship between LT, CEST and UTC is:
 $LT = CEST = UTC + 2 \text{ h.}$

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Final report

Synopsis

Aircraft EZY 899B

Operator	EasyJet Airline Company Limited, Luton, United Kingdom
Manufacturer	Airbus S.A.S., Toulouse, France
Aircraft type	A319-111
Country of registration	United Kingdom
Registration	G-EZAU
ATC flight plan callsign	EZY 899B
Callsign	EasyJet eight niner niner bravo
Flight rules	Instrument flight rules (IFR)
Type of operation	Scheduled flight
Departure point	LIMC, Milan Malpensa
Destination point	EGGW, London Luton

Aircraft BER 17Z

Operator	Air Berlin, Berlin, Germany
Manufacturer	Boeing Commercial Airplanes, Seattle, Washington, USA
Aircraft type	Boeing 737-800
Country of registration	Germany
Registration	D-ABKB
ATC flight plan callsign	BER 17Z
Callsign	Air berlin one seven zulu
Flight rules	IFR
Type of operation	Scheduled flight
Departure point	EDDN, Nuremberg
Destination point	LEPA, Palma de Majorca

Aircraft TOM 857

Operator	Thomson Airways LTD, Luton, United Kingdom
Manufacturer	Boeing Commercial Airplanes, Seattle, Washington, USA
Aircraft type	Boeing 737-800
Country of registration	United Kingdom
Registration	G-TAWF
ATC flight plan callsign	TOM 857
Callsign	Thomson eight five seven

Flight rules	IFR
Type of operation	Scheduled flight
Departure point	DTNH, Enfidha Hammamet
Destination point	EGNX, East Midlands
Location	10 NM north-north-west of MOLUS
Date and time	26 May 2013, 10:43 UTC
ATS unit	GVA ACC
Airspace	Class C
Applicable separation minima	5 NM or 1000 ft
Minimum distances	Between aircraft EZY 899B and aircraft BER 17Z: 2.6 NM and 850 ft Between aircraft BER 17Z and aircraft TOM 857: 1.5 NM and 675 ft
Airprox category	ICAO category B (safety not assured)

Investigation

The serious incident occurred on 26 May 2013 at 10:43 UTC. It was notified to the Swiss Accident Investigation Board (SAIB) on 27 May 2013 at 13:36 UTC. An investigation was opened on 31 May 2013 at 07:01 UTC.

The SAIB notified the serious incident to the authorities of the United Kingdom and Germany, which each appointed an accredited representative. The incident took place in Swiss airspace.

This final report is published by the Swiss Transportation Safety Investigation Board (STSB).

Summary

The incident occurred on 26 May 2013 at 10:43 UTC near waypoint MOLUS in the range of flight levels between FL 360 and FL 380. It was caused initially by the loss of separation between flight EZY 899B which was climbing, cleared in error to flight level FL 380, and flight BER 17B which was crossing on a perpendicular route at flight level FL 370. This conflict resulted in the issuing of resolution advisories by the airborne collision-avoidance systems of the two aircraft and the upward avoidance manoeuvre initiated by flight BER 17B caused an additional loss of separation with a third aircraft, TOM 857, which was on a route in the opposite direction at flight level FL 380.

Cause

The serious incident is attributable to a loss of separation between an aircraft cleared in error to flight level FL 380 and an aircraft which was crossing on a perpendicular route at flight level FL 370. The upward avoidance manoeuvre initiated by the latter resulted in a second loss of separation with a third aircraft which was on a route in the opposite direction at flight level FL 380.

Safety recommendations

In the context of the investigation no safety recommendation was pronounced.

1 Factual information

1.1 Flight preparations and history of the serious incident

1.1.1 General

The history of the serious incident was established with the aid of the radiotelephony communications, the radar data and tracks, the Mode S downlink transmissions of the aircraft in the conflict situation, the ASRs (air safety reports) completed by the pilots and the statements of the air traffic controllers involved in the serious incident.

At the time of the serious incident, sectors L5 and L6 of the area control centre (ACC) were in their basic configuration. They had been split approximately twenty minutes previously.

L6	FL 375+
L5	FL 355 – FL 374
L4	FL 335 – FL 354
L3	FL 315 – FL 334
L2	FL 285 – FL 314
L1	FL 245 – FL 284

1.1.2 History of the serious incident

At 10:31:41 UTC on 26 May 2013, the flight crew of the Boeing 737-800 which was making flight TOM 857 from Enfidha Hammamet to East-Midlands called sector L6 of Geneva ACC, indicating its flight level FL 380. It had just passed the Torino radio beacon (TOP) and the air traffic controller cleared it to fly towards waypoint MOLUS¹. A little later, he requested it to amend its route by 5 degrees to the left to separate it from traffic crossing at the same flight level.

At 10:35:45 UTC, the Boeing 737-800 which was making flight BER 17Z from Nuremberg to Palma de Majorca was approaching OLBEN and its flight crew reported to Geneva ACC sector L5 at flight level FL 370. The controller initially cleared it to fly towards MILPA before instructing it three minutes later to continue directly towards GIRKU.

At 10:40:48 UTC, the flight crew of the A319 Airbus which was making flight EZY 899B from Milan Malpensa to London Luton contacted control sector L5; the aircraft was climbing to flight level FL 350 and was en route towards IBODI. The controller replied that he would call back to clear it to continue its climb.

¹ In the remainder of the report, waypoints will be mentioned directly using their name written in capital letters

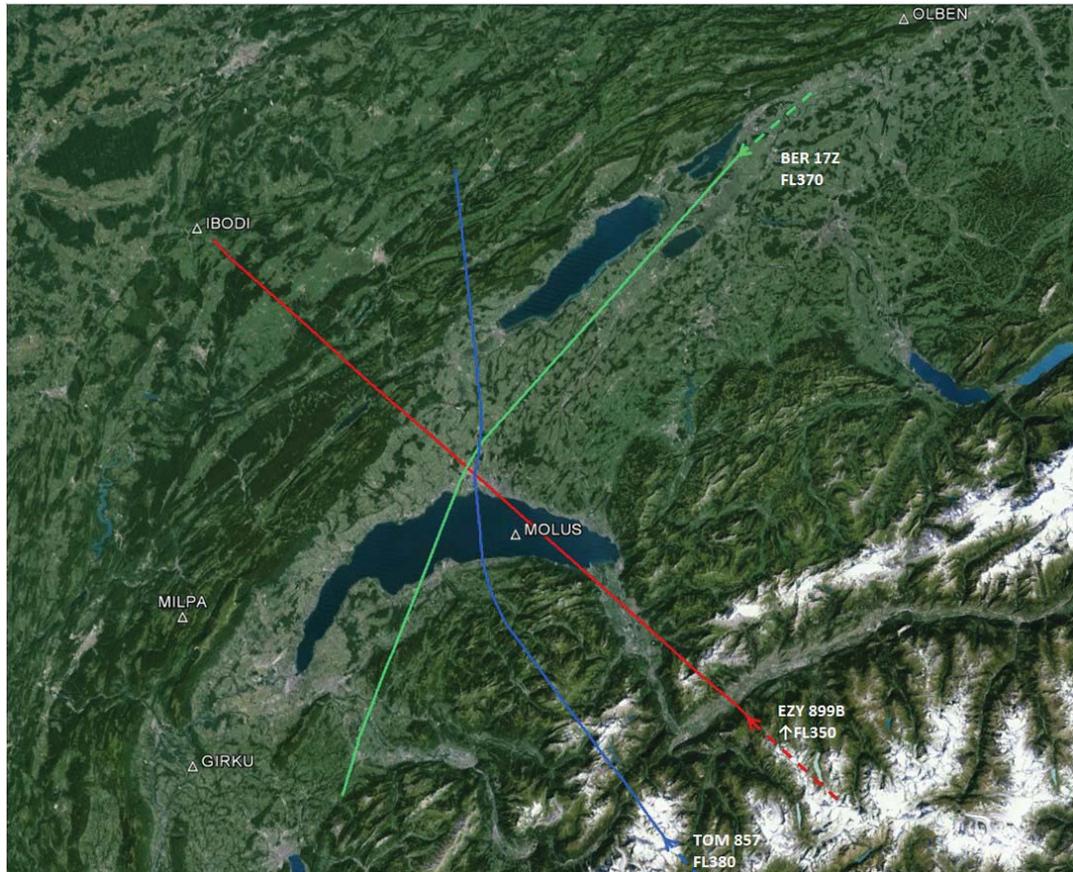


Figure 1: Trajectories of flights TOM 857, BER 17Z and EZY 899B and positions at 10:40 UTC

At 10:43:51 UTC, flight EZY 899B was cleared to climb to flight level FL 360. The instruction was not read back by its flight crew. Eight seconds later, it was cleared to flight level FL 380 and this time the readback was immediate.

At 10:44:42 UTC BER 17Z was cleared to continue directly towards BALSI.

At 10:44:56 UTC the sector L5 RE (radar executive) controller was carrying out a scan of his radar data and noted that the value displayed in the "Sel.Alt" window of the EZY 899B label was "38000". This indication meant that the flight crew had entered the climb instruction to flight level FL 380 in the automatic flight control system.

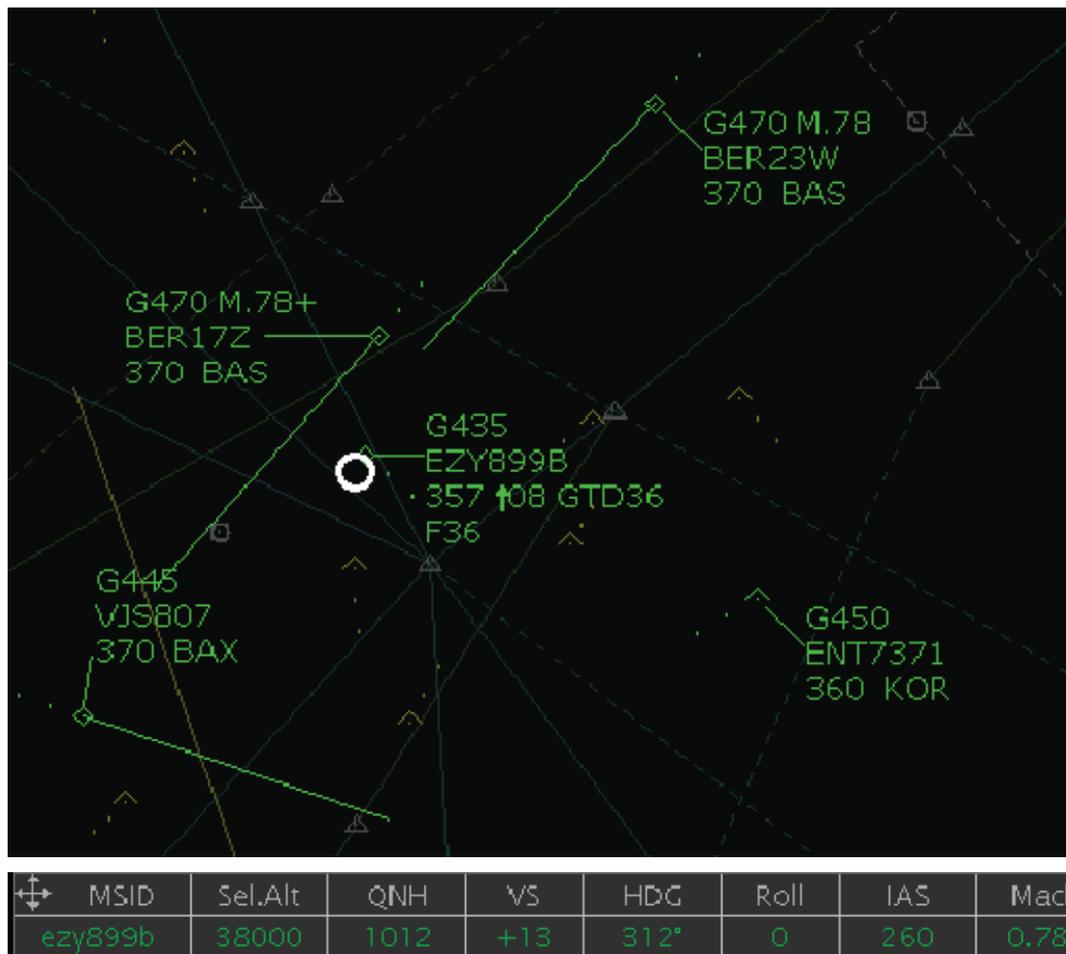


Figure 2: Section of the radar image and the MSID (Mode S identification) window of EZY 899B at control sector L5, at 10:44:56 UTC

At 10:44:59 UTC, the short term conflict alert (STCA) was triggered in sector L5 to indicate a potential conflict between flight EZY 899B, passing flight level FL 358 in a climb, and flight BER 17Z which was cruising at flight level FL 370. The lateral separation between the two aircraft at this time was 4.7 NM. The controller immediately instructed EZY 899B to maintain flight level FL 360.

A downward corrective resolution advisory “LEVEL OFF” was issued at 10:45:02 UTC by the airborne collision-avoidance system of EZY 899B, when the aircraft was passing 35 925 feet pressure altitude in a climb with a vertical speed of 2200 ft/min. The flight crew reacted promptly to the alert, reported “TCAS RA” (resolution advisory) to the controller and returned within approximately thirty seconds to flight level FL 360, having exceeded it by only 150 feet. The resolution advisory ended at 10:45:27 UTC.

At 10:45:06 UTC a “CLIMB” alert, also corrective but in the opposite direction, was issued by the TCAS (traffic alert and collision avoidance system) of BER 17Z.

The flight crew of BER 17Z carried out the upward avoidance manoeuvre issued by the TCAS, causing the aircraft's trajectory from then onwards to conflict with that of TOM 857.

The on-board collision-avoidance systems reacted to this new conflict configuration (multiple threat encounter) and at 10:45:16 UTC a corrective resolution advisory, this time downward “ADJUST VERTICAL SPEED” was issued on-board BER 17Z. The pilots halted the climb, remained between flight level FL 372 and FL 373 for almost a minute and then regained flight level FL 370.

At 10:45:19 UTC, this dangerous convergence with TOM 857 caused the activation of the STCA in sectors L5 and L6, when the two aircraft had a lateral separation of 5.1 NM and an altitude difference of 825 feet.

At 10:45:25 UTC, the sector L6 controller instructed TOM 857 to turn immediately onto heading 040° and then immediately afterwards onto heading 030°. The pilots immediately initiated the right turn and approximately ten seconds later their TCAS promptly issued a preventive resolution advisory “MONITOR VERTICAL SPEED” directly followed by the corrective resolution “CLIMB”. The autopilot was immediately disengaged, the avoidance manoeuvre was reported to the controller and 4 seconds later the TCAS voice alert “CLEAR OF CONFLICT” indicated the end of the conflict. Whilst still in the turn, the aircraft climbed slightly and reached a pressure altitude of 38 120 ft. The pilots halted the turn, regained flight level FL 380, engaged the automatic flight control systems and resumed their initial route in accordance with the air traffic controller's instruction.

The loss of separation (simultaneously less than 5 NM lateral separation and 1000 ft altitude difference) between EZY 899B and BER 17Z occurred between 10:45:05 and 10:45:15 UTC. Their closest point of approach occurred at 10:45:10 UTC when the aircraft had a lateral separation of 2.6 NM and an altitude difference of 850 ft.

The loss of separation between BER 17Z and TOM 857 occurred between 10:45:19 and 10:45:57 UTC; however, the trajectories of the aircraft were diverging during the last 17 seconds of this period. During the convergence, the closest point of approach occurred at 10:45:40 UTC when the aircraft had a lateral separation of 1.5 NM and an altitude difference of 675 ft.

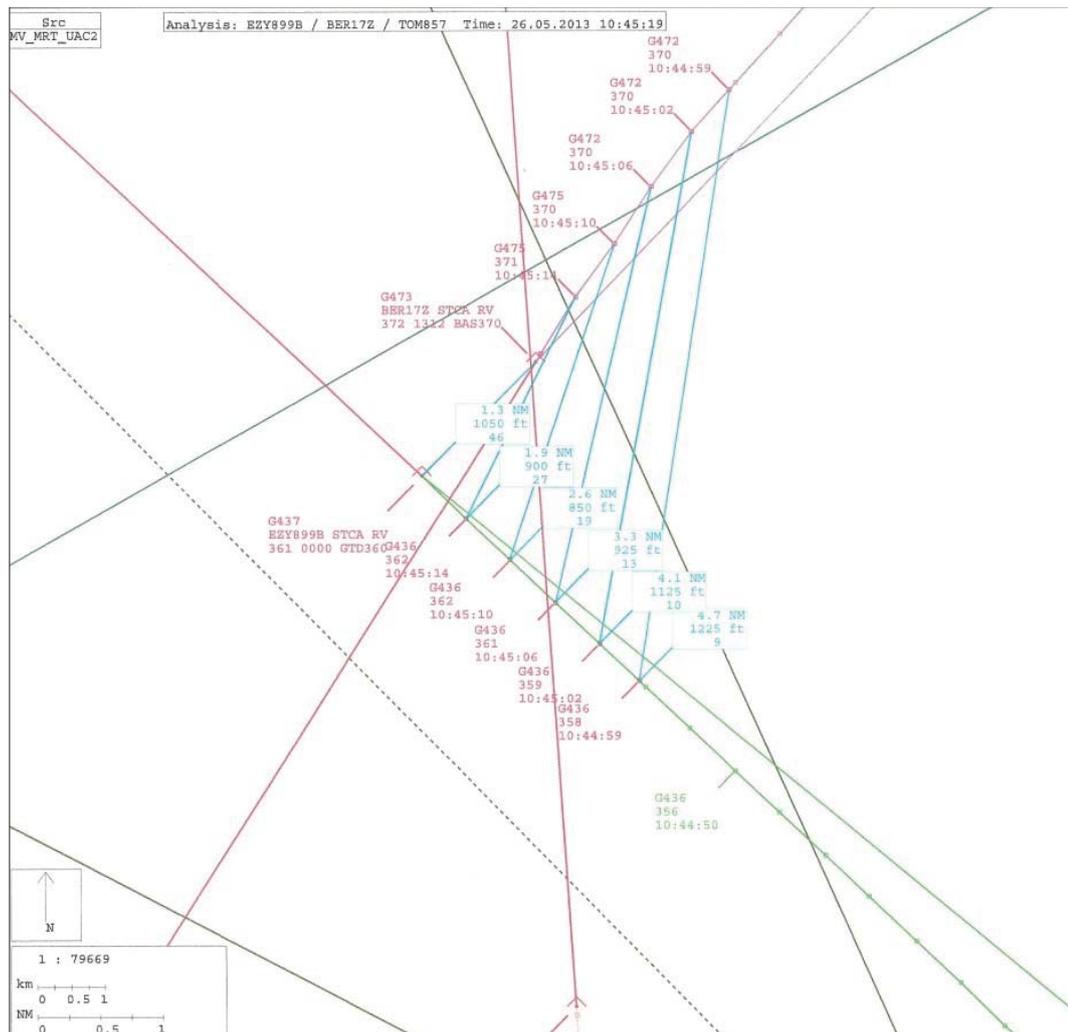


Figure 3: Vertical and horizontal distances during the STCA alert for EZY 899B and BER 17Z

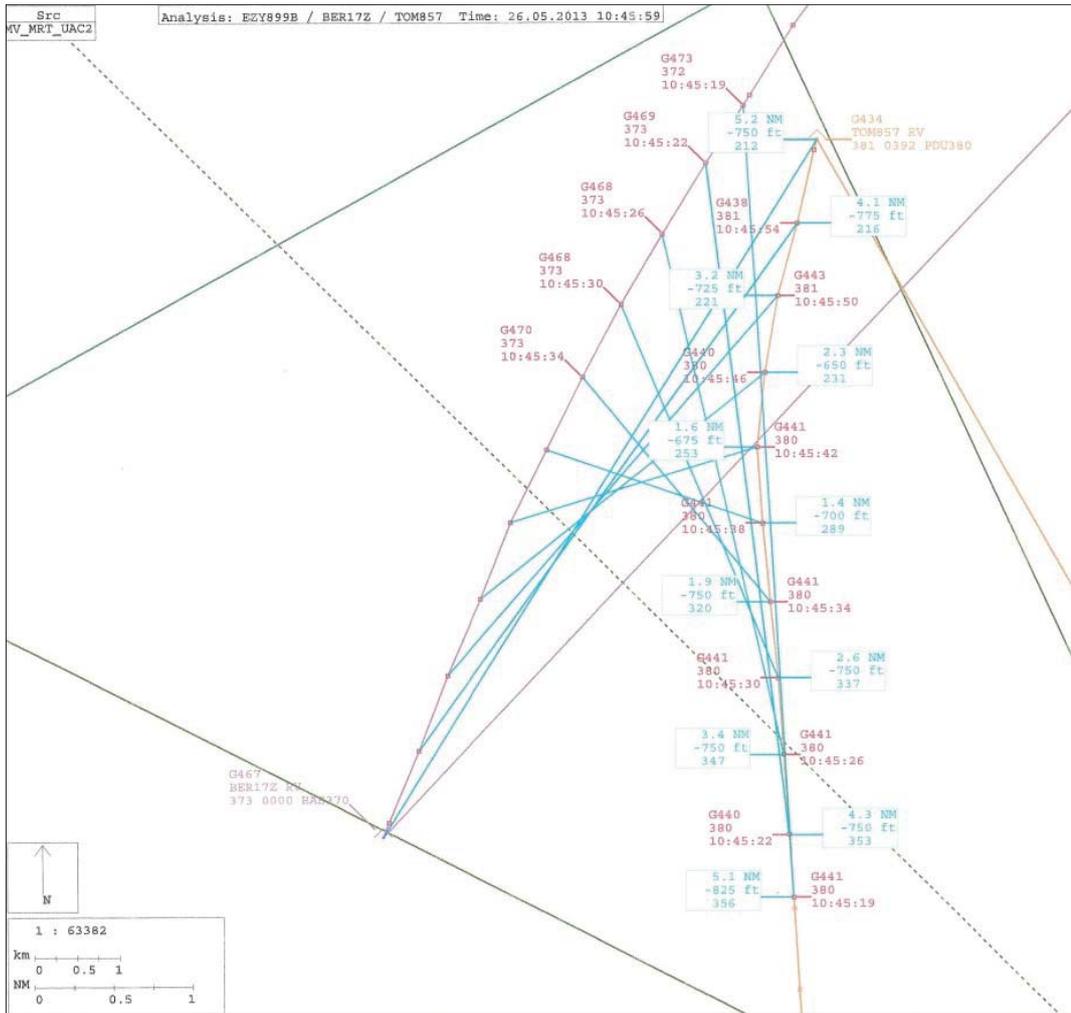


Figure 4: Vertical and horizontal distances during the STCA alert for BER 17Z and TOM 857

- 1.1.3 Time and location of the serious incident
 - Position 10 NM north-north-west of waypoint MOLUS
 - Date and time 26 May 2013 at 10:43 UTC
 - Lighting conditions Daylight
 - Coordinates of MOLUS 46 26 38.0 N, 006 40 46.0 E
 - Flight level Between FL 360 and FL 380

1.2 Personnel information

1.2.1 Flight crews

1.2.1.1 EZY 899B

1.2.1.1.1 Commander

Person British citizen, born in 1960

	Licence	Airline Transport Pilot Licence (Aeroplane) – ATPL(A) according to the Civil Aviation Authority (CAA) of the United Kingdom
	Airborne collision avoidance system (ACAS) training	26 January 2012
1.2.1.1.2	Copilot	
	Person	British citizen, born in 1970
	Licence	ATPL(A), issued by the United Kingdom CAA
	ACAS training	14 April 2012
1.2.1.2	BER 17Z	
1.2.1.2.1	Commander	
	Person	German citizen, born in 1955
	Licence	ATPL(A), issued by the <i>Luftfahrt-Bundesamt der Bundesrepublik</i> (LBA) of Germany
	ACAS training	14 November 2012
1.2.1.2.2	Copilot	
	Person	German citizen, born in 1990
	Licence	ATPL(A) issued by the German LBA
	ACAS training	22 February 2013
1.2.1.3	TOM 857	
1.2.1.3.1	Commander	
	Person	British citizen, born in 1969
	Licence	ATPL(A), issued by the United Kingdom CAA
	ACAS refresher course	9 December 2012
1.2.1.3.2	Copilot	
	Person	British citizen, born in 1979
	Licence	ATPL(A), issued by the United Kingdom CAA
	ACAS refresher course	26 November 2012
1.2.2	Air traffic controllers	
1.2.2.1	Radar Executive RE sector L5	
	Person	French citizen, born in 1989
	Licence	Air traffic controller based on directive 2006/23 of the European Community, issued by the Federal Office for Civil Aviation (FOCA) on 17 March 2010

	Unit	LSAG Sector-(Group) UTA valid till 26 July 2013
	Ratings	RAD (Radar) ACS (area control surveillance) valid till 26 July 2013 English level 4 valid till 18 February 2016
1.2.2.2	Radar Planner RP sector L5	
	Person	Serbian citizen, born 1970
	Licence	Air traffic controller, issued by the FOCA on 3 March 1994
	Unit	LSAG Sector-(Group) UTA valid till 24 May 2014
	Ratings	RAD ACS valid till 24 May 2014 OJTI (on the job training instructor) valid till 24 May 2014 English level 4 valid till 20 March 2015
1.2.2.3	Radar Executive RE sector L6	
	Person	Belgian citizen, born in 1972
	Licence	Air traffic controller, issued by the FOCA on 18 December 2009
	Unit	LSAG Sector-(Group) UTA valid till 5 September 2013
	Ratings	RAD ACS valid till 5 September 2013 English level 4 valid till 15 April 2016
1.2.2.4	Radar Planner RP sector L6	
	Person	British citizen, born in 1982
	Licence	Air traffic controller, issued by the FOCA on 17 March 2010
	Unit	LSAG Sector-(Group) UTA valid till 28 August 2013
	Ratings	RAD ACS valid till 28 August 2013 English level 4 valid till 18 February 2016
1.3	Aircraft information	
1.3.1	Aircraft EZY 899B	
	Registration	G-EZAU
	Aircraft type	Airbus A319-111
	Characteristics	Short- and medium-haul twin-jet
	Manufacturer	Airbus S.A.S., Toulouse, France
	Operator	EasyJet Airline Company Limited, United Kingdom
	Equipment	TCAS II version 7.1

1.3.2	Aircraft BER 17Z		
	Registration	D-ABKB	
	Aircraft type	Boeing 737-86J	
	Characteristics	Short- and medium-haul twin-jet	
	Manufacturer	Boeing Commercial Airplanes, Seattle, Washington, USA	
	Operator	Air Berlin Luftverkehrs KG, Germany	
	Equipment	TCAS II version 7.0	
1.3.3	Aircraft TOM 857		
	Registration	G-TAWF	
	Aircraft type	Boeing 737-8K5	
	Characteristics	Short- and medium-haul twin-jet	
	Manufacturer	Boeing Commercial Airplanes, Seattle, Washington, USA	
	Operator	Thomson Airways Ltd, Luton	
	Equipment	TCAS II, version not communicated ²	

1.4 Meteorological information

1.4.1 General weather situation

To the north of the Alps, polar maritime air was generating a typical ridge situation which dictated the distribution of pressures on the ground. At the same time, a low-pressure area located to the east of Germany was conveying milder air to the Alps.

1.4.2 Weather at the time and location of the serious incident

A Föhn wall cloud was present along the Savoyard Alps. Above this there was a layer of scattered and diffuse altocumulus. The sky was clear over Lake Geneva.

The serious incident occurred in the lower, cloudless part of the stratosphere.

Weather/cloud	The Payerne radio probe indicated an upper limit of the cloud layer at approximately 12 600 ft/AMSL	
Visibility	Greater than 70 km	
Wind at FL 350	350° / 16 KT	
Temperature / dewpoint at FL 350	-49 °C/ -66 °C	
Hazards	None	

1.4.3 Astronomical information

Position of the sun	Azimuth: 155°	Elevation: 63°
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² In Europe, version 7.0 has been mandatory since 1 January 2005

1.5 Communications

The recordings of the radiotelephony communications exchanged between control sectors L5 and L6 and the flight crews were made available to the SAIB for the requirements of the investigation. The one for sector L5 lasts some thirty minutes, including approximately 13 minutes before the serious incident and 17 minutes afterwards. The RE controller was replaced in his function some 12 minutes after the serious incident.

No fault in the radiotelephony communication equipment was reported by Skyguide's technical service.

1.6 Flight recorders

At the time when the serious incident was reported to the SAIB, the cockpit voice records were no longer available. Taking into account the elements already available to the investigation, it was not necessary to have recourse to the flight data recorder (FDR) data.

The EasyJet company provided the SAIB with the subsidiary internal investigation which it carried out at the time of this serious incident; it is based among other things on the on-board data flight recordings.

The Thomson Airways Ltd company forwarded to the SAIB a chronology of the events of the serious incident which it considered to be relevant, drawn up from the data of the on-board flight recordings.

1.7 Organisational and management information

1.7.1 Organisation of the control sectors

The "grouping" and "ungrouping" of the sectors correspond to the various configurations obtained by closing or opening some or all of the six control sectors making up the Geneva UAC (upper area control centre). During the night, all the radio frequencies are coupled to a single sector. During the day, the various sectors are activated according to the volume of traffic, which generally increases in the early morning and then decreases in the evening. They are configured so as to ensure the most efficient management of human resources.

Sectors L5 and L6 were "uncoupled" approximately twenty minutes before the serious incident. The management of sector L5 was assured by the team of controllers already on duty; two other RE and RP controllers took over sector L6.

1.7.2 Aspects relating to the air traffic management (ATM) system

Flights coming from the airports located in the border areas of Switzerland and whose destinations lie outside these regions enter the Geneva ACC airspace at flight levels lower than that of their specified cruising level. To ensure their integration, Skyguide's air traffic management system automatically shows the requested cruising level, if available, in the "flight plan" data at the disposal of the controllers. The controllers may change this value by entering a new flight level depending on the traffic situation. If necessary, this level is transmitted to the subsequent control centre; this constitutes what is commonly called the "exit level" or "coordinated level". The radar controllers then deliver the appropriate clearances so that at the time of the transfer of a flight to the adjacent centre, the cleared levels are the same as those which are in the air traffic management (ATM) system.

1.7.3 The close the loop procedure

When the RE radar controller assigns a "cleared flight level" (CFL) to a flight, he must enter this new value into the ATM system by means of a data-processing

action on the radar label of the flight concerned. According to the “stripless” control procedures, the RP radar coordinator must then confirm this new flight level thereby closing the loop, also by means of a data-processing click.

1.8 Additional information

1.8.1 The radar label of a flight

The radar track of a flight is established at the time when it is detected via its transponder by the network of radar tracking stations. The “flight plan” information contained in the ATM system (route, requested flight level, etc.) are associated with it and the flight is then said to be “correlated”. For the air traffic controller, its display takes the form of a radar label containing the relevant information for this flight.

The label of a specific flight will be visible in all the control sectors which it affects. The exit level changes carried out by controllers therefore have a direct impact on the distribution of this visualisation in the Geneva ACC airspace.

When an aircraft is the origin of an STCA alert with an aircraft flying in a different control sector, its radar label will be displayed in this sector for the visualisation requirements of this alert.

Flights BER 17Z and TOM 857 were in cruising phase at flight levels FL 370 and FL 380 respectively. The radar label of the first was therefore visible only in control sector L5, and that of the second only in sector L6. When, following the resolution advisory “CLIMB”, flight BER 17Z approached TOM 857 sufficiently to trigger the STCA at 10:45:19 UTC, its radar label became visible in sector L6.

Flight EZY 899B was initially integrated into the air traffic management (ATM) system with an envisaged exit level of FL 380. Before its first radiotelephony contact with Geneva ACC, it was therefore displayed in the control sectors through which it would have to pass, i.e. L3, L4, L5 and L6. When it was close to AOSTA, for traffic reasons the sector L5 RP controller decided to lower its exit level to FL 360. From then onwards, the label of flight EZY 899B disappeared from the sector L6 radars, which it no longer affected.



The label of flight EZY 899B after correlation. ATM links the data from the flight plan and the information transmitted by the aircraft's transponder. Its current altitude is 7000 ft (a70) and ATM assigns it the requested cruising level, FL 380 (38).



Flight EZY 899B is in contact with a sector below sector L5. It is cleared to climb to flight level FL 300 (F30).



Flight EZY 899B is in contact with a sector below sector L5. It is cleared to climb to flight level FL 350 and the value of its assigned cruising level is now FL 360.



Flight EZY 899B is in contact with sector L5. It has received clearance to climb to flight level FL 360 (F36). The “close the loop” manipulation by the RP controller has not yet been carried out (F36 in white). When it has been carried out, “F36” will change to green.

1.8.2 The MSID tool



Figure 5: Example of the MSID window display

On the radar screen, the downlink aircraft parameters (DAPS) can be displayed at the controller's request in a window dedicated for this purpose.

Among other things, this tool permits checking whether the level entered by the pilot into the automatic flight control system (selected altitude - Sel.Alt) corresponds to the cleared flight level CFL.

1.8.3 The short term conflict alert system STCA

Integrated into the radar processing system serving the civil sectors of the Geneva Control Centre, the STCA is a safety net which, in the event of hazardous convergence of aircraft in the vertical and horizontal planes, alerts the controller by means of an aural and visual alert. It is triggered with an advance warning time to allow for the reaction of the controller/pilot/aircraft loop: the controller evaluates the conflict situation, determines the appropriate action and if necessary issues appropriate instructions to the pilots.

In order to minimise unnecessary alerts, the STCA is parameterised according to the type of airspace which it serves and the characteristics of the traffic flying within it.

In the airspace in which the serious incident occurred, the STCA is parameterised to generate an alert in the event of a convergence of less than 900 ft in the vertical plane, if the separation prediction for the crossing is between 4.9 NM and 2.5 NM. If the latter is less than 2.5 NM, the triggering of the alert occurs as soon as the vertical distance becomes less than 1300 ft. In both cases, it is still necessary for the aircraft to have a positive combined vertical speed.

The STCA is also triggered when two aircraft maintaining a level converge on each other and are at a vertical distance of less than 750 ft.

At 10:44:59 UTC the distances between EZY 899B and BER 17Z were 4.7 NM horizontally and 1194 ft vertically, with a predicted separation of 0.72 NM. The STCA alert was triggered at the control sector L5 workstations when EZY 899B climbed through flight level FL 358.

When the flight crew of BER 17Z carried out the upward avoidance manoeuvre advised by the TCAS, the aircraft's trajectory interfered with that of TOM 857 and at 10:45:19 UTC caused the activation of the STCA in sectors L5 and L6. The two aircraft were 5.1 NM and 825 feet from each other.

1.8.4 Airborne collision-avoidance systems

1.8.4.1 Standard pilot model

Source: Annex 10 to International Civil Aviation Convention, Aeronautical Telecommunications, Volume IV and Supplement, Surveillance and collision avoidance systems.

“Since the pilot exercises such a major influence on the effectiveness of the system, it is necessary for any ACAS design to make certain assumptions concerning the response of the pilot. The ACAS implementation described in Section 4 uses a response delay of 5 seconds for a new advisory and a vertical acceleration of 0.25 g to establish the escape velocity. The response time reduces to 2.5 seconds for subsequent advisory changes. ACAS may not provide adequate vertical separation if the pilot response delay exceeds the expected pilot response delay assumed by the design.”

More precisely (section 4):

“The standard pilot model used in the assessment of the performance of the collision avoidance logic shall be that:

(...)

d) when an initial RA requires a change in altitude rate, the aircraft responds with an acceleration of 0.25 g after a delay of 5 s from the display of the RA;

(...)

h) that the delay used when an RA is modified is 2.5 s, (...).”

1.8.4.2 Visualisation of traffic and display of resolution advisories

The aircraft involved in the serious incident are equipped with airborne collision avoidance systems showing TCAS traffic, intruders and threats on the navigation parameters display screen (navigation display - ND). A threat is symbolised by a red square coupled with a vertical arrow indicating whether it is climbing or descending. Its vertical distance in relation to the aircraft is given in thousands of feet.

For the Airbus A320, the avoidance instructions are indicated on the display screen of the main flight parameters (primary flight display - PFD) by strips of grey/green/red colours on the scale of the vertical speed indicator. The red sector is the one which it is essential to exit, by means of a manoeuvre in the vertical plane.



Figure 6: Visualization of a “CLIMB” resolution advisory on the PFD and ND of the A320 in the left-hand position

For the Boeing 737-800, the avoidance instructions are visualised on the PFD by a red trapezoid delimiting the zone from which it is essential to exit by means of an attitude correction. They are additionally indicated by strips of red/black colours on the scale of the vertical speed indicator.



Figure 7: Visualisation in the right-hand position of a “CLIMB” on the PFDs and NDs of the Boeing 737-800

1.8.4.3 Versions 7.0 and 7.1 of TCAS II

Since the introduction in Europe (in 2000) of version 7.0 of TCAS II, several cases of incorrect follow-up to the “ADJUST VERTICAL SPEED, ADJUST” resolution advisory have been recorded. The pilots increased the vertical speed instead of decreasing it. Moreover, defects in the reversal logic of resolution advisories have been highlighted in certain encounter geometries in which two aircraft were converging towards each other at the same flight level.

In order to avoid incorrect pilot reactions, the voice alert “ADJUST VERTICAL SPEED, ADJUST” was replaced by “LEVEL OFF, LEVEL OFF” in the new version 7.1 of TCAS II. This resolution advisory can be issued as an initial RA or as a weakening RA when the vertical distance between the aircraft in a conflict situation increases.

In Europe, since 1 January 2005 all turbine-powered aircraft having a maximum take-off mass exceeding 5 700 kg, or a maximum approved passenger seating configuration of more than 19, must be equipped with TCAS II version 7.0.

On 16 December 2011, the European Commission published Implementing Rule 1332/2011) which imposed the carrying of ACAS II version 7.1 in European Union airspace:

- from 1 March 2012 for all aircraft with a maximum take-off mass exceeding 5700 kg or authorised to carry more than 19 passengers;
- except for aircraft subject to an individual certificate of airworthiness issued before 1 March 2012, which will have to be equipped on 1 December 2015.

1.8.5 Mode S downlink transmissions

1.8.5.1 Downlink transmission of ACAS resolution advisories, triggered on-board aircraft involved in the serious incident

When an ACAS resolution advisory is triggered, the ACAS transfers to its mode S transponder a resolution advisory report, for transmission to the ground in a "Comm-B" response³. Traffic advisories are not reported.

Analysis of this data made it possible to identify the various resolution advisories and their durations emitted on-board the three aircraft involved in the serious incident. Each time, the TCAS generating the alert transmitted a complementary resolution advisory restricting the choice of manoeuvres available to the TCAS of the other aircraft involved in the conflict (coordination process).

The first resolution advisory was issued on-board flight EZY 899B at 10:45:02 UTC; it related only to the threat constituted by flight BER 17Z, was of the downward corrective type, with a duration of 25 seconds. The corresponding indications given to the flight crew are the voice alert “LEVEL OFF, LEVEL OFF” and the appearance on the vertical speed indicator of a red strip extending from the upper limit of the scale as far as 0 ft/min and a green strip from 0 ft/min to -300 ft/min.

At 10:45:06 UTC, a resolution advisory relating to this threat was triggered on-board flight BER 17Z; it was of the corrective upward positive type and lasted 10 seconds. The corresponding indications given to the flight crew are the voice alert “CLIMB, CLIMB” and the appearance on the vertical speed indicator of a red strip extending from the lower limit of the scale as far as 1500 ft/min, with a green strip above up to +2000 ft/min.

At 10:45:16 UTC, the current advisory “CLIMB, CLIMB” on-board BER 17Z changed because of the new threat constituted by flight TOM 857; it was of the corrective type, required a correction in the downward direction and lasted 28 seconds. At this point and for the next 11 second the ACAS conflict resolution logic

³ Comm-B: response of 112 bits containing the message field “MB” of 56 bits. This field is used in the downlink communications by the “SLM” protocols, the protocols initiated on the ground and the message distribution protocols.

was processing the two simultaneous threats EZY 899B and TOM 857. The corresponding indications given to the flight crew were the voice alert "ADJUST VERTICAL SPEED" and the appearance on the vertical speed indicator of a red strip extending from the upper limit of the scale as far as 0 ft/min and a green strip from 0 ft/min to -300 ft/min.

At 10:45:27 UTC the end of the conflict situation for flight EZY 899B was reported to the pilots by the voice alert "CLEAR OF CONFLICT".

At 10:45:39 UTC, a resolution advisory relating to the threat constituted by BER 17Z was issued on-board flight TOM 857; it was of the preventive type, lasted only one second was reported to the flight crew by the voice alert "MONITOR VERTICAL SPEED". On the vertical speed indicator it was shown by a red strip extending from 0 ft/min to the lower limit of the scale.

Subsequently, the advisory changed at 10:45:40 UTC to become a positive, corrective upward resolution advisory, of 4 seconds duration. The corresponding indications given to the flight crew were the voice alert "CLIMB, CLIMB" and the appearance on the vertical speed indicator of a red strip extending from the lower limit of the scale as far as 1500 ft/min, with a green strip above as far as +2000 ft/min.

At 10:45:44 UTC the end of the conflict situation between flights BER 17Z and TOM 857 was reported to the pilots by the voice alert "CLEAR OF CONFLICT".

1.8.5.2 Downlink transmission of relevant flight parameters

On-board flight EZY 899B, the instruction to climb to flight level FL 380 was entered into the automatic flight control system at 10:44:05 UTC.

1.8.6 Reconstruction of the trajectories of the aircraft involved in the serious incident

On the basis of the recordings of the radar tracks, the 3D trajectories of the aircraft involved in the serious incident were reconstructed in the ARTAS co-ordinates reference (ATM surveillance tracker and server) at the 5 second refresh rate of la Dôle radar. Projections on the horizontal and vertical planes on which the resolution advisories are marked make it possible to highlight the dynamics of the conflict.

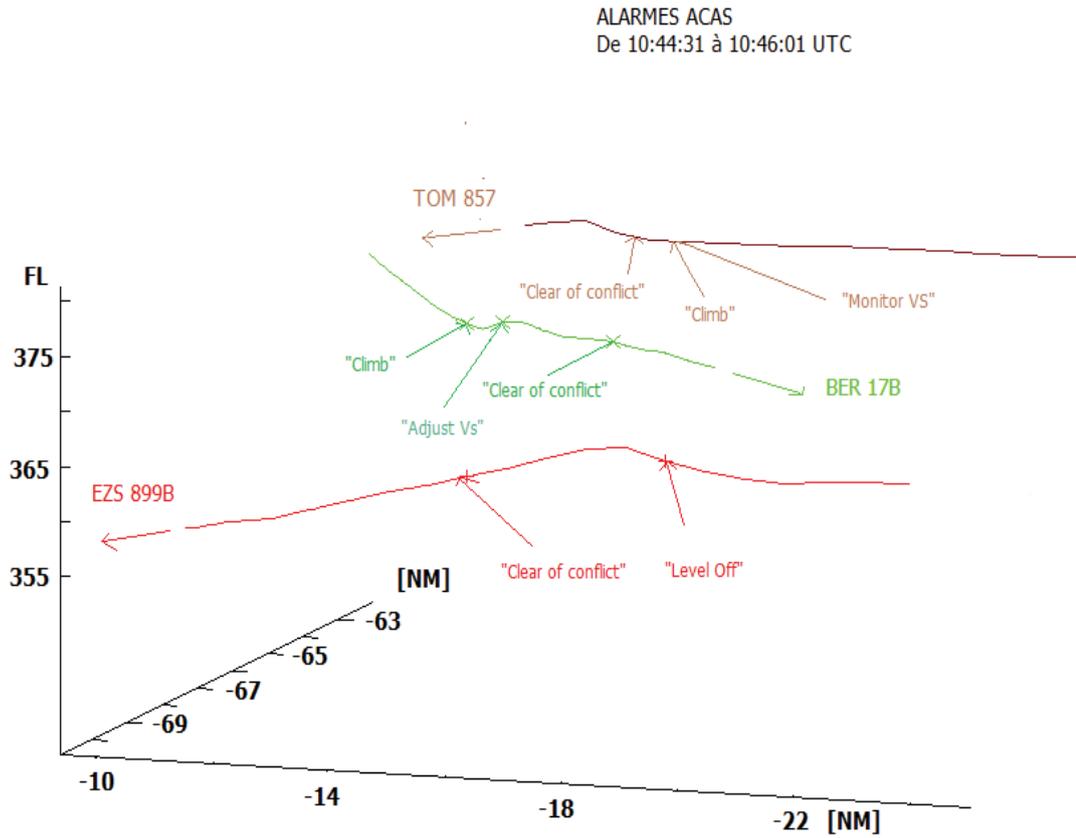


Figure 8: 3D representation of the trajectories with TCAS alerts

ALARMES ACAS - Situation horizontale
De 10:44:31 à 10:46:01 UTC

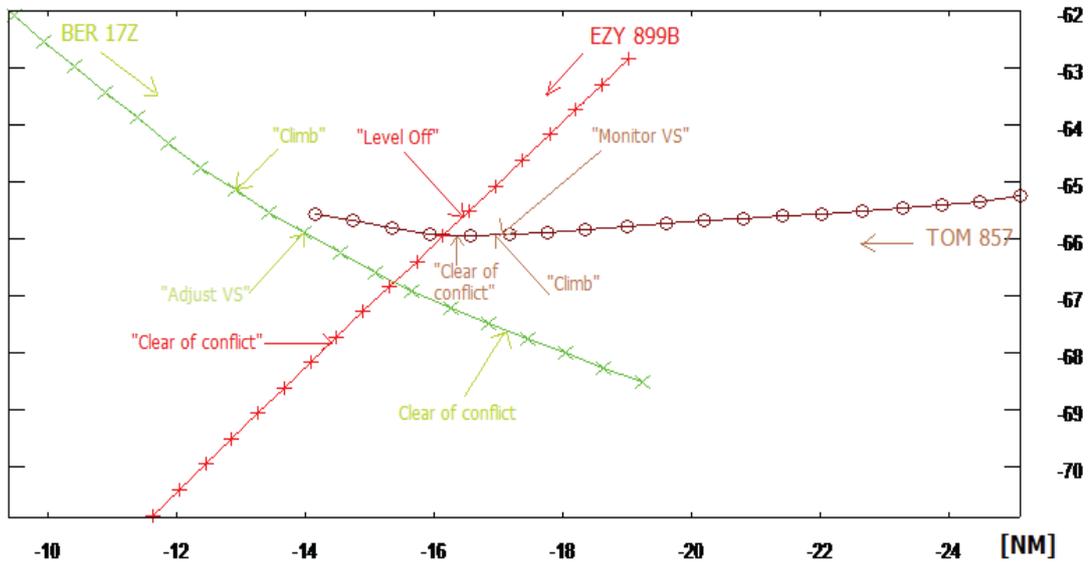


Figure 9: Projection of the trajectories in the horizontal plane with TCAS alerts

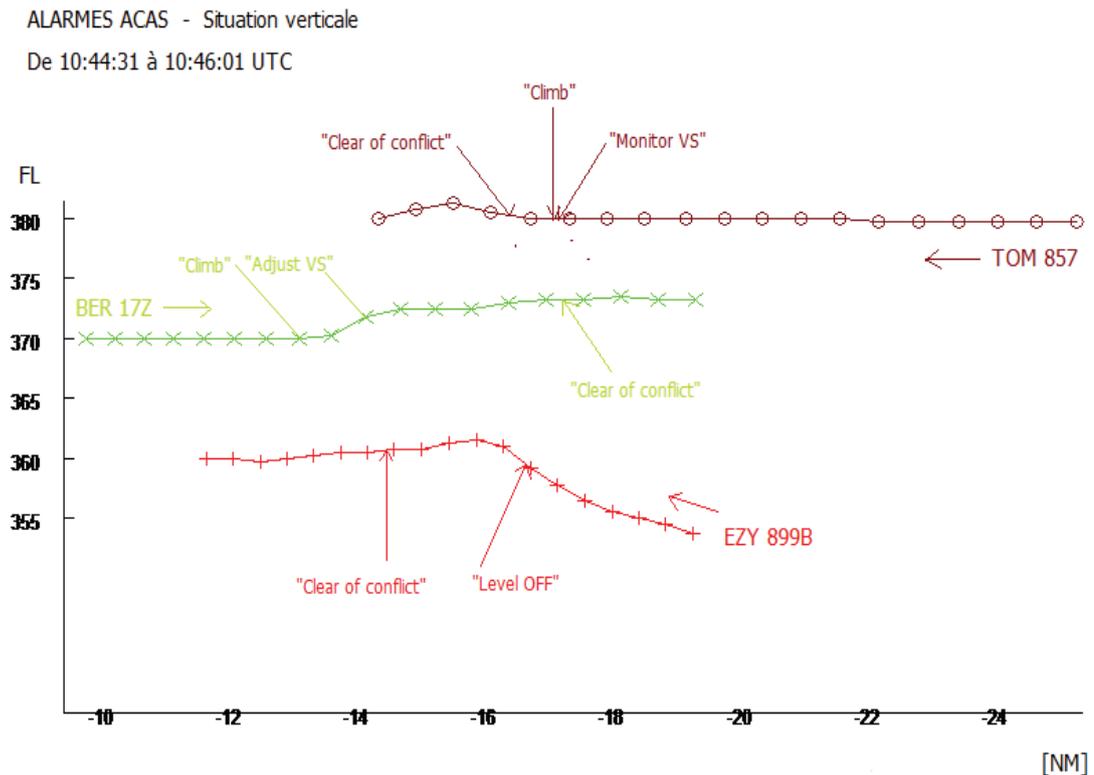


Figure 10: Projection of the trajectories in the vertical plane with TCAS alerts

1.8.7 Air traffic controllers' statements

The RE and RP controllers on duty in sectors L5 and L6 at the time of the serious incident gave statements for the purposes of the investigation.

1.8.7.1 Control sector L5

The L5 sector controllers judged that the workload was moderate to high with a high degree of traffic complexity, demanding in particular many telephone coordinations.

The sector L5 RE controller specified that there was significant traffic at flight level FL 370, with separations to be resolved and sequences to be implemented. He explained that when EZY 899B first made contact with him, he was unable to permit it to climb to flight level FL 360 because of another traffic established on this level which it first had to cross. Once this had happened, he cleared EZY 899B to flight level FL 360 but did not obtain a readback; he therefore called back a few seconds later to repeat the clearance.

During and after the conflict, he did not doubt at any time that he had assigned flight level FL 360 at the time of the second clearance. It was only later, when he listened to the recording of the radiotelephony conversations relating to the serious incident that he realised he had got the flight level wrong.

The RE controller does not think that his RP colleague communicated to him the revision of the FL 380 exit level to coordinated level FL 360 for EZY 899B. He therefore believes he saw this latter level directly on the radar label and does not remember initially seeing the exit level FL 380.

The sector L5 RP controller stated that he thought he had closed the loop (close the loop, cf. section 1.7.3) when his RE colleague cleared EZY 899B to climb to flight level FL 360. He was then busy with telephone coordinations and the STCA alert surprised him. Initially, he thought of an unnecessary alert triggered by the rate of climb of EZY 899B; in his mind the latter had been cleared to flight level FL

360, as he saw it on the radar label and as he had heard it. He became aware that an error had been made when the pilot of EZY 899B reported that he was cleared to flight level FL 380.

1.8.7.2 Control sector L6

The sector L6 controllers assessed the workload and complexity of the traffic as moderate.

The sector L6 RP controller explained why he and his RE colleague had only witnessed the conflict involving the opposing BER 17Z and TOM 857. It was only after having discussed it shortly afterwards with their colleagues in sector L5 that they understood that a third flight, EZY 899B, invisible on their radar screens, was involved in the serious incident.

1.8.8 Recording of telephone conversations in sector L5

The sector L5 RP controller was conducting a telephone coordination with the Zurich control centre between 10:43:54 and 10:44:03 UTC.

1.8.9 Relevant information extracted from ASRs and the reports of the companies involved in the serious incident

1.8.9.1 EZY 899B

The on-board data used in the subsidiary investigation carried out by EasyJet has made it possible to determine that the traffic advisory (TA) relating to the TCAS encounter with BER 17Z was issued approximately 3 seconds before the "LEVEL OFF" resolution advisory.

1.8.9.2 BER 17Z

The flight crew of flight BER 17Z completed an ASR following the serious incident. In relation to the TCAS alerts, it mentions only that a "CLIMB" corrective resolution advisory was issued immediately after a traffic advisory. The pilots located the intruder at their 9 o'clock, at a distance of 4 NM, climbing and having reached flight level FL 363. They mentioned that they did not acquire visual contact.

1.8.9.3 TOM 857

In the ASR which they completed at the time of the serious incident, the pilots of TOM 857 report that they had heard a traffic advisory relating to an intruder which they saw at their 11 o'clock on the NDs. The latter was 800 feet lower and climbing slowly. The resolution advisory which followed was "heard" as "MONITOR VERTICAL SPEED" and seen as "a red box" commanding a climb: "*We received a TCAS RA 'Monitor Vertical Speed' with the red box commanding a climb*". The avoidance manoeuvre carried out with the autopilot disengaged is then described, noting that the TCAS voice alert "CLEAR OF CONFLICT" was issued very quickly.

The chronology of the events of the serious incident established from the data of the on-board recordings exhibits the following significant elements:

10:45:29 UTC: when it was on heading 352°, the HDG mode was engaged with heading 040°;

10:45:38 UTC: passing heading 355°, a resolution advisory was issued for 6 seconds;

10:45:40 UTC: the autopilot and the autothrottles were disengaged;

10:45:54 UTC: the turn was halted, heading 010°.

2 Analysis

2.1 Air traffic control aspects

2.1.1 Losses of separation

Two successive losses of separation occurred, first between EZY 899B and BER 17Z, and then between the latter and TOM 857. They had different causes.

Before the serious incident, flight level FL 380 assigned to EZY 899B could not be cleared because of the envisaged crossing in the region of MOLUS with BER 17Z cruising at flight level FL 370 and TOM 857 at flight level FL 380. By changing EZY 899B's exit level to FL 360, the sector L5 RP controller prevented this flight from conflicting with the other two aircraft. This geometry, which featured convergence, high speeds and minimal vertical separation between the aircraft, therefore had a significant potential for triggering the STCA and TCAS safety nets, in the event of a vertical discrepancy between flight levels FL 360 and FL 380.

The first loss of separation occurred at 10:45:05 UTC, when EZY 899B passed flight level FL 360 converging on BER 17Z. It was the clearance, given in error, to climb to flight level FL 380 which was at the origin of this first conflict.

The second loss of separation occurred at 10:45:20 UTC between TOM 857 at flight level FL 380 and BER 17Z when the latter had left its cruising level of FL 370 in response to a corrective upward resolution advisory.

2.1.2 The erroneous clearance to the conflicting flight level FL 380

The sector L5 RE controller was unable to explain why he cleared EZY 899B to the conflicting flight level FL 380. If this had been assigned deliberately, in addition to a coordination with sector L6 it would have required additional entries in the ATM system. In addition, when ATC received the report of the resolution advisory from the pilot, the initial reaction of the RE controller was to justify this alert to him by the fact that he had only been cleared to level FL 360. It was only on listening to the recording of the radiotelephony conversations relating to the serious incident that he realised that he had given erroneous clearance to the conflicting flight level FL 380.

In the light of a mistake which was made unconsciously, it is appropriate to mention the potential trigger factors.

In order to be assigned in an unconscious fashion, flight level FL 380 had to be among the RE controller's possible options or had to have been in his memory, associated with EZY 899B. At the time of the serious incident, sectors L5 and L6 had already been split for approximately twenty minutes and flight level FL 380 was no longer part of sector L5 and could no longer represent an option.

When it appeared on the radar screens of sector L5, the radar label of flight EZY 899B displayed the exit level FL 380. It is possible that the RE controller saw this before the revision to coordinated level FL 360 was executed and that a distinct mental association between EZY 899B and flight level FL 380 occurred at this time. In the sustained and stressful phase of work which prevailed at the time of the serious incident, this value may have been unconsciously restored when the clearance to climb was issued a second time to EZY 899B.

At the teamwork level, the elements contained in the RP controller's statement make it possible to understand how the flight level FL 380 was assigned in error: the event unfolded in two phases.

The first clearance to climb to flight level FL 360 was clearly heard by the RP controller, who confirmed it by closing the loop (close the loop, cf. section 1.7.3). The

radar data bears witness to this action. The flight crew of EZY 899B did not read back this “clearance”, probably because of inattention.

In the second phase, the RE controller again issued clearance to climb, this time erroneously assigning the conflicting flight level FL 380. At this moment, the RP controller was carrying out a telephone coordination with the Zurich control centre and was therefore unable to notice the error.

2.1.3 Controllers’ reactions

The application of systematic working using the scan of radar data enabled the sector L5 RE controller to realise his mistake before the triggering of the STCA. He reacted rapidly and gave the instruction to maintain flight level FL 360 at the same time as the safety net alert occurred.

In sector L6, the activation of the STCA relating to the conflict between BER 17Z and TOM 857 caused the radar label of the former to appear on the control screens. The RE controller immediately reacted by issuing an avoidance radar heading and essential traffic information to TOM 857 which was on his working frequency. The fact that the three aircraft involved in the conflict were not in the same control sector did not play a role in the serious incident.

The convergent encounter geometries of this serious incident triggered the STCA and TCAS safety nets simultaneously, with short delays. This did not affect the reactions of the controllers who gave clearances consistent with avoidance manoeuvres proposed by the TCAS.

2.2 Flight management aspects

2.2.1 Pilots’ reactions to the TCAS alerts

2.2.1.1 EZY 899B

The flight crew of flight EZY 899B entered flight level FL 380 into the automatic flight control system at 10:44:05 UTC, i.e. during the read back of the clearance to climb to this level. The preceding instruction “*Easy eight niner niner bravo, climb flight level three six zero*” did not elicit a response from the pilots. It is coherent that it was not followed by operation of the automatic flight control system.

At 10:44:59 UTC, the sector L5 RE controller instructed the flight crew of flight EZY 899B to maintain flight level FL 360. At the same moment, the traffic advisory issued by the airborne collision-avoidance system reported that the intruder BER 17Z represented a possible threat. The “LEVEL OFF” resolution advisory occurred three seconds later, also during the radiotelephony message. This simultaneous occurrence represented a disturbing element in terms of the reaction of the flight crew to the alerts. Nevertheless and despite the short notice of traffic advisory, the latter was in conformity with the standard pilot model of the collision-avoidance logic, since the avoidance manoeuvre proposed was initiated 5 seconds after the corrective resolution advisory. The trajectory of the aircraft then exhibited a constant reduction in the rate of climb, from 2200 ft/min to approximately -300 ft/min, in accordance with the TCAS indications reported on the vertical speed indicator. The aircraft exceeded flight level FL 360 by only 150 ft.

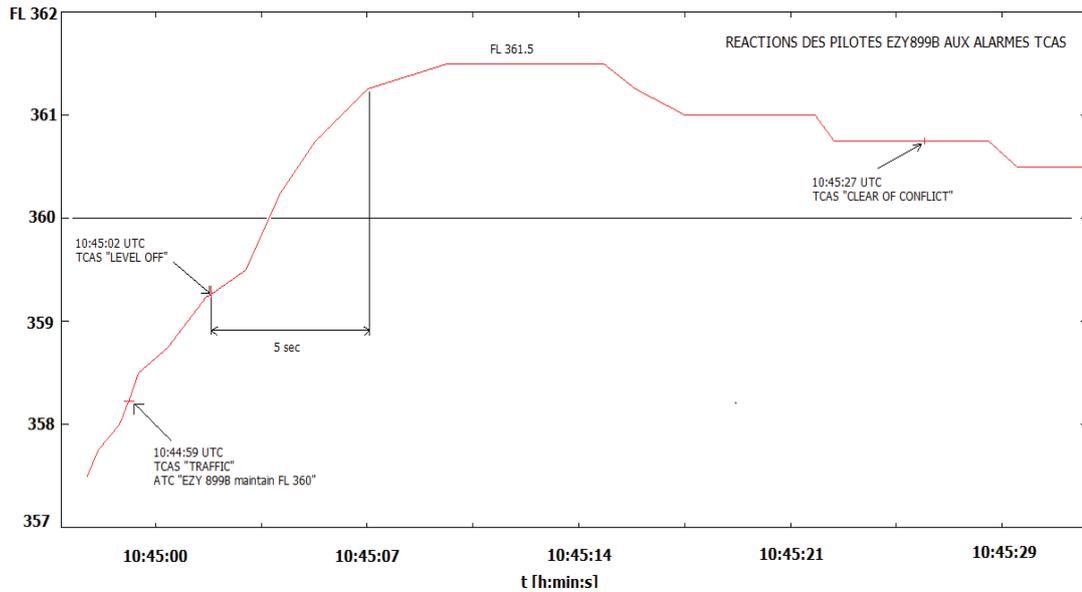


Figure 11: Flight level of EZY 899B as a function of time: reaction of the pilots to the TCAS alerts

2.2.1.2 BER 17Z

During the reaction time of the pilots of EZY 899B to the “LEVEL OFF” alert, the aircraft was on its climb trajectory with a rate of climb of approximately 2200 ft/min; this contributed to the triggering of a traffic advisory on-board BER 17Z followed immediately by the resolution advisory “CLIMB”. Its flight crew reacted within 5 seconds and adopted the vertical climb speed required by the TCAS. This avoidance manoeuvre positioned the aircraft in a conflict situation with TOM 857, causing the “ADJUST VERTICAL SPEED” resolution advisory to be issued, this time in the downwards direction. The pilots of BER 17Z reacted correctly to this change of direction, since after 2.5 seconds the rate of climb was gradually reduced towards 0 ft/min. These TCAS manoeuvres must be carried out in manual flight, as on the aircraft types involved in the serious incident the automatic flight control system is not designed to react sufficiently rapidly. The minimal variations in trajectory noted just before the end of the conflict “CLEAR OF CONFLICT” are due to the difficulty in accurately maintaining the flight parameters at high altitudes and speeds.

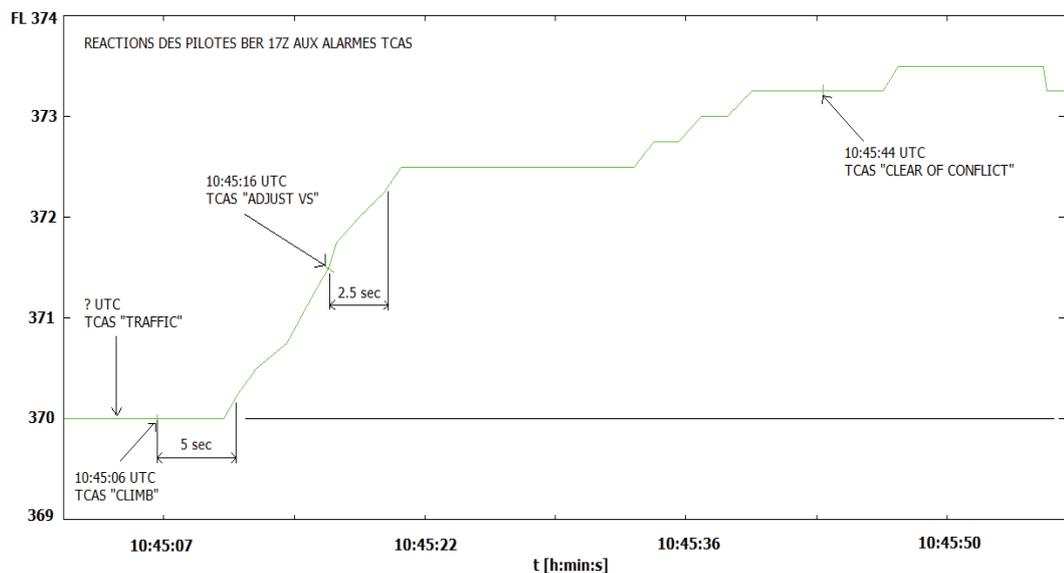


Figure 12: Flight level of BER 17Z as a function of time: reaction of the pilots to the TCAS alerts

With regard to the TCAS alerts, the ASR completed by the pilots of BER 17Z mentions only the “CLIMB” resolution advisory triggered by an intruder located at their 9 o'clock position, at a distance of 4 NM and 700 ft lower. It is unlikely that the flight crew realised that a second intruder, TOM 857, had become involved in the encounter geometry, triggering the “ADJUST VERTICAL SPEED” resolution advisory. This alert was certainly interpreted as the attenuation of the first “CLIMB” instruction whose intruder (EZY 899B) was located at this time at twelve o'clock on the NDs of BER 17Z. The latter, at a distance to the rear right, would still remain symbolised as such for 11 seconds, diverting the attention of the pilots from the new intruder TOM 857, located on the left on the navigation screen.

During a TCAS avoidance manoeuvre, the pilot at the controls (pilot flying - PF) disengages the autopilot and follows the instructions indicated on his PFD. This task requires focussed concentration on this instrument and does not generally allow monitoring of the intruder or intruders on the ND. To assist his colleague in his avoidance actions, the pilot monitoring (PM) also observes his PFD.

Instant 10:45:16 UTC

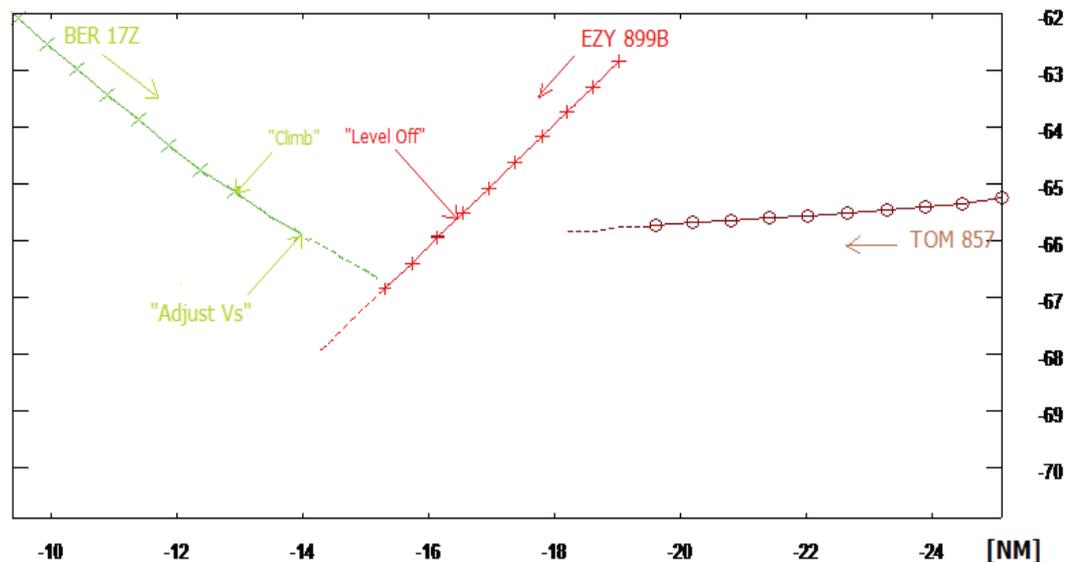


Figure 13: 10:45:16 UTC: intruders EZY 899B and TOM 857 for BER 17Z

2.2.1.3 TOM 857

On the PFDs, since it is preventive, the “MONITOR VERTICAL SPEED” advisory presents a situation where the model of the aircraft is outside the red trapezoid relating to the vertical avoidance manoeuvre. On the other hand, for the corrective “CLIMB, CLIMB” advisory it is on the inside, indicating to the pilots that an upward change of pitch must be carried out.



Figure 14: Preventive resolution advisory “MONITOR VERTICAL SPEED” on the left and corrective advisory “CLIMB, CLIMB” on the right

On-board flight TOM 857, the succession of these two alerts and the end-of-conflict notification lasted only 5 seconds, i.e. the equivalent of the response time of the standard pilot model used in the performance evaluation of the collision-avoidance logic. The pilots reacted 5 seconds after the appearance of the first advisory, at the very moment of the notification of the end of the conflict. Whereas it therefore no longer applied, the reaction consisted of an upward movement of approximately one hundred feet, with an extension of the right turn ordered a few seconds earlier by the air traffic controller. It responds to the last vertical avoidance manoeuvre instruction “CLIMB” which appeared on the PFDs and can be explained by the effect of stress on the pilots caused by the TCAS alerts.

The reaction time of the pilots was in conformity with that envisaged by the collision-avoidance logic and the variation in trajectory was minimal.

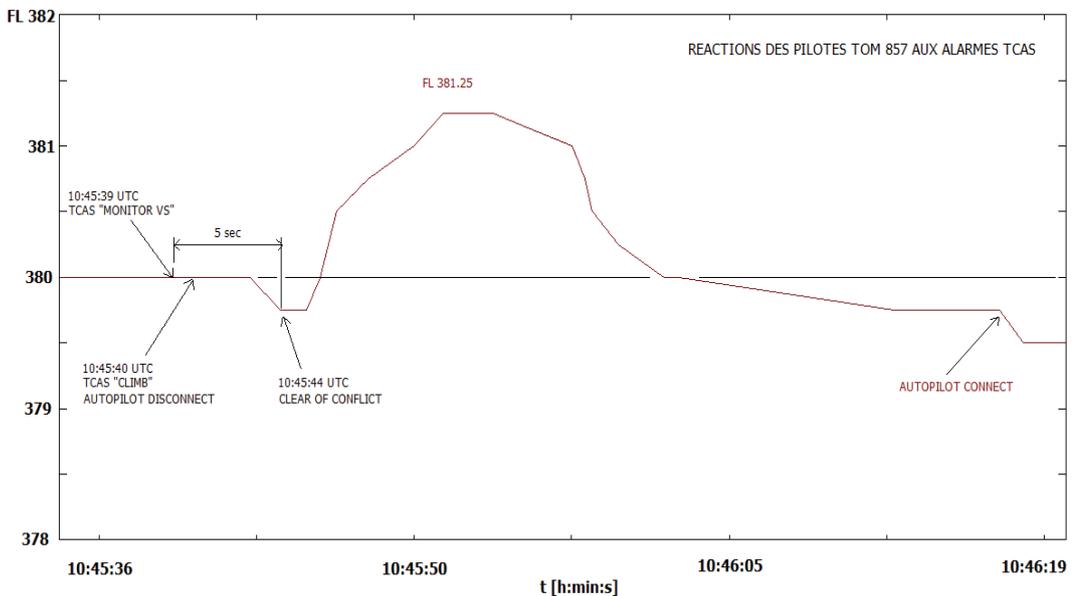


Figure 15: Flight level of TOM 857 as a function of time: reaction of the pilots to the TCAS alerts

2.3 Aviation safety

Air transport safety is contingent on a coherent structure of controlled airspace, which is managed and used by qualified persons, having at their disposal powerful systems and tools intended among other things to reduce the possibilities of human error. Safety nets such as STCA and TCAS make it possible to counter such error.

Even if the efforts to reduce human error are constant, it can never be completely removed from the safety system as a whole. Nevertheless, as this case of a serious incident indicates, the systems put in place to combat it are effective. The fact that it occurred in two different control sectors did not play a part. Thanks to a good working systematic, the sector L5 RE controller realised his mistake and reacted appropriately. The safety nets fulfilled their role. The flight crews correctly followed the avoidance manoeuvres proposed by their TCAS despite the short notice dictated by a convergent encounter geometry.

In this regard, it is worth noting that on each occasion the response to the TCAS alerts began in accordance with the delays envisaged by the standard pilot model used in the performance evaluation of the collision-avoidance logic.

3 Conclusions

3.1 Findings

3.1.1 General framework

- Sectors L5 and L6 were de-collapsed approximately twenty minutes before the serious incident.
- Flight EZY 899B was initially integrated into the air traffic management (ATM) system with an envisaged exit level of FL 380.
- When flight EZY 899B was close to AOSTA, the sector L5 RP controller decided to lower its exit level to FL 360 for traffic reasons.

3.1.2 Technical aspects

- The three aircraft involved in the serious incident were equipped with TCAS airborne collision-avoidance systems which issued alerts consistent with the geometries of the encounters.
- Control sectors L5 and L6 were equipped with STCA short-term conflict alert systems which issued alerts coherent with the encounter geometries.
- The investigation revealed no malfunctions which could have contributed to or caused the serious incident.

3.1.3 Air traffic controllers

- The air traffic controllers in sectors L5 and L6 were in possession of the appropriate licences.
- There is no indication that their state of health was affected at the time of the serious incident.
- The sector L5 controllers assessed the workload as moderate, with a high degree of traffic complexity.
- The sector L6 controllers assessed the workload and complexity of the traffic as moderate.
- The sector L5 RE controller was convinced he had assigned flight level FL 360 at the time of the second clearance.

3.1.4 History of the serious incident

- At 10:43:51 UTC, flight EZY 899B was cleared by the sector L5 RE controller to climb to flight level FL 360; the instruction was not read back by its flight crew.
- At 10:43:51 UTC, flight EZY 899B was cleared by the sector L5 RE controller to climb to flight level FL 380; the instruction was read back by its flight crew.
- The loss of separation between EZY 899B and BER 17Z occurred between 10:45:05 and 10:45:15 UTC. Their closest point of approach occurred at 10:45:10 UTC when the aircraft had a lateral separation of 2.6 NM and an altitude difference of 850 ft.
- The loss of separation between BER 17Z and TOM 857 occurred between 10:45:19 and 10:45:57 UTC. The closest point of approach occurred at 10:45:40 UTC when the aircraft had a lateral separation of 1.5 NM and an altitude difference of 675 ft.

- At 10:45:25 UTC, the sector L6 controller instructed TOM 857 to turn immediately onto heading 040° and then immediately afterwards onto heading 030°.

3.2 Cause

The serious incident is attributable to a loss of separation between an aircraft cleared in error to flight level FL 380 and an aircraft which was crossing on a perpendicular route at flight level FL 370. The upward avoidance manoeuvre initiated by the latter resulted in a second loss of separation with a third aircraft which was on a route in the opposite direction at flight level FL 380.

4 Safety recommendations, safety advices and measures taken since the serious incident**4.1 Safety recommendations**

None

4.2 Safety advices

None

4.3 Measures taken since the serious incident**4.3.1 EHS CLAM system**

The EHS CLAM alert function (Enhanced Cleared Level Adherence Monitoring) became operational at the ACC Geneva control positions on 9 November 2013. It monitors conformity of the cleared flight level (CFL) with that entered by the flight crew into the automatic flight control system (Sel.Alt). Any disparity between these two values is reported to the air traffic controller some 12 to 16 seconds (4 updates of the radar image) after the time at which the level is selected.

Note:

If this system had been operational at the time of the serious incident, the sector L5 RE controller would have been advised of his error approximately forty seconds earlier.

Payerne, 27 April 2016

Investigation Bureau STSB

This final report was approved by the Board of the Swiss Transportation Safety Investigation Board STSB (Art. 10 lit. h of the Ordinance on the Safety Investigation of Transportation Incidents of 17 December 2014).

Berne, 12 May 2016