

FINAL REPORT

from

Investigation of a serious incident related to a loss of separation, realized on June 4, 2016 with involved Airbus A320-232 aircraft, registration marks TC-ATK, and Boeing B737-8F2 aircraft, registration marks TC-JGF in the controlled air space of the Republic of Bulgaria.



2017

Purpose of the Report and responsibility

In accordance with Annex 13 of the Convention on International Civil Aviation of 7 December 1944, Regulation 996/2010 of the European Parliament and the Council on the investigation and prevention of accidents and incidents in civil aviation and Ordinance 13 of 27.01.1999 of the Ministry of Transport, Information Technology and Communications, the objective of the aviation occurrence investigation is without apportioning blame or liability to establish the causes that have led to its realisation in order these to be eliminated and not allowed in the future.

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01 List of abbreviations

| | |
|-------------|--|
| A/C | - Aircraft; |
| AAIU | - Aircraft Accident Investigation Unit; |
| ACAS | - Airborne Collision Avoidance System; |
| ACC | - Air Control Centre; |
| AFTN | - Aeronautical Fixed Telecommunication Network |
| AMRAIUD | - Aircraft, Maritime and Railway Accident Investigation Unit Directorate; |
| AO | - Aircraft Operator; |
| AP | - Autopilot |
| ATCAS | - Air Traffic Control Automated System |
| ATCO | - Air traffic controller (officer); |
| ATS | - Air Traffic Service; |
| AOM | - Aircraft Operating Manual; |
| BULATSA | - Bulgarian Air Traffic Services Authority; |
| CAA | - Civil Aviation Act; |
| CALL SIGN | - Call sign of the aircraft; |
| CDW | - Conflict Display Window |
| CPA | - Closest Point of Approach |
| DCT | - Direct to |
| DFL | - Division flight level |
| DG CAA | - Directorate General “Civil Aviation Administration”; |
| EASA | - European Aviation Safety Agency; |
| EUROCONTROL | - European Organisation for the Safety of Air Navigation |
| EXE ATCO | - Radar Air Traffic Controller; |
| F/C | - The flight crew; |
| FCTM | - Flight Crew Techniques Manual |
| FDP | - Flight Data Processing; |
| FL | - Flight level; |
| FLCHG | - Flight Level Change; |
| FS | - Family Sectors; |
| GAT | - General Air Traffic; |
| ICAO | - International Civil Aviation Organization; |
| IFR | - Instrument Flight Rules ; |
| InCAS | - Interactive Collision Avoidance Simulator |
| MTCD | - Medium Term Conflict Detection; |
| MTITC | - Ministry of Transport, Information Technology and Communications; |
| KKK5LP | - Aircraft Airbus A320-232, registration marks TC-ATK |
| ODS | - Operational Display Sub-system |
| OLDI | - On Line Data Interface |
| PF | - Pilot Flying |
| PLN ATCO | - Planning Air Traffic Controller; |
| PM | - Pilot Monitoring |
| RA | - Resolution advisory; |
| RA Downlink | - Automatic notification to the controller about Resolution Advisories (RAs) generated in the cockpit by the Airborne Collision Avoidance System (ACAS); |
| RCR | - en-Route Clearance with Re-routing |
| SCL | - Family Sector Sofia West - Lower; |
| SCU | - Family Sector Sofia West - Upper; |
| SDL | - Family Sector Sofia East - Lower; |
| SDU | - Family Sector Sofia East - Upper; |
| SSR | - Secondary surveillance locator |

- STCA
 - TA
 - TCAS/ACAS
 - TCP
 - THY7FX
 - UTC
 - XFL
- Short-term conflict alert;
 - Traffic advisory;
 - Traffic Alert and Collision Avoidance System/Airborne Collision Avoidance System;
 - Transfer control point;
 - Aircraft B737-8F2, registration marks TC-JGF
 - Universal Coordinated Time.
 - Exit Flight Level;

1 Introduction

Date and hour of the aviation occurrence: 04.06.2016, at 15: 19 h UTC. The difference between local and universal coordinated time (UTC) is +3 h. All times in this report are given in the universal coordinated time (UTC) format.

Informed authorities: Aircraft, Maritime and Railway Accident Investigation Unit Directorate and Directorate General “Civil Aircraft Administration” at the Ministry of Transport, Information Technology and Communications of the Republic of Bulgaria (MTITC), the European Commission, the International Civil Aviation Organization (ICAO), the National Bureau of Aviation Occurrences Investigation (BEA) of the Republic of France, Ministry of Transport, Maritime Affairs and Communications, Accident Investigation Board of the Republic of Turkey and the National Transportation Safety Board of the USA.

According to the provisions of Article 9, par. 1 of Ordinance No 13 dated 27.01.1999 on Investigation of aviation accidents, the occurrence is classified as a serious incident by the Aircraft Accident Investigation Unit at the “Aircraft, Maritime and Railway Accident Investigation Unit” Directorate (AMRAIU) at the Ministry of Transport, Information Technology and Communications. The materials on the aviation occurrence are filed in case No 04/04.06.2016 to the archive of the AMRAIU.

In accordance with the provisions of Article 5, par. 1 of Regulation (EU) No 996/2010 on the investigation and prevention of accidents and incidents in civil aviation, Article. 142. Par. 2 of the Civil Aviation Act of the Republic of Bulgaria dated 01.12.1972 and Article 10, par. 1 of Ordinance No 13 of the Ministry of Transport dated 27.01.1999 on the Investigation of aviation occurrences, by Order No ПД-08-341 dated 14.07.2016 of the Minister of Transport, Information Technology and Communications, Commission is appointed for the investigation of the serious incident.

On 4 June 2016 at 15:19 UTC in the controlled airspace of the Republic of Bulgaria, sector “Sofia-West”, it was admitted a violation of the standard for safe minimum separation between aircraft transiting in the upper airspace of Bulgaria. Airbus A320-232 aircraft, registration marks TC-ATK of AO “Atlasjet” performing flight KKK5LP and Boeing 737-8F2 aircraft, registration marks TC-JGF of AO “Turkish Airlines”, flight THY7FX, passed each other with minimal horizontal distance of 2,6 nm and 500 ft. vertical separation. Due to the approach admitted, the automated collision avoidance systems (ACAS) on board of both aircrafts reacted. Both pilots in command reported “TCAS RA”.

Based on the results of the performed investigation, including the research and analysis of the available factual information, the Investigation Commission concluded that the serious incident resulted from the following causes:

Main cause:

Incorrect assessment of the air situation and issuing of permission for changing the trajectory of A/C THY7FX without carrying out relevant coordination by the ATCO of sector SCL with the ATCO of sector SCU, uncommanded climb of A/C KKK5LP and no response to TCAS RA by the crew of A/C KKK5LP.

Contributing cause:

Inefficient performance of coordination procedures between ATCOs of SCL and SCU sectors, ACC-Sofia, upon work in vertically separated sectors in accordance with Part 2 of the Manual on Air Traffic Services of the ACC-Sofia.

2 Factual information

2.1 Flight history

2.1.1 Flight number, type of operation, last point of departure, destination point of the involved aircraft.

| Aircraft | Aircraft-1 | Aircraft-2 |
|-------------------------|------------------|-------------------|
| Operator | Turkish Airlines | Atlasjet |
| Operation type | Commercial | Commercial |
| Type | Boeing B737-8F2 | Airbus A320-232 |
| Call sign | THY7FX | KKK5LP |
| Registration | TC-JGF | TC-ATK |
| SSR code | 2313 | 7654 |
| SSR mode | S | S |
| Flight Rules | IFR | IFR |
| Operation phase | Climb | Cruise |
| Last point of departure | Istanbul - LTBA | Dusseldorf - EDDL |
| Destination point | Rome - LIRF | Istanbul - LTBA |

2.1.2 Flight preparation, description of the flight and events leading to the serious incident.

On June 4th, 2016, aircraft B737-8F2, registration marks TC-JGF of “Turkish Airlines” AO performs flight on the route of Istanbul-Rome with flight number THY7FX. According to the flight plan, the aircraft should enter the air space of the Republic of Bulgaria through VADEN Transfer Control Point (TCP) at FL340, to fly on a one-way track L615 and to leave the serviced air space of the Republic of Bulgaria through DOLAP TCP at FL380.

Aircraft A320-232, registration marks TC-ATK of „Atlasjet” AO performs a flight on the route of Dusseldorf-Istanbul with call sign KKK5LP. According to the flight plan, the aircraft should enter the air space of the Republic of Bulgaria through ETIDA TCP at FL370, to fly on a one-way track M19 to LETVA TCP and to leave the serviced air space of the Republic of Bulgaria on track T72 through RILEX TCP at FL270.

According to the schedule approved by the Director of ACC-Sofia, a change of working shift of air traffic controllers including EXE ATCO and PLN ATCO takes place on June 4th, 2016, at 12.00 h assuming responsibility for the air traffic control of ACC-Sofia, Sofia Family Sectors.

At 14:53:27 UTC aircraft, B737-8F2 with registration marks TC-JGF enters the serviced air space of ACC-Sofia at FL320 in the area of VADEN TCP. The EXE ATCO from SDL sector identifies the aircraft as THY7FX. The flight crew reports that they are flying at FL320 and are willing to climb to FL380. The EXE ATCO issues instructions for climbing to FL340.

At 14:57:00, a change of the EXE ATCO in SCL sector is carried out. The EXE working position is taken over by the PLN ATCO working to the moment in the same sector.

At 15:06:23, the EXE ATCO from SCL sector establishes radio communication with aircraft B737-8F2 with registration marks TC-JGF and identifies the aircraft as THY7FX. The flight crew reports they are flying at FL340 and are willing to climb to FL380. The EXE ACTO informs the flight crew that FL380 must be coordinated with the neighbouring sector.

At 15:06:58, the PLN ATCO from SCL sector coordinates with the PLN ATCO from SCU sector through ATCAS SELEX about XFL FL380 for A/C THY7FX.

At 15:07:35, PLN ATCO from SCU sector confirms through ATCAS SELEX FL380 of the XFL proposed for A/C THY7FX.

At 15:08:10, PLN ATCO from SCL sector informs on ATCAS SELEX the PLN ATCO from SCU sector for his intention to change FL340 of A/C THY7FX to FL380 - FLCHG (FLIGHTLEVELCHANGE).

At 15:10:56, A/C A320-232 with registration marks TC-ATK enters the controlled air space of ACC-Sofa at FL370 in the area of ETIDA TCP. The EXE ATCO from SCU sector establishes radio communication and identifies the aircraft as KKK5LP.

At 15:11:28, PLN ATCO from SCU sector coordinates by phone with Belgrade Control the Exit FL380 for A/C THY7FX. The PLN ATCO informs Belgrade that to the moment the aircraft maintains FL340 because of traffic, but will climb to FL380.

At 15:12:00, PLN ATCO of sector SCU is changed.

At 15:14:30, PLN ATCO of SCU sector confirms to ATCAS SELEX FLCHG FL380 for aircraft THY7FX.

At 15:15:20 EXE ATCO of SCL sector issues instructions to A/C THY7FX for climbing to FL380 and turning 10° . „THY7FX, climb FL380, turn 10° to the right“. The flight crew repeats the instructions received and EXE ATCO confirms them.

PLN ATCO of SCL sector enters XFL340 for A/C THY7FX into ATCAS SELEX. This resulted in disappearance of the radar label of A/C THY7FX on the SCU sector’s work position. At 15:15:23, the distance is 52NM between A/C THY7FX and the opposite A/C KKK5LP which is under other sector’s control.

At 15:15:55, A/C THY7FX starts climbing at a height of FL340.

At 15:16:36, A/C THY7FX crosses FL350 upon climbing and its radar label appears again in SCU sector, as the indication FLCHG on line 0 is already annulled. The distance between A/C THY7FX and A/C KKK5LP is 34,8 NM.

At 15:16:39, ATCAS SELEX generates warning for MTCO between A/C THY7FX and A/C KKK5LP. The potential conflict is not completely visualized in the two SCU and SCL sectors, as is in both the sectors one red dot for conflict is shown only, without displaying the related second red dot in the zero radar label of the other aircraft. The distance between the two aircraft is 34.1 NM.

At 15:17:55, A/C THY7FX crosses FL370 while climbing with vertical speed of 600 ft/min, which is the FL of A/C KKK5LP. The distance between the two aircraft is 14.1 NM.

At 15:18:02, ATCAS SELEX generates warning for STCA between A/C THY7FX and A/C KKK5LP, which is displayed at both the working positions of SCU and SCL sectors. The distance between the two aircraft is 12,8 NM.

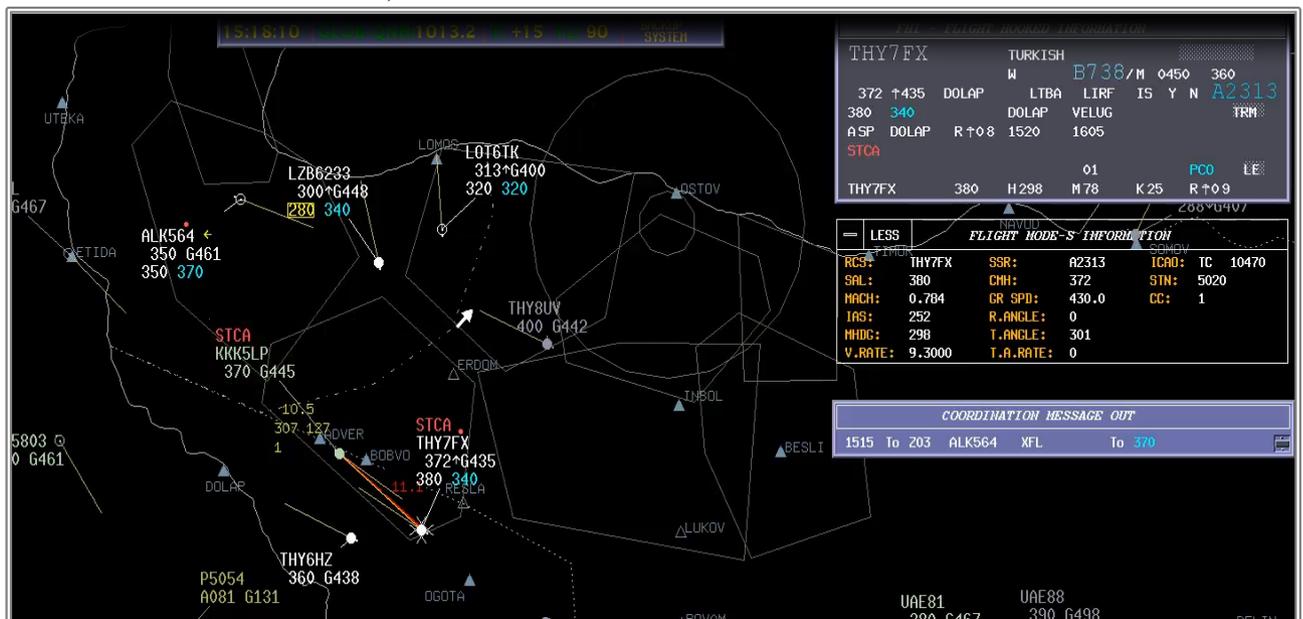


Fig. 1

At 15:18:10 EXE ATCO from SCU sector issues instructions to the flight crew of A/C KKK5LP for immediate turn to the left with 60°, after that specifies the instruction for turning left, heading 060: “KKK5LP, immediately turn left 60 degrees, KKK5LP immediately turn left heading 060“. At this moment, the aircraft is on FL370 level cruise. The flight crew does not confirm the instruction of the EXE ATCO for changing of heading. (See fig. 1)

At 15:18:10 the flight crew of A/C KKK5LP disconnects the autopilot while receiving TCAS TA indication and 6 s later FDR reports increased positive VS as a result of increased pitch angle.

At 15:18:15, EXE ATCO from SCL sector issues instructions to the flight crew of A/C THY7FX to turn 40° left: “THY7FX maintain... desc (dis...)... THY7FX, turn 40° to the left“. The flight crew does not respond.

At 15:18:19 the flight crew of A/C KKK5LP receives TCAS RA DON'T CLIMB and 5 s later the FDR reports altitude of 37132 ft and 113 degrees heading. The TCAS RA indication lasts 15 s.

Note: The KKK5LP crew received TCAS RA DON'T CLIMB indication which produces an oral annunciation “LEVEL OFF, LEVEL OFF” (cf. TCAS II MOPS, EUROCAE Ed-143, table 2-16, page 167). The FDR reports indicates the name of the RA, the Final report (for clarity) states what the aural annunciation was.

The RA Downlink message shows that A/C KKK5LP receives indication LEVEL OFF RA between 15:18:19 and 15:18:20.

The FDR reports that A/C THY7FX receives indication “CLIMB” at 15:18:21. After 2 s the flight crew disconnect the AP.

RA Downlink message shows that A/C THY7FX receives indication CLIMB RA between 15:18:21 and 15:18:22.

At 15:18:24 A/C KKK5LP starts changing its altitude of FL370 climbing without instructions from EXE ATCO from SCU sector and without the flight crew informing of it. The distance between the two aircraft is 7.1 NM. The flight crew does not report TCAS RA yet. (See fig. 2)

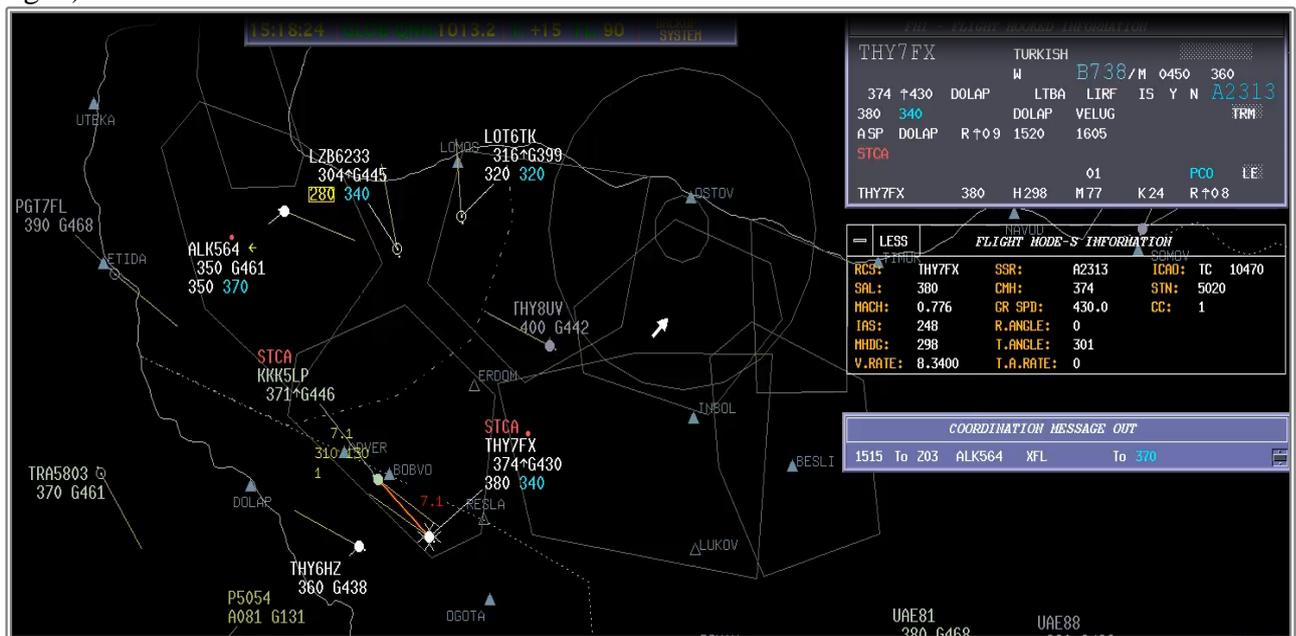


Fig. 2

At 15:18:24, the EXE ATCO from SCL sector repeats the instructions to the aircraft: „THY7FX turn immediately 40° to the left“. The flight crew of A/C THY7FX confirms and reports TCAS RA „Roger, turn left, we have TCAS RA”.

At 15:18:30, the EXE ATCO form SCL sector issues instructions to A/C THY7FX for immediate climb to FL380. The flight crew of THY7FX reports they have avoided the conflict traffic: “Now we are cleared of traffic, THY7FX. “ (See fig. 3). FDM reports that A/C THY7FX receives indication CLEAR OF CONFLICT at 15:18:32.

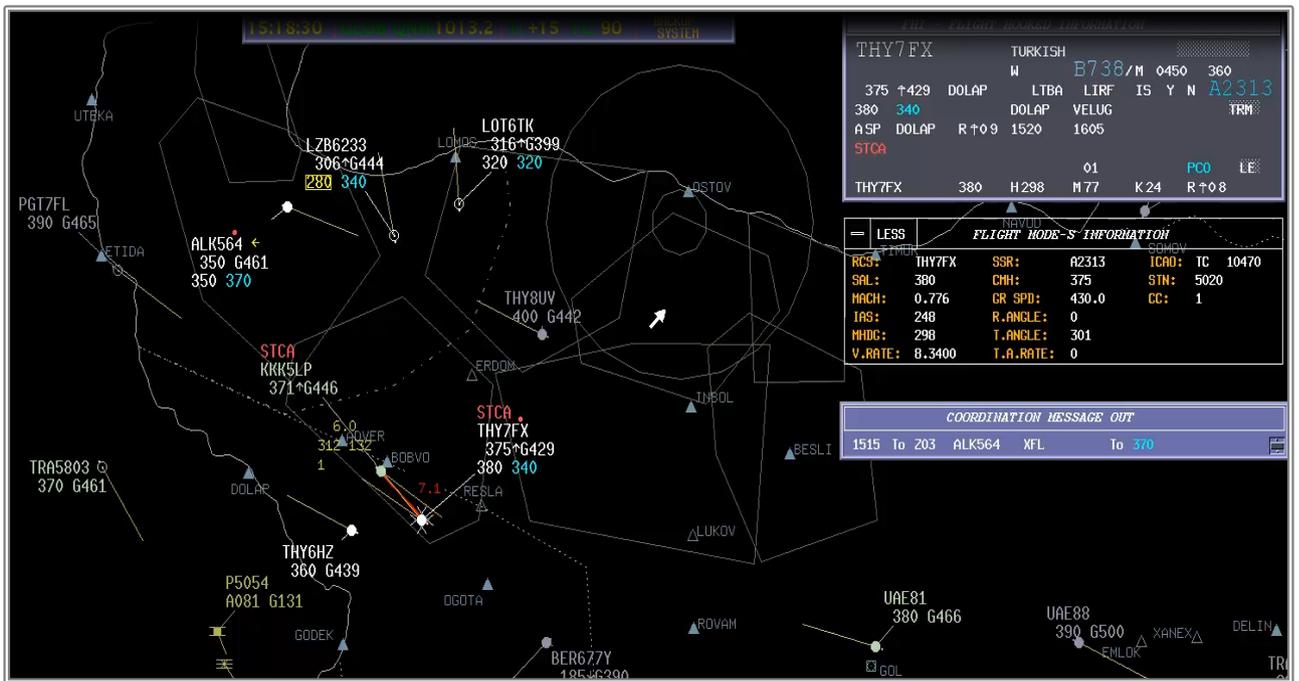


Fig.3

At 15:18:34, the norm for minimal radar separation of 5 NM horizontally and 1000 ft. vertically is infringed (See fig. 4). FDR reports that A/C KKK5LP receives indication CLEAR OF CONFLICT at 15:18:34 while the A/C KKK5LP is still gaining altitude (currently passing 37264 ft) with increased pitch angle and changing its heading according the ATCO instruction.



Fig. 4

At 15:18:46, A/C KKK5LP reaches FL374 after climbing initiated 23 s before.

FDM reports that A/C KKK5LP continues climbing till 15:18:47, reaching 37399 ft., despite the associated TCAS RA “LEVEL OFF” activated.

At 15:18:53, the horizontal distance between A/C THY7FX and A/C KKK5LP is 2.6 NM and the difference in their heights is 500 ft., as determined by extrapolation of the radar plots. THY7FX crosses FL379 upon climbing and KKK5LP is flying at FL374 (See fig. 5).

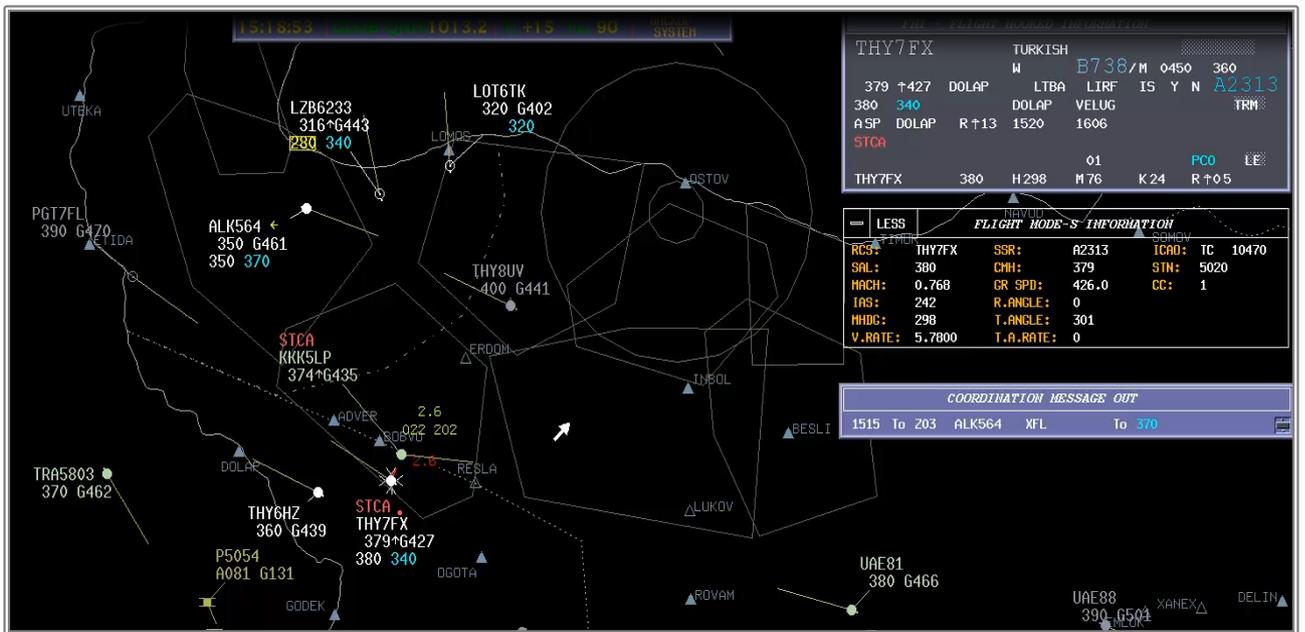


Fig. 5

According to the results from the simulation performed (Appendix 1), the closest point of approximation occurred at 15:18:54. The horizontal distance between the two aircraft is 2.65 NM, and the vertical distance is 575 ft. (See Fig. 6)

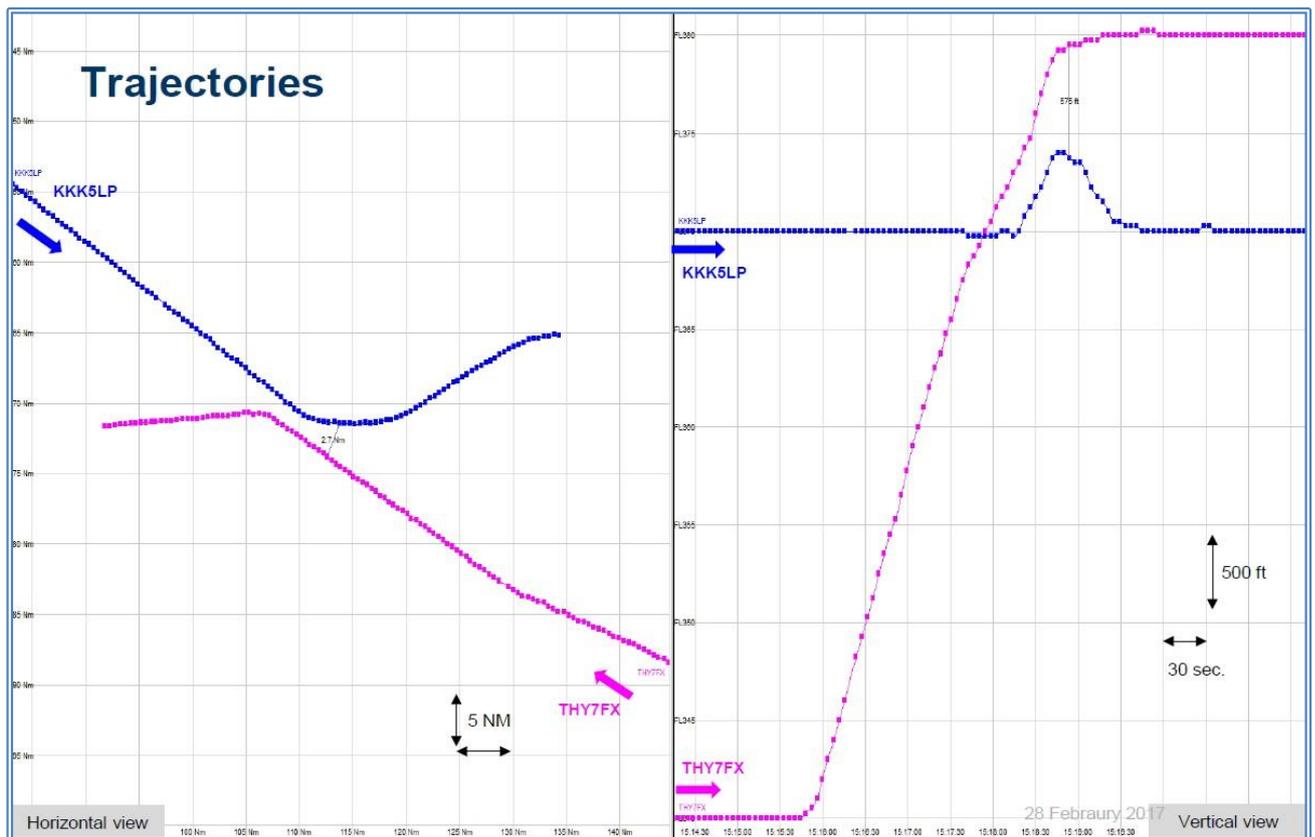


Fig. 6

At 15:19:06, EXE ATCO from SCL sector issues instructions to the flight crew of A/C THY7FX to follow a heading to VELOG TCP and transfers it at the frequency of Belgrade Control.

At 15:19:07, A/C KKK5LP starts descending to FL370 without reporting to EXE ATCO of SCU sector on this change still without reporting about the TCAS RA received (see fig.7).

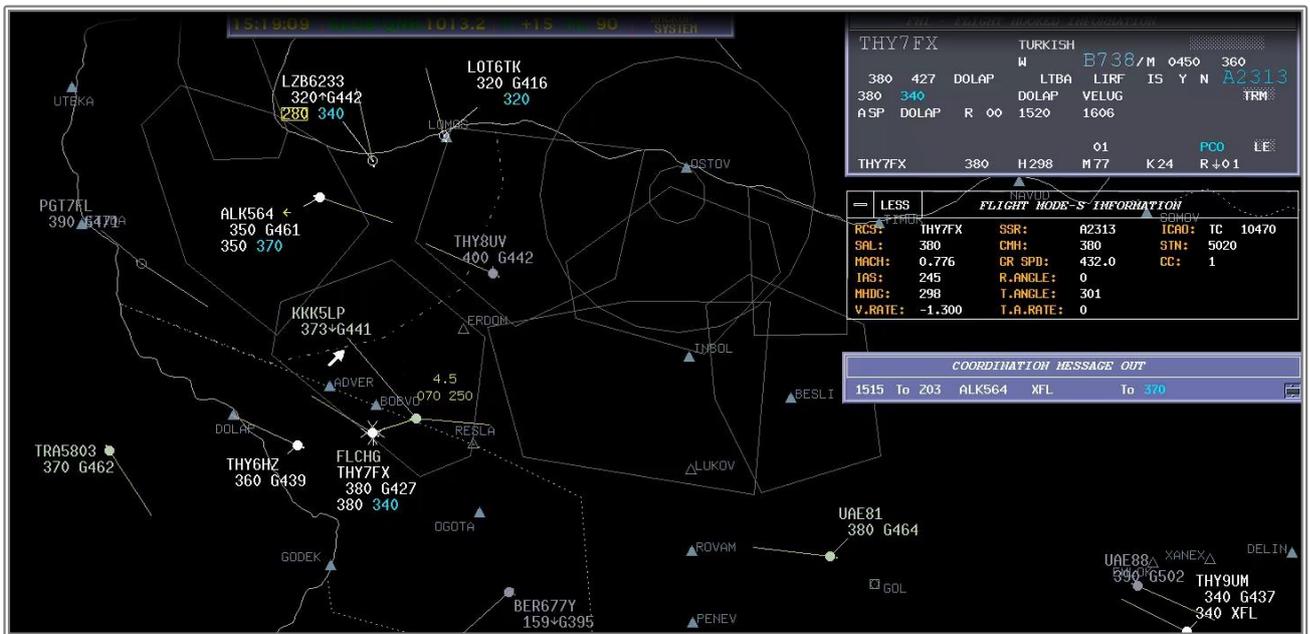


Fig.7

At 15:19:11 the minimum radar separation of 5 NM is recovered.

At 15:19:34 A/C KKK5LP occupies FL370 again and the FDM records confirm it as it happened at 15:19:31.

At 15:20:45 A/C KKK5LP reports to the EXE ATCO from SCU sector that they are flying on heading 60° and that they have had TCAS RA indication.

At 15:20:53, the EXE ATCO from SCU sector issues instructions to A/C KKK5LP to continue its flight on its own navigation directly towards GERGI TCP and clarifies that the cause for the TCAS RA indication is an opposite traffic climbing to FL380.

At 15:27:09, EXE ATCO from SCU sector issues instructions to the flight crew of A/C KKK5LP to transfer to the frequency of SDU sector.

2.1.3 Location of the aviation occurrence.

15 NM to the East of DOLAP point in the controlled airspace of the Republic of Bulgaria.

Date and time: June 4, 2016, 15:18:54 h UTC.

Air space classification: Class C.

2.2 Injuries to persons.

No flight crewmembers, passengers or any other persons were injured in result of the occurrence.

2.3 Damages to aircraft.

No damages.

2.4 Other damages.

None.

2.5 Personnel information.

2.5.1 Flight crew of Airbus A320-232 aircraft with call sign KKK5LP

2.5.1.1 Captain Pilot Flying

Gender: Male;
 Age: 48 Years;
 Employment: Captain Pilot Flying
 Experience: 9950 Flight Hours;

ATPL valid: 16.12.2018;
Medical Cert: 21.10.2017;
Line check: 11.12.2015;
Type Rating: 31.01.2017;
Theoretical: 10.06.2016;
ENGLISH LEVEL LEVEL 5.

2.5.1.2 First Officer:

Gender: Male;
Age: 32 Years;
Employment: First Officer;
Experience: 1200 Flight Hours;
ATPL valid: 20.01.2020;
Medical Cert: 18.10.2017;
Line check: 21.03.2016;
Type Rating: 31.01.2017;
Theoretical: 09.05.2016;
ENGLISH LEVEL LEVEL 5.

2.5.2 Flight crew of Boeing 737-8F2 aircraft with call sign THY7FX

2.5.2.1 Captain Pilot Flying:

Gender: Male;
Age: 62 Years;
Employment: Captain Pilot Flying – 27.04.2010
Experience: THY 5421 Flight Hours;
ATPL valid: 31.01.2017;
Medical Cert: 22.01.2017;
Line check: 12.10.2016;
Type Rating: ATPL;
SIM check: 28.01.2016 (LPC);
ENGLISH LEVEL LEVEL 6.0.

2.5.2.2 First Officer:

Gender: Male;
Age: 28 Years;
Employment: First Officer - 17.04.2013
Experience: THY 756 Flight Hours;
ATPL valid: 30.04.2017;
Medical Cert: 26.03.2017;
Line check: 12.10.2016;
Type Rating: FATPL;
SIM check: 18.02.2016 (LPC);
ENGLISH LEVEL LEVEL 6.0.

2.5.3 BULATSA, SOFIA ACC FS Sofia West Upper;

2.5.3.1 EXE ATC:

Gender: Male;
Year of birth: 1981; 35 Years;
ATCL BGR.ATCL;
Rating FS Varna ACS – RAD, valid till 22.10.2016;

ENGLISH LEVEL 5 FS Sofia ACS – RAD, valid till 17.03.2017;
valid until 18.12.2019;
Medical Cert valid until 25.01.2018.

2.5.3.2 PLN ATC:

Gender: Male;
Year of birth: 1968, 47 Years;
ATCL BGR.ATCL;
Rating FS Varna ACS – RAD valid till 19.10.2016
FS Sofia ACS – RAD valid till 19.10.2016

ENGLISH LEVEL 5 valid until 16.03.2019
Medical Cert valid until 25.01.2018

2.5.4 BULATSA, SOFIA ACC FS Sofia West Lower;

2.5.4.1 EXEATC

Gender: Female;
Year of birth: 1982, 34 Years;
ATCL BGR.ATCL;
Rating FS Sofia ACS – RAD valid till 25.09.2016
ENGLISH LEVEL 5 valid until 21.11.2020
Medical Cert valid until 03.10.2016

2.5.4.2 PLN ATC

Gender: Male;
Year of birth: 1972, 44 Years;
ATCL BGR.ATCL;
Rating FS Sofia ACS – RAD valid till 22.10.2016;
ENGLISH LEVEL 5 valid until 19.03.2019;
Medical Cert valid until 08.12.2016;

ATCOs from ACC Sofia who participated in the event and the flight crews of Airbus A320-232 with call sign KKK5LP and Boeing B737-8F2 with call sign THY7FX possess the qualification and medical certification necessary to carry out their duties.

2.6 Aircraft information

There is no evidence of technical failures of the on-board systems neither in the flight crews reports nor in the analysis of the FDR readouts. Since the event is only associated with the ACAS systems of the two aircraft functioning, the information below is provided only for this system.

2.6.1 Airborne Collision Avoidance System – ACAS II

Commission Regulation (EU) No 1332/2011, subsequently amended by Commission Regulation (EU) 2016/583 is mandating the carriage of ACAS II, version 7.1 within the EU Airspace by all civil aircraft with MTOM exceeding 5700 kg or authorised to carry more than 19 passengers.

The two aircraft are equipped with ACAS/TCAS systems.

ACAS is an automated system for avoidance of near mid-air collisions or mid-air collisions between aircraft in flight. In accordance with Part I, §6.18.2 of Annex 6 to the International Civil Aviation Convention, all aircraft with take-off weight of over 5700 kg shall be equipped with ACAS system of the second generation – ACAS II. In conformity with the ICAO standards, the ACAS/TCAS version 7.1 software is available effective from December 1-st, 2015.

The automated system of second generation, designated for the avoidance of near mid-air collisions or mid-air collisions between aircraft in flight, operates on the principle of the secondary surveillance radar and uses data from transponders on board. Via a directed antenna, assembled on each aircraft and data exchange between the transponders of aircraft, ACAS II monitors for the

availability of aircraft flying in dangerous proximity and, where requested, the automated system for avoidance of collision on board of the two aircraft performs data exchange and synchronizes issuing of differentiated commands for vertical manoeuvring aimed at avoiding of potential conflicts. Aircraft not transmitting data in Mode C and Mode S from the transponder not is detectable.

ACAS II has two Modes of operation - TA (Traffic advisory) and RA (Resolution advisory). The TA Mode is activated in case the system detects an aircraft, which may come into conflict with the relevant aircraft in a short-term plan. After the activation of this Mode, the system displays on board a radar sign in yellow and its spatial location versus the relevant aircraft. The visual indication is accompanied by an audible warning signal for dangerous approach of an aircraft through repetition of the word “Traffic”.

Where the aircraft continues its movement following a conflicting trajectory or, in violation of the specified norms on normal separation, enters in a predetermined radio area around the conflicting traffic, the system reports the dynamic parameters of the flight of the aircraft under surveillance and analyses the data received from the estimated data exchange with the opposite on board transponder. Where the analysis shows that the two aircraft move on conflicting routes, the norms on minimum separation being violated, and there is a real danger for direct collision, the system generates a command for fulfilment of vertical manoeuvring on the part of the flight crew, aimed at solving the existing conflict and avoidance of collision with the aircraft under surveillance. The flight crew of the aircraft, found under surveillance by ACAS II, also receives a command for fulfilment of vertical manoeuvre. The two commands have differentiated instructions, as the ACAS system coordinated the generated commands issued to the two aircraft, to ensure the performance of opposite manoeuvres. Once RAs have been generated, the flight crews of the two aircraft receive commands for implementation of vertical manoeuvres, respectively CLIMB for the one aircraft and DESCEND for the other aircraft, or vice versa.

In case of an activated RA Mode and timely performance of the issued commands on the part of the flight crews of the two aircraft, after solving of the conflict and avoiding of the collision, on board of the two aircraft the system announces conflict free overcoming of the dangerous proximity through an audible message “Clear of conflict”.

Pursuant to § 3.2 (c) of the USE OF ACAS INDICATORS, Chapter 3 of Operation Airborne Collision Avoidance System (ACAS), Part III of Aircraft Operating Procedures and Part I of Doc. 8168 - ICAO Aircraft Operations (PANS-OPS), all aircraft crews are required, in the event of an ACAS II RA mode activated, to execute without delay the generated conflict resolution commands ignoring any instructions given by ATS.

Doc. 8168 “Procedures for air navigation: Aircraft operations”:

“3.2 USE OF ACAS INDICATORS

The indications generated by ACAS shall be used by pilots in conformity with the following safety considerations:

a) pilots shall not manoeuvre their aircraft in response to traffic advisories (TAs) only;

Note 1. - TAs are intended to alert pilots to the possibility of a resolution advisory (RA), to enhance situational awareness, and to assist in visual acquisition of conflicting traffic. However, visually acquired traffic may not be the same traffic causing a TA. Visual perception of an encounter may be misleading, particularly at night.

Note 2. — The above restriction in the use of TAs is due to the limited bearing accuracy and to the difficulty in interpreting altitude rate from displayed traffic information.

b) on receipt of a TA, pilots shall use all available information to prepare for appropriate action if an RA occurs; and

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c) in the event of an RA, pilots shall:

1) respond immediately by following the RA as indicated, unless doing so would jeopardize the safety of the aeroplane;

Note 1. — Stall warning, wind shear, and ground proximity warning system alerts have precedence over ACAS.

Note 2. — Visually acquired traffic may not be the same traffic causing an RA. Visual perception of an encounter may be misleading, particularly at night.

2) follow the RA even if there is a conflict between the RA and an air traffic control (ATC) instruction to manoeuvre;

3) not manoeuvre in the opposite sense to an RA;

Note. — In the case of an ACAS-ACAS coordinated encounter, the RAs complement each other in order to reduce the potential for collision. Manoeuvres, or lack of manoeuvres, that result in vertical rates opposite to the sense of an RA could result in a collision with the intruder aircraft.

4) as soon as possible, as permitted by flight crew workload, notify the appropriate ATC unit of any RA which requires a deviation from the current ATC instruction or clearance;

Note.— Unless informed by the pilot, ATC does not know when ACAS issues RAs. It is possible for ATC to issue instructions that are unknowingly contrary to ACAS RA indications. Therefore, it is important that ATC be notified when an ATC instruction or clearance is not being followed because it conflicts with an RA.

5) promptly comply with any modified RAs;

6) limit the alterations of the flight path to the minimum extent necessary to comply with the RAs;

7) promptly return to the terms of the ATC instruction or clearance when the conflict is resolved; and

8) notify ATC when returning to the current clearance.

Note. — Procedures in regard to ACAS-equipped aircraft and the phraseology to be used for the notification of manoeuvres in response to a resolution advisory are contained in the PANS-ATM (Doc 4444), Chapters 15 and 12 respectively.

„.....“

2.7 Meteorological information

An evolution of well-developed Cumulonimbus clouds in the control area sectors SCL and SCU, and active avoiding of affected space by the flying over aircraft.

The country is under the influence of a relatively low-pressure area. The air mass is warm, moist and unstable. Cold atmospheric front moves toward to the country from north, causing formation of convective clouds TCU and Cb (Cumulonimbus) and thick Nimbostratus - Ns clouds. Because of the low convective potential, the tops of the convective clouds are in the range of FL320-FL340, some separate clouds are observed with tops reaching FL350 at its highest stage. From 15:00 UTC to 15:30UTC around the ERDOM point, separate convective clouds with tops at FL 300 - FL 320 are observed, moving from northwest to southeast, with speed of 15kt.

The analysis of the charts that must be provided to the aircraft crew during pre-flight briefing shows a forecast for isolated, embedded Cb, with tops reaching FL320, in the area north of Stara Planina Mountain.

The wind and temperature are as follows:

FL 340: 300/30 kt TEMP: - 52°;

FL 360: 300/30 kt TEMP: - 56°;

FL 390: 300/25 kt TEMP: - 57°;

Convective clouds around the ERDOM point are included in the archival description.
Archival description:

14:00 h: There is Cb at ERDOM point and another Cb at a distance 20km inn direction E/SE of ERDOM, tops are between FL290 and FL330;

14:15 h: There is Cb at ERDOM point and another Cb at a distance 25km E/SE of ERDOM, tops are between FL290 and FL320;

14:30 h: there is Cb 30 km east of ERDOM, tops is between FL290 and FL350;

14:45 h: There are TCU (convective clouds) around ERDOM point located in radius of 15 km and there are two developing Cb with growing tops, but currently reaching FL320 positioned 25 km NW / N of ERDOM.

15:00 h: there is Cb at ERDOM point with top reaching FL320 and another Cb 25km NW/N of ERDOM with top reaching FL330, there are several Cb S / SW and 30-40km away from the point.

15:10 h: there is Cb at ERDOM point with top reaching FL300 and another Cb 20km NW/N of ERDOM with top reaching FL330, there are several CB S/SW and 35-40km away from the point.

15:20 h: there is Cb at ERDOM point with top reaching FL300 and another Cb 15 km NW/N of ERDOM with top reaching FL310, there are several Cb S/SW and 35-45km away from the point with tops reaching FL300;

15:30 h: there is Cb 20km NW of ERDOM with top reaching FL310, there is another Cb 50km S of the point with top reaching FL300, there is a developing Cb NW/N of ERDOM with top reaching FL 260.

The meteorological conditions at the time of the aviation occurrence cause deviation of air traffic in the controlled air space of SCL and SCU sectors and increase of the workload of the controllers.

2.8 Navigation

The two aircraft fulfilled the flights with standard navigation equipment for the type of aircraft type.

The flights of the two aircraft were carried out in the upper air space of Bulgaria, under the conditions of zonal navigation and in conformity with the Instrument Flight Rules. There is no information about technical failures of the navigation system of the Bulgarian Air Traffic Services Authority (BULATSA), which could be able to cause the occurrence. All facilities included in the national net operated normally.

The 24-hour information bulletin of RC for ATS-Sofia does not contain reported failures of technical equipment, which effect directly the operational activity at the time of the incident.

The analysis of the log files and the operative information dated 04 June 2016 proves that ATCAS - SATCASv3MS2 has operated without any interruption of its functionalities, but there were 7 switches between the main and the stand-by servers from the FDP subsystem:

| | | | | | |
|----------|----------|-----|-----|------|----------|
| 4.6.2016 | 10:52:36 | SOF | FP1 | AFS: | STARTING |
| 4.6.2016 | 10:53:46 | SOF | MN2 | MNA: | STARTING |
| 4.6.2016 | 14:45:05 | SOF | LN2 | LNR: | STARTING |
| 4.6.2016 | 16:39:56 | SOF | LN1 | LNR: | STARTING |
| 4.6.2016 | 16:55:09 | SOF | MN2 | MNA: | STARTING |
| 4.6.2016 | 16:57:49 | SOF | MN1 | MNA: | STARTING |
| 4.6.2016 | 17:05:25 | SOF | FP2 | AFS: | STARTING |

In two of the cases of switching regarding LNR servers, this was done manually from operator's console and in the other cases this was executed automatically. Manual switch results from delayed processing of OLDI and AFTN messages. There is no loss of information but only slow operation of the FDP subsystem. Presumably, this is an effect from the increased traffic and problems with the software application.

The SATCAS configuration envisages DFL365 between SCL and SCU sectors, filters are introduced by the EXE ATCO ensuring surveillance of traffic from FL350 upwards for SCU sector and respectively up to FL380 for SCL sector.

2.9 Communications

The two aircraft fulfilled the flights with standard communication equipment for the type of aircraft.

The air-ground radio communication in the SCU is carried out at the frequency of 128.530 MHz. The air-ground radio communication in SCL is carried out at the frequency of 135,025 MHz. The two aircraft remained in contact with two different, superimposed sectors. The Bulgarian Air Traffic Services Authority provided a transcript of the radio-conversations of Sofia Control, FS SCU and FS SCL, at frequencies 128,530 MHz and 135,025 MHz, as well as of the telephone communication between the PLN ATC and the neighbouring sectors of air traffic service before, during and after the time of the aviation occurrence. After hearing the radio conversations at the work frequencies of FS SCU and FS SCL, the Investigation Commission found that there had been no loss of radio communication and that there are no interruptions and disturbances during radio broadcasting with no aircraft in the sector.

There had been interruptions or disturbances during the radio exchange with one aircraft in the sector. There is information about technical failures of the communication system of the Bulgarian Air Traffic Services Authority (BULATSA) which could be able to cause the occurrence. All facilities, included in the national net, have operated normally.

2.10 Aerodrome information

The occurrence is not realized at an aerodrome.

2.11 Flight data recorders

- Data were used from the flight data recorders of the Common National Air Traffic Control Centre (CNATCC) of the Bulgarian Air Traffic Services Authority (BULATSA) in regards to the radar picture and radio communications, as well as records of the telephone communication of the Planning Air Traffic Controller with the other sectors.

- Data were used from FDR of A320-232 aircraft, registration marks TC-ATK of AO „Atlasjet” and of the B737-8F2 aircraft, registration marks TC-JGF of AO „Turkish Airlines”.

2.12 Wreckage and impact information

Not applicable

2.13 Medical and pathological information

Not applicable

2.14 Fire

Not applicable.

2.15 Survival aspects

Not applicable

2.16 Tests and research

For the purposes of the safety investigation, the Commission carried out and conducted:

- Collecting, documenting, studying, listening and analysing the radar picture recordings, radio conversations, the telephone connection between work position Sofia - Control – SCL sectors and the neighbouring ATS sectors;
- Listening, documenting and analysing call records between SCL and SCU sectors;
- Discussions with the EXE ATCO, the PLN ATCO and the Air Traffic Controller – Supervisor who performed air traffic control during the serious incident;

- Analysis of the actions of the ATCO from FS SCL и SCU;
- Analysis of the flight crews actions of the two aircraft during the aviation occurrence;

The Commission also requested, discussed and analysed data from:

- The flight crew report of B737-8F2 aircraft with call sign THY7FX;
- The flight crew report of A320-232 aircraft with call sign KKK5LP;
- FDR data records of A320-232 aircraft, registration marks TC-ATK of AO „Atlasjet”
- FDR data records of B737-8F2 registration marks TC-JGF of AO „Turkish Airlines”
- Analysis of the flight crews actions of the two aircraft during the aviation occurrence based on FDR readouts and pilot reports only;
- Airbus A320-232 flight simulation performed on Airbus A320 flight simulator.

To determine the reasons for triggering of the TCAS as well as the actions of the crews of the aircraft, the Commission for safety investigation coordinated with the EUROCONTROL and a simulation of the event was implemented on InCAS v3.3 (Interactive Collision Avoidance Simulator). The simulation results are given in Annex 2.

2.17 Information on the organization and management

A major document specifying the rules, procedures, instructions and information on the performance of Air Traffic Servicing by the air traffic servicing authorities at the RC for ATS-Sofia is the Manual on air traffic servicing of BULATSA.

Part 2 of the Manual stipulates:

“2.6 Coordination between ATCOs upon work in vertically separated sectors.

2.6.1 When working in two vertically separated sectors, PLN ATCOs from both sectors usually coordinate the first directional flight level of the neighbouring high/low sector. Where requested, during the coordination process PLN ATCOs from the two sectors can also agree another FL. The EXE ATCO from the transferring sector starts descending/climbing to the FL that has been already electronically concurred.

2.6.2 If an electronic co-ordination process between vertically divided sectors does not occur when introducing XFL(due to logic of the trajectory building 'as late as possible' and 'descent as soon as possible', in a set), then the PLN ATCO from the transmitting sector performs the procedure FORCED ACT from the CALLSIGN MENU on the aircraft's label and reintroduces the same XFL value for electronic coordination.

2.6.3 The start of descending/climbing is a subject of concurrence between EXE ATCOs through the FLCHG functionality. After acceptance of the proposed FLCHG coordination, the EXE ATCO, under whose servicing the aircraft is, issues instructions for descending/climbing of aircraft to the concurred FL. If for whatever reason the issuing of the instruction for descending/climbing is not accomplished immediately, the EXE ATCOs concur by phone a new start of changing of the flight profile of the aircraft.

2.6.4 Issuing of instruction for descending/climbing is permitted only in the presence of accepted coordination for FLCHG at 0 line on the aircraft label.

2.6.5 Where after accepted coordination for FLCHG, the PLN ATCO from the transferring sector introduces a new value of XFL, the warning on line 0 disappears. In this case, it is necessary the EXE ATCOs from the two sectors to implement FLCHG coordination again.

2.7 For controlling the trajectory within one sector only, all available functions may be used - DCT, RCR, EDIT and CLHDG. Where the change of the trajectory affects another sector, only DCTTO function is used (the function initiates automatically coordination between the sectors). Where the change necessitates using of the other three functions - RCR (rerouting), EDIT and CLHDG, the concurrence if it by phone as a must.”

2.18 Additional information

2.18.1 ATCAS - SATCAS v3MS2

The major risk in Air Traffic Servicing (ATS) is the risk of collision between two aircraft. Early detection and resolving of conflicts is one of the most important tasks of the safe ATS systems. By putting in operation of the Air Traffic Control Automated System (ATCAS) SATCAS at the Common Air Traffic Control Centre of BULATSA, Air Traffic Servicing is carried out via contemporary automated equipment for detection of conflicts. The problem of the automated conflict detection is solved in a complex manner at four levels depending on the time expected to the conflict (time horizon):

Long Term Conflicts are detected by means of planning. They are far ahead in more than 20 minutes.

By the MTCO (Medium Term Conflict Detection) functionality of the flight information processing subsystem, the medium-term conflicts are forecasted, where forthcoming simultaneous loss of horizontal and vertical separation between two aircraft may be detected on the basis of the aircraft's systemic trajectories. Such forecast is made for a period of 20 minutes ahead. It uses the data from the systemic flight plans for building of systemic trajectories.

By the STCA (Short Term Conflict Alert) functionality of the Safety Nets subsystem the short-term conflicts are detected with time horizon of up to 5 min (typically 2 min).

The last barrier to aircraft collision are the on-board automated ACAS, which function within a time horizon of less than 2 min (typically 40 s).

The functionalities of these four different levels work together and are interconnected. They form "a chain" which ensures four consecutive automated barriers to avoid crashing. This way each shorter-term functionality ensures the previous one and this way a high safety of flights is ensured.

The MTCO and STCA functionalities, which are used directly by ATS, are designated as well for the following tasks:

- to support ATCO in considering variants for a solution of the type "What will happen if

- to warn ATCO through an alarm if a mistake was made on ATCO's part and allow ATCO to rectify the mistake by his/her own.

In the case investigated, the MTCO and STCA functionalities were activated.

MTCO functionality generates warning in case of a forecast is produced that two or more aircraft will be in conflict within the prognosticated period of time established (up to 20 min). Upon automatic detection of conflict in the trajectories of aircraft, which are found in a potentially dangerous situation, a warning at the ATCO's working position is received. The detected conflict is automatically displayed as a red dot on the 0 line of the aircraft's label and additionally in the Conflict Display Window (CDW), with information about the conflict and the call signs of the aircraft found in a conflict situation.

The STCA functionality generates visual and audible warning (alarm), if two or more aircraft are already in conflict (an existing conflict), or it is forecasted that they will be in conflict within the pre-set forecast time (2 min). Depending on the time when they will happen, forecasted conflicts are divided into urgent and non-urgent. Upon automated detection of conflicts, the trajectories of aircraft found in a potentially dangerous situation are coloured in red and a warning message is received. Detected conflicts are recorded in a table entitled "RDP Alarm List". It contains details about the conflict, such as the call signs of the aircraft found in a conflict situation, the urgency of the conflict, etc. When an alarm occurs, an audible signal is activated. Audible signalling may be switched off after its activation.

The STCA algorithm is carried out continuously and in cycles. Conflicts are detected on the basis of actual and forecasted trajectories of aircraft. A short-term conflict warning message occurs where the horizontal and vertical distances between two aircraft at the same time are less (in an existing conflict) or in a short time (in case of a predicted conflict) will be less than the relevant threshold values.

For existing and emergency conflicts, the alarm is done immediately in a visual and audible way. For reducing the frequency of false warnings, non-urgent conflicts are additionally processed via an algorithm for confirmation, and if confirmed, a relevant warning is generated thereof.

In order to be perceived immediately, the message for conflict is displayed at the ATCO's working position with the highest priority. Additionally, the alarm signal is sent and recorded in the Recording and Playback System (RPB) and in the Technical Monitoring and Control System (TMCS). Moreover, in the process of work diagnostic messages on the functioning of STCA are sent to TMCS. Any partial or complete dropout of the STCA function is recorded and can be found immediately or later on.

2.18.2 Division of the air space into Family Sectors Sofia at the time of the incident

- Sofia Control – FS SCL Sofia West Lower from FL95 to FL365;
- Sofia Control – FS SCU Sofia West Upper from FL370 to FL660;
- Sofia Control – FS SDL Sofia East Lower from FL95 to FL355;
- Sofia Control – FS SCU Sofia West Upper from FL360 to FL660;
- Division flight level between FS SCL and FS SCU is FL365
- Division flight level between FS SDL and FS SDU is FL355

The division of the air space into sectors is shown on Fig. 8

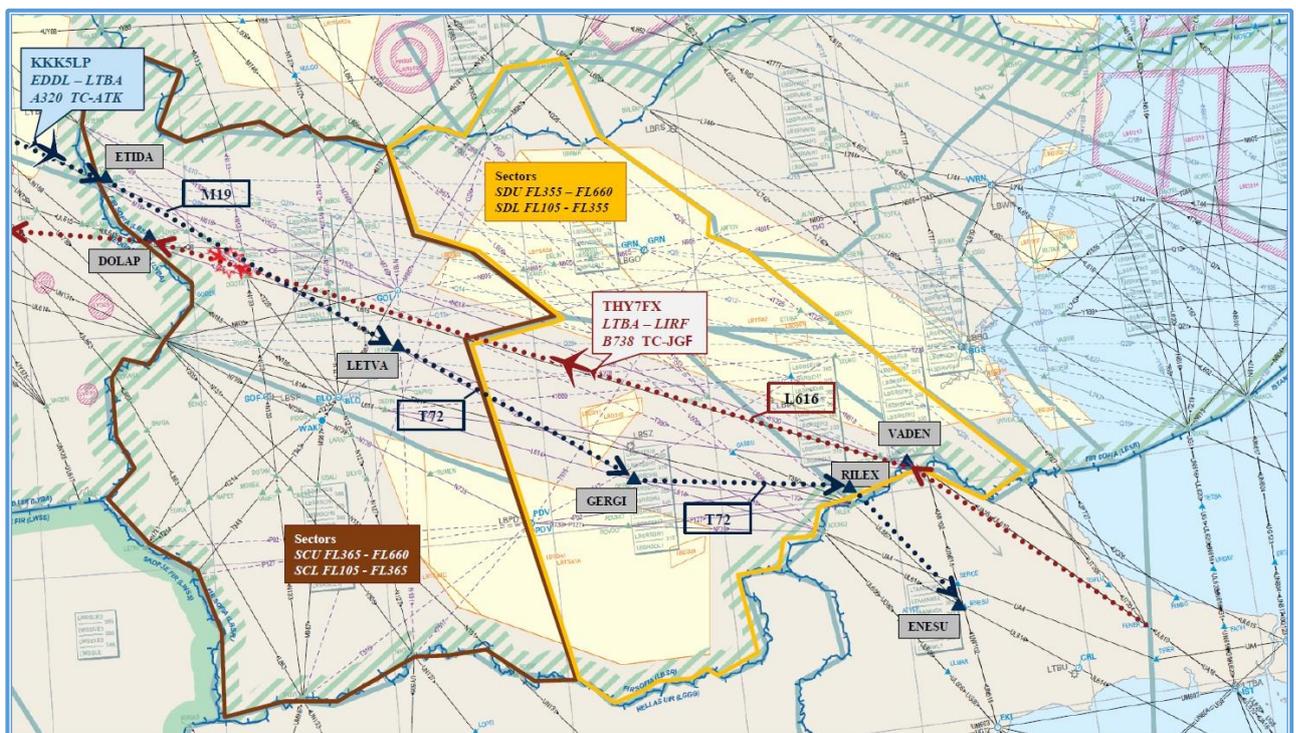


Fig. 8

2.18.3 Activated warning systems and warning procedure

- The ACAS/TCAS system on board of aircraft B737-8F2 with call sign THY7FX is activated in RA mode and it generates a “CLIMB” command for performing a vertical manoeuvre.
- Accordingly to the simulation results the ACAS/TCAS system on board of aircraft A320-232 with call sign KKK5LP is activated in RA mode generating “LEVEL OFF” command for maintaining of the FL.
- ATCAS SELEX generates a warning message for a mid-term conflict between aircraft B737-8F2 with call sign THY7FX and aircraft A320-232 with call sign KKK5LP, which conflict is not fully visualized at both sectors of SCU и SCL. At both sectors, there is one-sidedly displayed red dot for conflict, without displaying the relevant corresponding red dot in the 0-radar label of the second aircraft. The distance between the two aircraft is 34.1 NM.

- ATCAS SELEX generates a warning message for a short-term conflict (STCA) between aircraft B737-8F2 with call sign THY7FX and aircraft A320-232 with call sign KKK5LP, which is displayed at the working positions of SCU and SCL sectors. The distance between the two aircraft is 12.8 NM.

2.18.4 Procedures in regard to aircraft equipped with airborne collision avoidance systems (ACAS)

“15.7.3.1 The procedures to be applied for the provision of air traffic services to aircraft equipped with ACAS shall be identical to those applicable to non-ACAS equipped aircraft. In particular, the prevention of collisions, the establishment of appropriate separation and the information, which might be provided in relation to conflicting traffic and to possible avoiding action, shall conform with the normal ATS procedures and shall exclude consideration of aircraft capabilities dependent on ACAS equipment.

15.7.3.2 When a pilot reports an ACAS resolution advisory (RA), the controller shall not attempt to modify the aircraft flight path until the pilot reports “Clear of Conflict”.

15.7.3.3 Once an aircraft departs from its ATC clearance or instruction in compliance with an RA, or a pilot reports an RA, the controller ceases to be responsible for providing separation between that aircraft and any other aircraft affected as a direct consequence of the manoeuvre induced by the RA. The controller shall resume responsibility for providing separation for all the affected aircraft when:

a) the controller acknowledges a report from the flight crew that the aircraft has resumed the current clearance; or

b) the controller acknowledges a report from the flight crew that the aircraft is resuming the current clearance and issues an alternative clearance which is acknowledged by the flight crew.

Note.— Pilots are required to report RAs which require a deviation from the current ATC clearance or instruction (see PANS-OPS (Doc 8168), Volume I, Part III, Section 3, Chapter 3, 3.2 c) 4)). This report informs the controller that a deviation from clearance or instruction is taking place in response to an ACAS RA.

15.7.3.4 Guidance on training of air traffic controllers in the application of ACAS events is contained in the *Airborne Collision Avoidance System (ACAS) Manual* (Doc 9863).

15.7.3.5 ACAS can have a significant effect on ATC. Therefore, the performance of ACAS in the ATC environment should be monitored.

15.7.3.6 Following a significant ACAS event, pilots and controllers should complete an air traffic incident report.

Note 1. — The ACAS capability of an aircraft may not be known to air traffic controllers.15/11/12

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No. 2

Note 2. — Operating procedures for use of ACAS are contained in PANS-OPS (Doc 8168), Volume I, Part III, Section 3, Chapter 3.

Note 3. — The phraseology to be used by controllers and pilots is contained in Chapter 12, 12.3.1.2.”

3 Analysis

For the establishment of causes for the realized serious incident, the following hypotheses were reviewed:

- Eventual technical failure of the ATCAS on the ground;
- Eventual technical failure of any of the aircraft systems on-board;
- Inefficient implementation of procedures by ATCO upon the provision of air traffic servicing.

- Incorrect implementation of procedures by the flight crews of aircraft B737-8F2 with call sign THY7FX and/or aircraft A320-232 with call sign KKK5LP upon receiving of RA indication from ACAS/TCAS;

The first hypothesis presumes possible technical failure of ATCAS. From the information received by the Commission it is found that ATCAS - SATCASv3MS2 has operated without any interruption of its functionalities, though there were 7 switches between the basic server and the stand-by server from the FDP subsystem, where no information was lost. These switching operations have impact on the safety of the ATS provided by ATCOs.

Considering the contents of paragraphs 2.1.2, 2.6 and 2.18 above, the Commission declines the possibility that the event has resulted from a technical failure of ATCAS.

Under the second hypothesis, the Commission did not find any information about the violation of the normal operation of the board systems of aircraft B737-8F2 with registration marks TC-JGF and aircraft A320-232 with registration marks TC-ATK.

Considering the contents of paragraphs 2.1.2 and 2.6 above, the Commission declines the possibility that the event has resulted from a technical failure of any of the on-board systems of the aircraft.

The third hypothesis is related to inefficient implementation of procedures by ATCO upon the provision of air traffic servicing.

At the time of the working shifts overlapping at 12.00 h UTC in the controlled air space of SCL and SCU sectors, the air conditions were complicated by the development of strong dense rainy clouding, requiring detouring by the air traffic. This led to creation of a complicated situation in the sectors and increased the workload of ATCOs. During the period of the aviation event realization, SCL and SCU sectors served about 10-15 aircraft simultaneously.

According to the flight plan, A/C THY7FX enters the air space of the Republic of Bulgaria through VADEN TCP. The EXE ATCO from SDL sector at the ACC – Sofia identifies the aircraft as THY7FX, issues instruction for climbing from FL320 to FL340 and does not undertake any action for further climbing to FL380 as requested by the aircraft. The EXE ATCO transfers the control and radio communication to SCL sector.

The EXE ATCO from SCL sector identifies the aircraft as THY7FX. The flight crew report flying at FL340 willing to climb to FL380 and that they can change the trajectory of flight to the right, if this would help. The EXE ATCO from SCL sector coordinates FLCHG with the EXE ATCO from SCU sector in respect of the same aircraft. At the same time two more FLCHG are coordinated in regards to other aircraft

Upon received confirmations of FLCHG from SCU sector, the EXE ATCO from SCL sector consecutively issues the respective permissions for changing of the FL of the aircraft. Particularly, the EXE ATCO issues instructions to aircraft with call sign THY7FX for climbing to FL380 and change of heading with 10 degrees to the right with a delay of about 40 seconds after receiving the confirmation for FLCHG of the aircraft. At this moment, the EXE ATCO does not concur by phone with the EXE ATCO from SCU sector the beginning of the flight profile change. Moreover, the EXE ATCO does not coordinate with the EXE ATCO from SCU sector the instruction issued to aircraft with call sign THY7FX for turning right.

At 15:16:39 a MTCN with a red dot warning is displayed for an aircraft with call sign THY7FX. Such a red dot warning is not displayed in regards to second conflict aircraft. In this complicated situation, due to the lack of time for selection with the mouse where the entire newly emerged trajectory of the MTCN warning is traced, the EXE ATCO from SCL sector is deprived of the possibility for earlier forecasting the conflict.

At 15:18:02 ATCAS SELEX through the Safety Nets subsystem generates a short-term conflict warning (STCA) between A/C THY7FX and A/C KKK5LP, which is displayed at the working positions of both the SCU and SCL sectors. The distance between the two aircraft is 12,8 NM. The EXE ATCO from SCL sector reacts and issues instructions to A/C THY7FX to turn 40° left for avoiding the conflict situation. With the same purpose while monitoring the aircraft

climbing resulted from the initial climb instruction, the EXE ATCO repeats the instruction to climb again after the flight crew has reported for triggering of RA mode of the TCAS on board of A/C THY7FX.

The PLN ATCO from SCL sector coordinates with the PLN ATCO from SCU sector XFL (FL380) for THY7FX, after that he processes in XFL FL340 for A/C THY7FX at the moment when the EXE ATCO from SCL sector issues instruction to the aircraft for climbing to FL380. As a result of this action, the label of the A/C THY7FX disappears from SCU sector's display for a period of 1 min and 12 s (till the moment when the aircraft reaches FL351 as it is pre-set in the display filter).

Due to absence of audio recording devices on the status of the surrounding conditions at the ATS working positions, the Commission does not dispose complete information about the plan elaborated by PLN ATCO from SCL sector, what exit FL he/she has concurred with the EXE ATCO and how the plan has been amended in respect of the exit FL for the purpose of avoiding a potential conflict between A/C THY7FX and A/C KKK5LP.

According to the flight plan, A/C KKK5LP enters the controlled air space of Republic of Bulgaria through ETIDA TCP. The EXE ATCO from SCU sector at ACC - Sofia identifies the aircraft as KKK5LP. The EXE ATCO receives consecutively three coordination messages about FLCHGs. Since the EXE ATCO from SCU sector is work overloaded, the PLN ATCO confirms the coordination messages about FLCHG and informs the EXE ATCO accordingly. At 15:16:39, displayed is a MTCD red dot warning for A/C KKK5LP, but without a corresponding red dot warning for a second conflict aircraft. In this complicated situation, due to the lack of time for selection with the mouse, upon which the entire newly emerging trajectory of MTCD warning is traced, the EXE ATCO from SCU sector is also deprived of the possibility for earlier forecasting of the conflict. Upon generated at 15:18:02 warning for a short-term conflict (STCA) between A/C THY7FX and A/C KKK5LP, EXE ATCO from SCU sector reacts timely and issues instructions to KKK5LP for immediate turn left with more than 30° for avoiding the conflict situation.

The PLN ATCO from SCU sector confirms FLCHG FL380 for A/C THY7FX requested by the PLN ATCO of SCL sector and coordinates exit FL380 for the same aircraft with Belgrade Control by phone. The PLN ATCO from SCU sector informs Belgrade Control that A/C THY7FX maintains FL340, but later on, it would occupy FL380. Instead of EXE ATCO, PLN ATCO from SCU sector confirms the requested permission from SCL sector for climbing of aircraft (FLCHG) from FL340 to FL380.

According to the third hypothesis, the inefficient performance of procedures upon providing Air Traffic Services leads to infringement of the minimum norms for safe separation between aircraft, which makes the situation grow from complicated flight conditions to a situation threatening the safety of flight.

The Commission associates the forth hypothesis with an inadequate performance of procedures by the crews of aircraft B737-8F2 with call sign THY7FX and/or aircraft A320-232 with call sign KKK5LP upon receipt of RA indication from ACAS/TCAS. From the information received it is established that the ACAS/TCAS systems on-board of both the aircraft were activated in RA mode generating CLIMB command for aircraft B737-8F2 and LEVEL OFF command for aircraft Airbus A320-232.

In respect to the flight of aircraft B737-8F2 with call sign THY7FX:

According to the explanations of the F/C of THY7FX implemented by B737-8F2 and the FDR data obtained, during the flight in the controlled air space of ACC Sofia in a given course and issued instruction for climbing from FL340 to FL380, the F/C receives an indication of TCAS RA CLIMB, in which the F/C turns the autopilot off and executes the RA given without delay. At the same time, the EXE ATCO of ACC Sofia issues instructions for changing the course. F/C report about a TCAS RA received and 9 s later - about received TCAS message "Clear of Conflict". From

the examination of InCAS performed at EUROCONTROL it was confirmed that aircraft THY7FX received command CLIMB RA for avoiding of collision while being in climb at a vertical speed of +1000 ft/min. In accordance with the technical specifications determined by EUROCONTROL, the TCAS II on-board system issues command for climbing for avoiding of collision CLIMB RA with aircraft with expected vertical speed for fulfilment by the aircraft crew equal or greater than +1500 ft./min. In this situation the flight crew of THY7FX initially maintains the climbing speed of +1100 ft./min and from the 5-th to 9-th s after the activation of TCAS RA increases to +1900 ft./min.

In respect to the flight of aircraft A320-232 with call sign KKK5LP:

According to the explanations of the flight crew of KKK5LP, during the flight in the controlled air space of Sofia "Control" at FL370 on M-19 airway between ADVER and PENEV control points the flight crew was instructed to turn immediately left heading 060°. The flight crew have immediately fulfilled the instruction and all of a sudden, they received TCAS TA indication for an aircraft in the 12 hours direction of, 300 ft. lower, climbing in height. Afterwards and while turning left the flight crew received indication TCAS RA for DESCEND. The flight crew performed "DESCEND" in conformity with TCAS RA and a few seconds later they received message CLEAR OF CONFLICT. The flight crew informed Sofia "Control" about the TCAS RA indication.

No evidence has been found in support of the crew statement mentioned above. There is evidence to suggest that A/C KKK5LP starts to climb a height without receiving TCAS RA or instructions for it and continues to climb after receiving LEVEL OFF RA. In accordance with the FDR data received, PF incorrectly disconnects the autopilot in the TCAS TA indication, starts climbing and turning to the left of course 120. Nine seconds after receiving the TA, a LEVEL OFF RA from TCAS is activated. PF and PM do not perform CROSS-CHECK in accordance with the procedures specified in the GOLDEN RULES and FCTM by the AIRBUS manufacturer. The PF must announce any change in flying the aircraft and take action after confirmation by the PM. Incorrect actions of the F/C are probably due to impaired interaction between its members or due to inadequate training for responding to abnormal and emergency situations during a flight.

According to the radar information provided by BULATSA for the period of the incident including LEVEL OFF RA a decrease of the vertical speed of the aircraft was not observed, but on the contrary – observed was climbing from FL370 to FL374.

Upon the simulation using InCAS performed at EUROCONTROL covering the period of conflict of the two aircraft, substantiated conclusion is drawn that the flight crew with call sign KKK5LP received TCAS RA LEVEL OFF and at the same time, the flight crew with call sign THY7FX received TCAS RA CLIMB. The expected reaction to LEVEL OFF command is decreasing the vertical speed to 0 ft/min. Nevertheless, the aircraft with call sign KKK5LP continued climbing additional 22-23 s reaching 37399 ft.

In view of the contents of the fourth hypothesis and in paragraph 2.6.1 given above, the following conclusions may be drawn:

- The flight crew with call sign THY7FX performs the TCAS RA CLIMB command generated for climbing in height.
- The flight crew with call sign KKK5LP does not fulfil immediately the LEVEL OFF RA command generated to reduce the vertical speed to 0 ft./min and continues climbing, which worsens the situation and increases the risk of crashing.

In view of stated so far, conclusion may be made that the serious incident investigated is predetermined by dominating factors related to the third and fourth hypotheses above, as follows:

1. Incorrect assessment of the air situation and issuing of permission for changing the trajectory of A/C THY7FX without carrying out relevant coordination by the ATCO of sector SCL with the ATCO of sector SCU
2. Uncommanded climb of A/C KKK5LP.

3. No response by the flight crew of A/C KKK5LP of „Atlasjet” AO, upon activation of TCAS in RA mode.
4. Inefficient performance of coordination procedures between ATCOs of SCL and SCU sectors, ACC-Sofia, upon work in vertically separated sectors in accordance with Part 2 of the Manual on Air Traffic Services.

4 Conclusion

4.1 Findings

4.1.1 Findings regarding the aircraft and their systems

- Aircraft A320-232 of AO “Atlasjet”, registration marks TC-ATK, is airworthy at the moment of the aviation occurrence realization;
- Aircraft B737-8F2 of AO “Turkish Airlines”, registration marks TC-JGF, is airworthy at the moment of the aviation occurrence realization;
- Accordingly to the FDR data of aircraft A320-232 of AO “Atlasjet”, registration marks TC-ATK, the ACAS/TCAS system activates in RA mode and generates a LEVEL OFF (DON’T CLIMB) command for maintaining the FL;
- Accordingly to the FDR data of aircraft B737-8F2 of AO “Turkish Airlines”, registration marks TC-JGF, the ACAS/TCAS system activates in RA mode and generates a CLIMB command for performing a vertical manoeuvre.

4.1.2 Findings regarding the flight crew

- The flight crew of aircraft A320-232, registration marks TC-ATK of AO “Atlasjet”, Captain Pilot Flying and First Officer, are licensed and possess the requested qualification and medical capability for the performance of flights in conformity with the applicable regulations;
- The flight crew of aircraft A320-232, registration marks TC-ATK, does not react to the LEVEL OFF RA indication of TCAS;
- The flight crew of aircraft A320-232, registration marks TC-ATK, starts climbing in contradiction to the LEVEL OFF command of TCAS RA;
- The flight crew of aircraft A320-232, registration marks TC-ATK, starts climbing without related ATCO instructions issued;
- PF of aircraft A320-232, registration marks TC-ATK disconnects the autopilot when the TCAS TA indication is received;
- PM of aircraft A320-232, registration marks TC-ATK does not notify EXE ATCO about the TCAS RA and CLEAR OF CONFLICT received indications;
- The flight crew of aircraft A320-232, registration marks TC-ATK does not execute CROSS-CHECK;
- Impaired interaction among F/C members of aircraft A320-232, registration marks TC-ATK by TCAS activation in TA and/or TA modes.
- The flight crew of aircraft THY7FX, registration marks TC-JGF correctly disconnect the autopilot upon TCAS RA activation and respond adequately to the generated command CLIMB RA;
- - The flight crew of aircraft THY7FX, registration marks TC-JGF inform the EXE ATCO about the RA and CLEAR OF CONFLICT indications of TCAS received.

4.1.3 Findings regarding aircraft operations

- The flight of aircraft A320-232, registration marks TC-ATK, is carried out in accordance with the flight plan on the route from Dusseldorf to Istanbul (Call sign KKK5LP).
- The flight of aircraft B737-8F2, registration marks TC-JGF, is carried out in accordance with the flight plan on the route from Istanbul to Rome (Call sign THY7FX).

4.1.4 Findings regarding the Air Traffic Service

- The ATCOs performing official duties at the time of the event are licensed, have the necessary qualifications and medical fitness;

- The meteorological conditions at the time of occurrence of the aviation event do not affect the aircraft flights, but cause deviation of air traffic in the controlled air space of SCL and SCU sectors and complicate the work conditions of ATCOs.
- The minimum norm for radar separation in the controlled air space of Sofia Control is violated;
- The requirements for coordination between ATCOs upon work in vertically separated sectors according to Section III, page 2, p. 2.6.3, p.2.6.4, p.2.6.5 of the Manual on ATS are not fulfilled;
- The PLN ATCO of SCU sector confirms the change of the FL of A/C THY7FX (FLCHG) from FL340 to FL380 requested by SCL sector, which is a function of the EXE ATCO;
- The MTCDS subsystem detects a mid-term conflict between A/C THY7FX and A/C KKK5LP and generates a warning at the working positions of SCL and SCU sectors that is not visualized completely. In both the sectors only one red dot for conflict is displayed in the radar label without displaying the corresponding red dot in the 0 radar label of the second aircraft;
- The Safety Nets subsystem of ATCAS SELEX detects conflict between A/C THY7FX and A/C KKK5LP and generates alarm at the ATCOs' working positions of SCL and SCU sectors;
- The EXE ATCO from SCU sector reacts correctly and immediately to the alarm of the Safety Nets subsystem generated and issues instructions to A/C KKK5LP for turning left in order to avoid the conflict situation;
- The EXE ATCO from SCL sector reacts correctly and immediately to the alarm of the Safety Nets subsystem generated and issues instructions to A/C THY7FX for turning left in order to avoid the conflict situation;
- The EXE ATCO from SCL sector does not perform additional coordination with the EXE ATCO from SCU sector regarding the change of trajectory of A/C THY7FX before issuing instructions for turning right with 10°;
- The PLN ATCO from SCL sector processes in a XFL340 for A/C THY7FX at the moment when the EXE ATCO issues instructions to the aircraft for climbing to FL380. In result of this action, the radar label of A/C THY7FX disappears from the SCU sector's display for a period of 1 min 12 s (till the moment when the aircraft reaches FL351 as pre-set into the display filter).
- The EXE ATCO of SCL sector does not perform additional coordination of the change of XFL from FL380 as entered by the PLN ATCO of SCL sector to FL340;
- The EXE ATCO of SCL sector does not use the word "immediately" in his/her instruction for climbing to FL380 after the establishment of the conflict with the purpose of speeding up the implementation.
- EXE ATCO from SCL issued instruction to climb after the flight crew reported the triggering TCAS RA on board of the aircraft THY7FX.

4.2 Causes

Based on the analysis performed, the Commission points out that the serious incident resulted from the following causes:

Main cause:

Incorrect assessment of the air situation and issuing of permission for changing the trajectory of A/C THY7FX without carrying out relevant coordination by the ATCO of sector SCL with the ATCO of sector SCU, uncommanded climb of A/C KKK5LP and no response to TCAS RA by the crew of A/C KKK5LP.

Contributing cause:

Inefficient performance of coordination procedures between ATCOs of SCL and SCU sectors, ACC-Sofia, upon work in vertically separated sectors in accordance with Part 2 of the Manual on Air Traffic Services of the ACC-Sofia.

5 Safety recommendations

In view of the causes for the realized serious incident and the deficiencies found in the course of investigation, the Commission proposes following safety recommendations to be fulfilled:

BG.SIA-2016/04/01. BULATSA shall carry out a workshop with ATCOs from the ACC-Sofia, where to discuss the causes and conclusions related to ATS as addressed in the Final Report on the event investigation. A record of proceedings on the conduct of the workshop shall be drawn up and submitted to the Aircraft, Maritime and Railway Accident Investigation Unit Directorate with the Ministry of Transport, Information Technology and Communications.

BG.SIA-2016/04/02. BULATSA shall install audible recording devices at each working position of the ATS with the purpose to ensure recording of complete information on the status of the surrounding conditions at the working positions in case of aviation event endangering the safety of flights.

BG.SIA-2016/04/03. BULATSA shall consider the possibility for amending the procedure related to FLCHG coordination, as the requirement for confirmation shall be active only for a certain period of time as determined, after which it shall be included into the ATCAS.

BG.SIA-2016/04/04. BULATSA shall include simulator exercises on the coordination between ATCOs upon work in vertically separated sectors in their recurrent training program.

BG.SIA-2016/04/05. BULATSA shall consider the possibility and the operative effect of the MTCDD function warning change, as the depiction of red dot on the 0 line of the aircraft label shall be visible for each relevant corresponding conflict aircraft, irrespective of its location and its owner.

BG.SIA-2016/04/06. "Atlasjet" AO shall include additional theoretical and practical exercises in the recurrent simulator training program for the flight crews for training of actions upon receiving of TCAS TA/RA indication, by paying special attention to the mandatory and exact fulfilment of the RA commands generated by TCAS.

BG.SIA-2016/04/07. Atlasjet AO to include more demanding scenarios covering the TCAS TA/RA commands and related requirements for pilots in both roles of PF and PM in its recurring mandatory CRM training.

NOTE:

After providing the Draft Final Report for the investigation to the parties concerned, the Commission on safety investigation received responses as follows:

1. The National Bureau of Aviation Occurrences Investigation (BEA) declared it has no comments and no remarks on the report content;
2. The EASA declared it has no comments and no remarks on the report content;
3. The EUROCONTROL declared it has no comments and no remarks on the report content;
4. BULATSA declared it has no comments and no remarks on the report content;
5. The Turkish Accident Investigation Board (KAİK), Republic of Turkey provided in its respond:
 - Data readouts from the FDR of A320-232 aircraft, registration marks TC-ATK of AO „Atlasjet”;
 - KAİK's comment paper that include objections and suggestions for additions to the Draft Final Report, as well as notes on technical or terminological mistakes allowed in it.

Commission on safety investigation examined in detail and compared the newly submitted FDR data of aircraft A320-232 with these available to the moment and after discussing the comments provided made the following substantiated changes to the final report:

- Information regarding the data from FDR of A320-232 aircraft, registration marks TC-ATK of AO „Atlasjet” has been added to the FR;
- A copy of the Earth-to-Air radio communication is enclosed in Appendix 1;
- Corrected is the typing mistake made in AO "Turkish Airlines" name;

- After a thorough analysis of the facts and circumstances information on the actions of ATCO, the state of the ATM system and the actions of the flight crews of the two aircraft at the time of event the main cause is defined again. While the conflict conditions have been created, ATCAS generates a warning message and the EXE ATCOs issue instructions to avoid the conflict. After triggering on of the ACAS/TCAS systems on board of two aircraft, the actions of flight crew of A320-232 aircraft, registration marks TC-ATK complicate the situation by reducing the vertical separation and eventually lead to the serious incident. For further correctness, the work of ACAS/TCAS systems during the time of the event has been reproduced using the InCAS v3.3 simulator of the EUROCONTROL in its premises in Brussels.

- The safety recommendation BG.SIA-2016/04/07 is based on facts set out in the report and on the additional information received from the FDR data, and it is made with the intention of preventing accidents or incidents in the future and it is not aimed at creating a presumption of blame or liability for the serious incident. The Safety Investigation Commission notes that the actions of the crew of A320-232 aircraft are probably due to an inadequate interaction between its members and/or due to gaps in their training in the event of abnormal or emergency situations in flight.

Copies of the data and comment document received from KAIK are attached to the case of the event under investigation and may be made available to interested parties in accordance with the requirements of Regulation (EU) No 376/2014 of the European Parliament and of the Council of 3 April 2014.

Appendix 1 and 2 constitute an inseparable part of this report.

The Investigation Commission reminds hereby to all organizations, to which safety measures have been communicated, that on the grounds of Art. 18 of Regulation 996/2010 on the investigation and prevention of accidents and incidents in civil aviation, and Art. 19, par. 7 of Ordinance No 13 on the investigation of aviation events they are obliged to notify in writing the Aircraft, Maritime and Railway Accident Investigation Unit Directorate at with the Ministry of Transport, Information Technology and Communications on the status of safety measures.

Chairman of the Commission:

Valeri Karaliyski

Appendix 1 - ATC-Aircraft communication transcripts

Sofia Control – sector SDL- frequency 129,100 MHz

14:53:27: THY7FX - THY7FX “Dobar den komshu“ * maintain FL 320 request FL 380.

14:53:32: EXE ATC - Radar contact climb FL 340 initially.

14:53:40: THY7FX- Climbing FL 340 THY7FX.

Sofia Control – sector SCL - frequency - 135,025 MHz

15:06:23 - THY7FX - “Sofia Dobar den komshu“Level 340

15:06:29 - EXE ATC – THY7FX “Dobar den komshu “– Identified.

15:06:34 - THY7FX And requesting FL 380 when available and we can take right turn ...

15:06:40 - EXE ATC: Copied Standby to coordinate, 7FX

15:15:20 - EXE ATC: – THY7FX, climb FL380, turn 10° to the right“.

15:15:24 - THY7FX- Just confirm 10° to the right and then climb FL 380

15:15:33 - EXE ATC THY7FX affirm

15:15:34 - THY7FX - Thank you!

15:18:15 - EXE ATC - THY7FX maintain... desc (dis...)... THY7FX, turn 40° to the left“.

15:18:16 - THY7FX No answer

15:18:22 - EXE ATC - „THY7FX turn immediately 40° to the left“

15:18:23 - THY7FX - Roger, turn left, we have TCAS RA“

15:18:30 - EXE ATC climb 380 immediately

15:18:31 - THY7FX - Now we are cleared of traffic, THY 7FX.

15:18:32 - EXE ATC – Affirm

15:19:02 - THY7FX - Which heading do you like?

15:19:06 - EXE ATC - THY7FX proceed direct to VELOG contact Belgrade 129.230

15:19:16 - THY7FX- Belgrade 129.230 7FX Good-bye!

Sofia Control – sector SCU - frequency - 128,530 MHz

15:11:08 - KKK5LP: Atlasjet 5LP: maintaining 370 on course ETIDA

15:11:11 - EXE ATC: Atlasjet 5LP Sofia Control identified.

15:18:09 - EXE ATC: Atlasjet 5LP immediately turn immediately turn left heading 060, Atlasjet 5LP immediately turn 60 degrees to the left.

15:18:28 - EXE ATC: Atlasjet 5LP immediately turn 60 degrees to the left.

15:18:30 - KKK5LP: Atlasjet 5LP immediately turn ...

15:20:45 - KKK5LP Atlasjet 5LP heading 060 also we have received TCAS RA

15:20:52 - EXE ATC: Atlasjet 5LP Copied, you can resume own navigation to GERGI.

15:21:01 - KKK5LP: Own navigation to GERGI Please say the reason the TCAS RA reason.

15:21:10 - EXE ATC: An opposite traffic climbing FL 380

*Note: “Dobar den komshu“ – “Good Day neighbor”

Appendix 2



Network Manager
nominated by
the European Commission



Appendix 2

TCAS analysis for the Bulgarian Aircraft, Maritime and Railway Investigation Unit Directorate

KKK5LP & THY7FX on 4 June 2016

(version 3)

Stan Drozdowski

Senior ACAS Expert

28 February 2017

 stanislaw.drozdowski@eurocontrol.int



Background

- A loss of separation between KKK5LP and THY7FX occurred on 4 June 2016 at 15:18 UTC in Bulgarian airspace.

| | Aircraft 1 | Aircraft 2 |
|----------------|------------|------------|
| Callsign | KKK5LP | THY7FX |
| Aircraft type | A320 | B737-800 |
| Registration | TC-ATK | TC-JGF |
| Mode S address | 4B868B | 4BA8E6 |
| SSR Code | 7654 | 2313 |

- The Aircraft, Maritime and Railway Investigation Unit Directorate of the Bulgarian Ministry of Transport, Information Technology and Communications asked EUROCONTROL to conduct analysis of the event to establish whether TCAS II performed as required.



Previous analysis of this event

- EUROCONTROL previously conducted an assessment of this event on 18 January 2017 based on the tracker data.
- As now ASTERIX recording files have become available, the analysis are repeated as it is believed the information contained in the ASTERIX files is of higher fidelity and will produce results of higher credibility.
- **The current version of the report (version 3 dated 28 February 2017) supersedes all previous version of this report.**



TCAS II equipage

- Both aircraft, based on their MTOM and/or passenger seating were required to be equipped with TCAS II (Traffic alert and Collision Avoidance System) version 7.1¹⁾.
- **THY7FX:** Mode S downlink BDS10 indicates that the aircraft was equipped with and operating TCAS II version 7.1
- **KKK5LP:** No radar data (BDS10 register) regarding the equipage was available (probably because the equipage interrogation occurred outside the timeframe of the provided recordings). For the purpose of this report, it has been assumed that KKK5LP was equipped as required.

¹⁾ Commission Regulation (EU) No 1332/2011 and Commission Regulation (EU) No 2016/583



InCAS v3.3 (Interactive Collision Avoidance Simulator)

- InCAS shows events with horizontal and vertical views.
- InCAS can also:
 - Show pilot displays;
 - Simulate idealised pilot response;
 - Give details of ACAS decision making.
- InCAS altitudes and vertical rates are interpolated between radar updates.



Data source & processing

- The following radar data was provided by the Bulgarian Aircraft, Maritime and Railway Investigation Unit Directorate :
 - Pilot reports (ASRs)
 - KKK5LP FDM analysis printout
 - THY7FX FDR records (TCAS-relevant fields)
 - Binary ASTERIX files from Otopeni, Koviona and Vitosha radars.
- ASTERIX data was converted to .eu1 format for InCAS processing.
- Additionally, RA downlink messages (BDS30) and TCAS equipage messages (BDS10) were extracted.
 - Note: TA are not downlinked.
- Data from the Koviona radar (fastest update rate) was used to recreate trajectories.
- Results were cross checked versus THY7FX FDR data and KKK5LP FDM printout.



Analysis of the event

- For clarity of results, the trajectories were truncated to start at ~15:14:00 and terminate at ~15:21:50 (i.e. ~300 seconds before and ~170 seconds after Closest Point of Approach).



RA downlink vs. InCAS simulation

- Typically, InCAS is used for this type of incident analysis to recreate TCAS alerts.
- In the case examined here, RA downlink messages were available and were compared with InCAS simulation.
- Since InCAS produced different sequences and times of events from those obtain via RA downlink, it has been decided to use only RA downlinks for further analysis.
 - RA downlink messages provide information on RAs as they occurred on the aircraft (with the latency of up to the time of radar rotation cycle).
 - InCAS assumes “perfect” TCAS air-to-air surveillance, i.e. there is no possibility to reproduce “as was” TCAS air-to-air surveillance.
 - The results on InCAS recreation are shown in the Appendix.
 - Finally, expert judgement was used to assess if TCAS performance was as expected.



Timings of RA downlink messages

| Event (cockpit aural annunciation) | Vitosha Radar first/last detection (10 sec. update rate) | Koviona Radar first/last detection (4 sec. update rate) | Otopeni Radar first/last detection (8 sec. update rate) | Derived time of the event |
|---|--|---|---|------------------------------|
| KKK5LP Level Off RA (Level off, level off) | 15:18:22 15:18:32 | 15:18:22 15:18:30 | 15:18:20 15:18:28 | 15:18:19 / 15:18:20 |
| KKK5LP RA Terminated (Clear of conflict) | 15:18:42 15:18:42 | 15:18:34 15:18:50 | 15:18:36 15:18:42 | 15:18:33 / 15:18:34 |
| THY7FX Climb RA (Climb, climb) | 15:18:22 15:18:22 | 15:18:22 15:18:30 | 15:18:28 15:18:28 | 15:18:21 / 15:18:22 |
| THY7FX RA Terminated (Clear of conflict) | 15:18:32 15:18:42 | 15:18:34 15:18:46 | 15:18:36 15:18:44 | 15:18:31 / 15:18:32 |

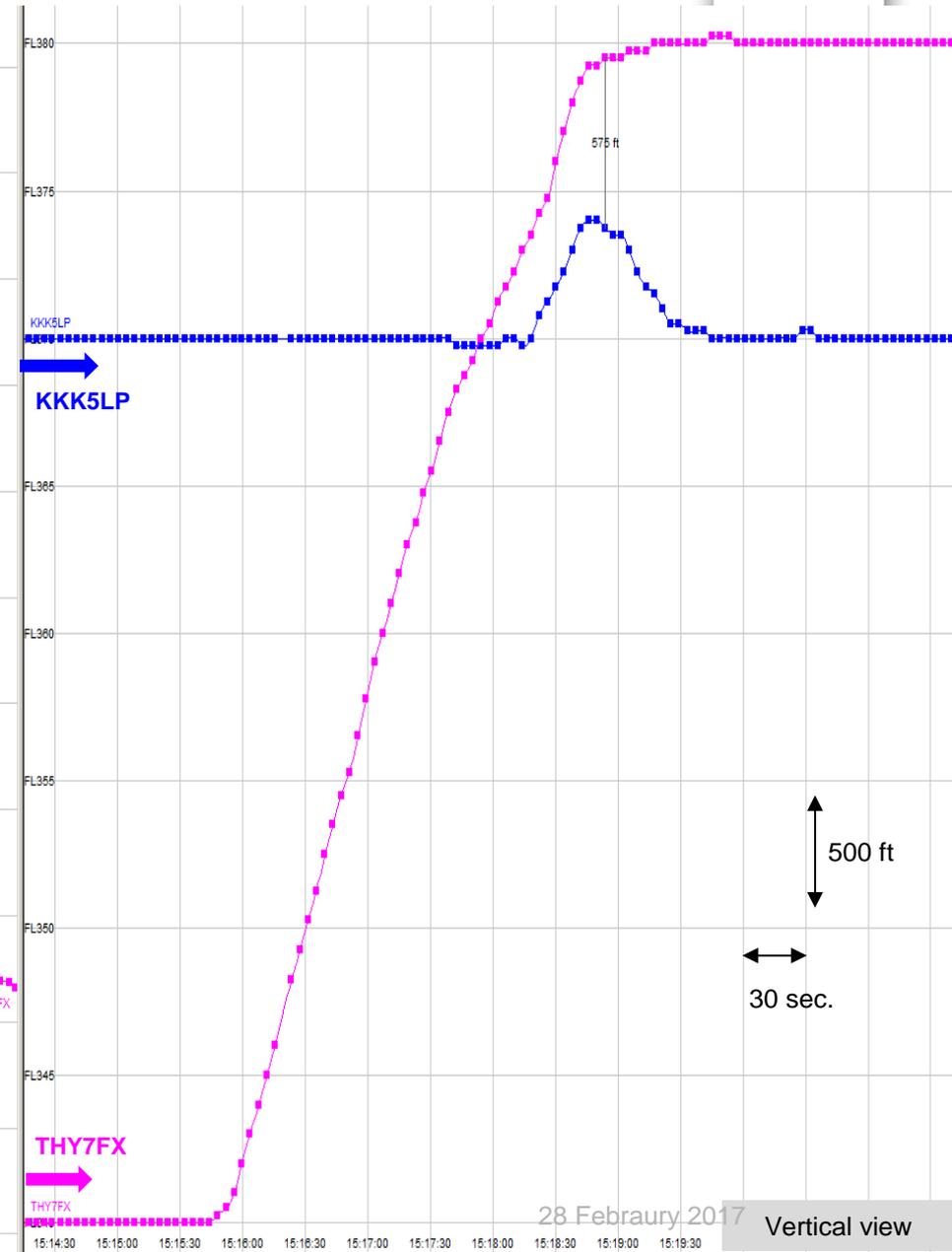
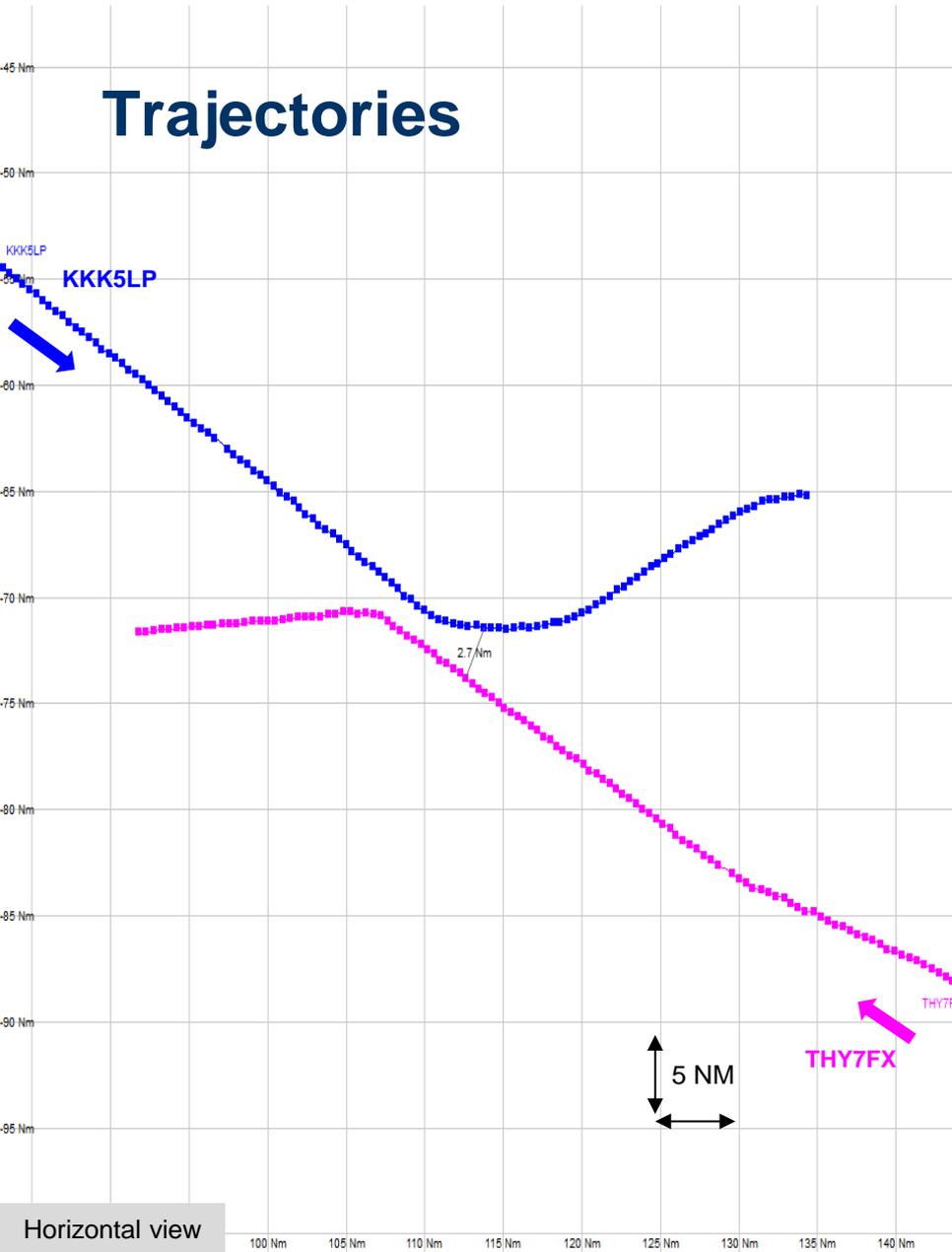
RA downlink messages identified KKK5LP and THY7FX, respectively, as the intruders (by Mode S address)

Notes:

- Perfect reliability of radar detection has been assumed.
- The timing of RA based on the RA downlink message is delayed up to the number of seconds representing the update rate
- The earliest of the derived times is used in the subsequent analysis.

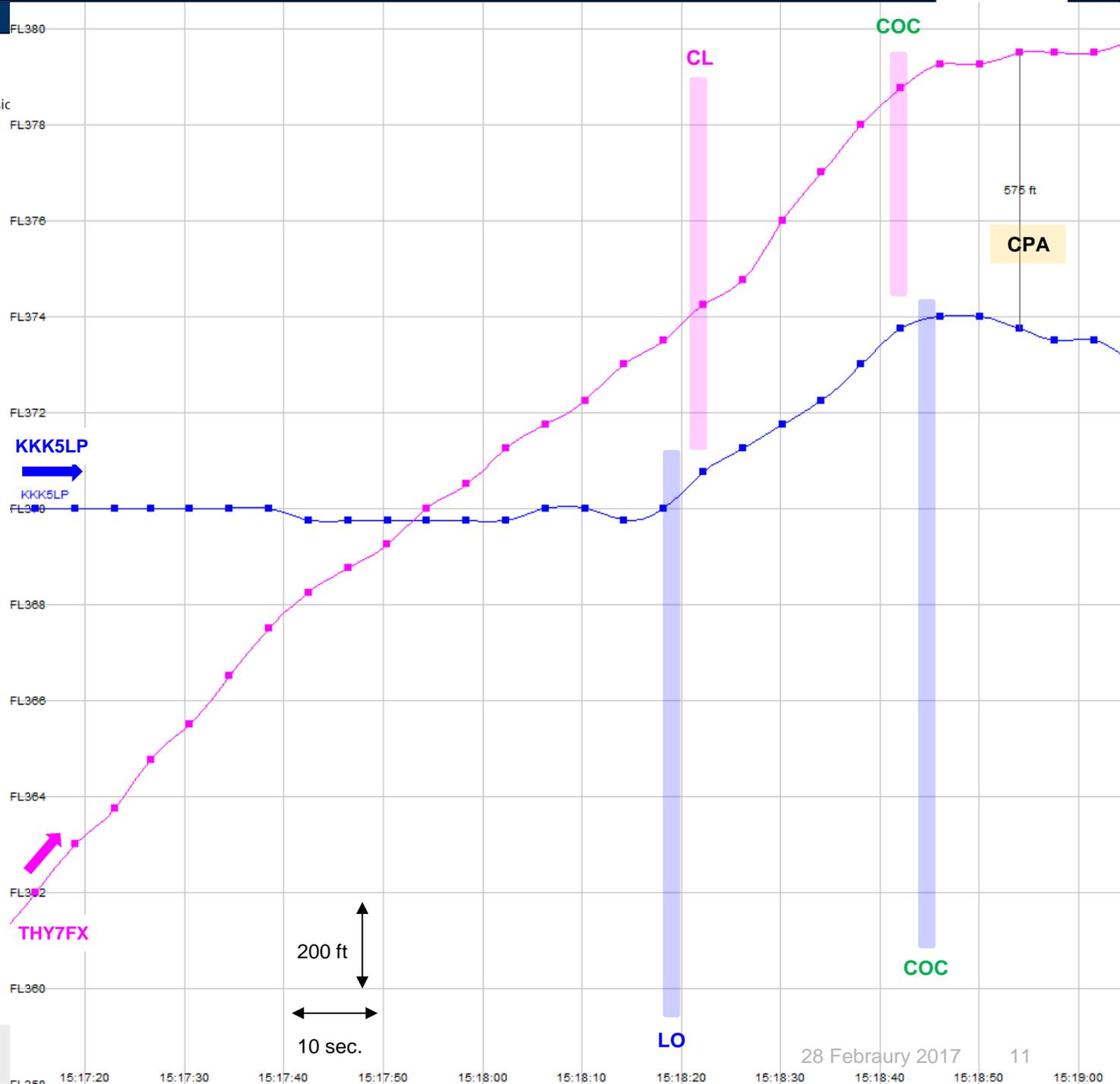


Trajectories





Vertical trajectories (close-up) & RAs





Timing of events (1)

| Time | Event (cockpit aural annunciation) | Horizontal separation [NM] | Vertical Separation [ft] | KKK5LP | | THY7FX | |
|------------|--|-------------------------------|-----------------------------|------------------|---------------------------|------------------|---------------------------|
| | | | | Altitude [ft] | Vertical Rate [ft/min] | Altitude [ft] | Vertical Rate [ft/min] |
| 15:14:06 | Start of simulation | 70.9 | -3000 | 37000 | 0 | 34000 | 0 |
| 15:15:45 | THY7FX starts to climb | 46.4 | -2995 | 37000 | 0 | 34004 | +300 |
| 15:17:55 | THY7FX crosses KKK5LP's altitude | 14.1 | +45 | 36975 | 0 | 37020 | +600 |
| 15:18:16 | KKK5LP starts to climb | 9.2 | +344 | 36997 | +300 | 37321 | +600 |
| 15:18:19*) | KKK5LP Level Off RA (Level off, level off) | 8.5 | +351 | 37012 | +1000 | 37363 | +1100 |
| 15:18:21*) | THY7FX Climb Resolution Advisory (Climb, climb) | 8.1 | +352 | 37052 | +1200 | 37404 | +1100 |

... continued on the next page ...



Timing of events (2)

| Time | Event (cockpit aural annunciation) | Horizontal separation [NM] | Vertical Separation [ft] | KKK5LP | | THY7FX | |
|------------|---|-------------------------------|-----------------------------|------------------|---------------------------|------------------|---------------------------|
| | | | | Altitude [ft] | Vertical Rate [ft/min] | Altitude [ft] | Vertical Rate [ft/min] |
| 15:18:29 | 10 sec. after KKK5LP Level Off RA | 6.2 | +401 | 37160 | +700 | 37561 | +2000 |
| 15:18:31*) | THY7FX RA terminates (Clear of conflict) | 5.8 | +440 | 37184 | +700 | 37624 | +1600 |
| 15:18:33*) | KKK5LP RA terminates (Clear of conflict) | 5.3 | +464 | 37209 | +700 | 37673 | +1300 |
| 15:18:46 | KKK5LP levels off | 3.0 | +525 | 37399 | 0 | 37924 | +300 |
| 15:18:54 | Closest Point of Approach | 2.65 | +575 | 37374 | -500 | 37949 | +200 |

*) The earliest of the times derived from RA downlink messages.

Note:

In the Vertical Separation column, the + sign indicates that THY7FX was above KKK5LP, the – sign indicates that THY7FX was below. In the Vertical Rate columns, the + sign indicates a climb, the – sign indicates a descent.



Analysis of responses to RAs: KKK5LP

| Time ^{*)} | Event | Required Vertical Rate [ft/min.] | Actual Vertical Rate [ft/min.] | Δ [ft/min.] |
|--------------------|------------------------|----------------------------------|--------------------------------|--------------------|
| 15:18:19 | Level Off RA | 0 | +1000 | +1000 |
| 15:18:24 | Level Off RA +5 sec. | 0 | +700 | +700 |
| 15:18:29 | Level Off RA +10 sec. | 0 | +700 | +700 |
| 15:18:32 | RA termination -1 sec. | 0 | +700 | +700 |

*) The earliest of the times derived from RA downlink messages.

Note:
In the Vertical Rate columns, the + sign indicates a climb, the – sign indicated a descent.

In the Δ column, the + sign indicates a reaction weaker than required, the – sign indicated a reaction stronger than required.



Analysis of responses to RAs: THY7FX

| Time ^{*)} | Event | Required vertical rate [ft/min.] | Actual vertical rate [ft/min.] | Δ [ft/min.] |
|--------------------|------------------------|----------------------------------|--------------------------------|--------------------|
| 15:18:21 | Climb RA | +1500 | +1000 | +500 |
| 15:18:27 | Climb RA +6 sec. | +1500 | +1700 | -200 |
| 15:18:30 | RA termination -1 sec. | +1500 | +1900 | -400 |

*) The earliest of the times derived from RA downlink messages.

Note:
In the Vertical Rate columns, the + sign indicates a climb, the – sign indicated a descent.

In the Δ column, the + sign indicates a reaction weaker than required, the – sign indicated a reaction stronger than required.



THY7FX: InCAS trajectory, RA downlink message and FDR recordings compared

- FDR and ground system clocks are not synchronised; therefore it is not possible to reliably compare the timing of events. Altitudes were used instead for comparison.
- The following events were compared:

| Event | FDR Altitude [feet] | Recreation Altitude [feet] | Δ |
|----------------|---------------------|----------------------------|----------|
| Climb RA | 37363 | 37404 | -41 |
| RA termination | 37597 | 37624 | -27 |

- The FDR recording shows the RA duration to be 10 sec.
- RA downlink messages indicate the RA duration of 10 sec., too.



KKK5LP: InCAS trajectory, RA downlink message and FDM recordings compared

- FDM and ground system clocks are not synchronised; therefore it is not possible to reliably compare the timing of events. Altitudes were used instead for comparison.
- The following events were compared:

| Event | FDR Altitude [feet] | Recreation Altitude [feet] | Δ | FDR Vertical Rate [ft/min.] | Recreation Vertical Rate [ft/min.] | Δ |
|------------------------------------|---------------------|----------------------------|----------|-----------------------------|------------------------------------|----------|
| RA (FDM does not indicate RA type) | 37024 | 37012 | 12 | +1100 | +1100 | 0 |
| RA termination | 37264 | 37217 | 47 | +1100 | +1100 | 0 |

- The FDM recording shows the RA duration to be 15 sec. InCAS simulation shows the RA duration of 14 sec.



Sequence of events (1)

- At 15:17:55 THY7FX crossed KKK5LP's altitude at the distance of 14.1 NM climbing with a rate of 600 ft/min.
- At 15:18:16 KKL5LP's vertical rate started to increase and KKL5LP established a climb.
- RA downlink messages indicate that KKK5LP received a Level Off RA between 15:18:19 and 15:18:20. At this time KKK5LP was climbing at +1000 ft/min.
- The expected reaction to a Level Off is the reduction of vertical speed to 0 ft/min., i.e. a level off.
- There was no visible decrease of KKK5LP vertical rate during the RA.
- RA downlink messages indicate that KKK5LP received a Clear of Conflict annunciation between 15:18:33 and 15:18:34.
- KKK5LP continued to climb until 15:18:46, reaching 37399 feet when it levelled off .



Sequence of events (2)

- RA downlink messages indicate that at between 15:18:21 and 15:18:22 THY7FX received a Climb RA.
- The expected reaction to a Climb RA is a climb at the rate of +1500 ft/min.
- THY7FX increased its rate of climb to +1100 ft/min. 5 sec. after the RA and +1900 ft/min. 9 sec. after the RA.
- RA downlink messages indicate that at between 15:18:31 and 15:18:32 THY7FX received Clear of Conflict message (RA termination).
- RA downlink messages indicate that at between 15:18:33 and 15:18:34 KKK5LP received Clear of Conflict message (RA termination).
- The Closest Point of Approach occurred at 15:18:54. The separation was 2.65 NM and 575 feet.



Analysis

- KKK5LP started to climb before receiving an RA against THY5LP.
- KKK5LP continued to climb after receiving a Level Off RA.
- There was no visible decrease of KKK5LP's vertical until after the RA termination.
- THY7FX received a Climb RA while climbing at +1000 ft/min. TCAS II will issue a Climb RA to a climbing aircraft if the vertical rate is below +1500 ft/min.
- THY7FX increased its vertical to 1300 and then 1400 ft/min.



Conclusions

1. Radar data together with Mode S RA downlink messages and airborne recordings provided a credible picture of the event.
2. Although not confirmed by InCAS simulations, expert judgement is that TCAS worked as expected and played a role in resolving the conflict providing vertical spacing between the aircraft.
3. RAs were issued as the aircraft were projected to be close in range and predicted vertical miss distance was below the alarm threshold value (700 feet).
4. KKK5LP did not respond to the Level Off RA and continued to climb.
5. THY7FX established a 1500 ft/min. rate of climb within ~6 sec. of the Climb RA.



Network Manager
nominated by
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Appendix: InCAS simulation (not used for this analysis)

