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Swiss Accident Investigation Board SAIB

Aviation Division

Final Report No. 2208 by the Swiss Accident Investigation Board SAIB

concerning the serious incident (near collision)

involving the Airbus A340-313 aircraft, registration HB-JMN, under flight plan call sign SWR 39

and the ASW 20 glider, registration HB-1519

on 11 August 2012

in TMA LSZH 2, 17 NM north-west of Zurich Airport

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General information on this report

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

In accordance with Art 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 German language.

All times in this report, unless otherwise indicated, follow the coordinated universal time (UTC) format. At the time of the incident, Central European Summer Time (CEST) applied as local time (LT) in Switzerland. The relation between LT, CEST and UTC is:
LT = CEST = UTC + 2 hours.

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Final Report

Synopsis

Aircraft 1	
Owner	Maple Leaf Leasing 8 Limited, Cayman Islands
Operator	Swiss International Air Lines Limited, Switzerland
Manufacturer	Airbus S.A.S., Toulouse, France
Aircraft type	Airbus A340-313
Country of registration	Switzerland
Registration	HB-JMN
Commercial flight number	LX 39
Flight plan call sign	SWR 39
Radio call sign	Swiss three niner
Flight rules	Instrument flight rules (IFR)
Type of operation	Scheduled flight
Departure point	San Francisco (KSFO)
Destination point	Zurich (LSZH)
Aircraft 2	
Owner	Private
Operator	Private
Manufacturer	Alexander Schleicher GmbH & Co., Germany
Aircraft type	ASW 20
Country of registration	Switzerland
Registration	HB-1519
Flight rules	Visual flight rules (VFR)
Type of operation	Training flight
Departure point	Bohlhof glider airfield D
Destination point	Bohlhof glider airfield D
Location	17 NM north-west of Zurich Airport, German sovereign territory
Date and time	11 August 2012, 13:32 UTC
ATS unit	Zurich Final (FIN)
Airspace	Class C
Minimum separation of the two aircraft (according to analyses of the two flight paths)	At approximately the same height, approximately 260 m horizontally
AIRPROX category	ICAO Category A (high risk of collision)

Investigation

The serious incident occurred on 11 August 2012 at 13:32 UTC. The notification was received on 13 August 2012 by the Swiss Accident Investigation Board (SAIB). After preliminary clarifications, which are typical with this type of serious incident, the investigation was opened by the SAIB on 7 September 2012, after the handling of this event had been delegated by the German Federal Bureau of Aircraft Accident Investigation (BFU). The BFU appointed an authorised representative, who with his advisors assisted with the investigation.

This final report is published by the SAIB.

Summary

On 11 August 2012 a commercial aircraft, an Airbus A340-313, registration HB-JMN, was on a scheduled flight from San Francisco to Zurich. After an uneventful flight, the crew received clearance to descend to 4000 ft QNH from the Zurich Final (FIN) air traffic control officer at 13:32:04 UTC. At this time the aircraft was in Class C airspace in terminal control area (TMA) LSZH 2 at an altitude of 6000 ft QNH, with a rate of descent (ROD) of 2500 ft/min and an indicated airspeed of 245 KIAS (knots indicated airspeed).

At the same time, an ASW 20 glider, registration HB-1519, which had taken off from the Bohlhof glider airfield on a training flight at 12:59 UTC, was located on the southern boundary of TMA LSZH 2 at an altitude of just over 4700 ft QNH.

While turning onto the localiser axis, the third pilot of the A340-313, who was in the central third occupant seat in the cockpit, surprisingly caught sight of the glider, which was at the same altitude on a collision course. He warned the two pilots conducting the flight and a pronounced avoidance manoeuvre was initiated. The recordings show a maximum bank angle of 36 degrees to the left and an increase in attitude to approximately 5 degrees, which generated a normal acceleration of 1.6 g. At this time the aircraft was still in Class C airspace in TMA LSZH 2 at an altitude of 4700 ft QNH, with a rate of descent (ROD) of 350 ft/min and a speed of 248 KIAS.

According to the recordings of the two flight paths, the two aircraft passed at approximately the same height at a lateral distance of approximately 260 m.

The air traffic control officer (ATCO) was unable to detect the glider at any point as it was not equipped with a transponder and therefore could not be detected by radar. The ground-based and aircraft-based safety nets were not able to respond for the same reason.

After the avoidance manoeuvre, SWR 39 landed on runway 14 in Zurich at 13:38 UTC. The glider continued its flight and landed at Bohlhof glider airfield at 13:59 UTC.

Causes

The near collision is attributable to the fact that a glider, without a respective clearance, was in airspace class C in which a commercial aircraft was directed below the minimum radar vector altitude.

The following factors were identified as the direct cause of this near collision:

- Lack of risk awareness on the part of the glider pilot.
- The ATCO issued a descend clearance to an altitude which was, in the airspace in which the clearance was given, below the minimum radar vector altitude for instrument flights, without monitoring a possible violation.

The following factor was identified as a systemic cause:

- The absence of a compatible safety system for gliders, commercial aircraft and air traffic control which could have warned of the dangerous convergence.

The following was identified as a contributing systemic factor:

- The air navigation services company did not realise that the minimum radar vector altitude was occasionally violated when clearance to descend was issued.

The following factors were identified neither as causal nor as contributory but as systemic factors to risk:

- The airspace structure around Zurich airport is complex, make it demanding for crews to use and for air traffic control officers to manage.
- The airspaces around Zurich airport are, regarding their vertical dimension, designed in a way that also relatively small mistakes can already lead to dangerous situations.

Safety recommendations

In the context of the investigation, five safety recommendations were issued.

According to the provisions of Annex 13 of the ICAO, all safety recommendations listed in this report are intended for the supervisory authority of the competent state, which has to decide on the extent to which these recommendations are to be implemented. Nonetheless, any agency, any establishment and any individual is invited to strive to improve aviation safety in the spirit of the safety recommendations pronounced.

Swiss legislation provides for the following regulation regarding implementation in the Ordinance on the Investigation of Aircraft Accidents and Serious Incidents:

"Art. 32 Safety recommendations

[1] DETEC, on the basis of the safety recommendations in the SAIB reports and in the foreign reports, shall address implementation orders or recommendations to the FOCA.

[2] The FOCA shall inform DETEC periodically about the implementation of the orders or recommendations pronounced.

[3] DETEC shall inform the SAIB at least twice a year on the state of implementation by the FOCA."

1 Factual information

1.1 Pre-history and history of the serious incident

1.1.1 General

The recordings of the radio communication, radar data, the flight data for SWR 39, the recordings of the FLARM collision avoidance system on board the glider as well as the statements of crew members and the air traffic control officer involved were used for the following description of the pre-history and history of the serious incident.

Flight SWR 39 was conducted according to instrument flight rules; the glider flight was conducted according to visual flight rules (VFR).

The serious incident occurred in the Swiss Radar Area East sector, within the area of responsibility of the Zurich Final (FIN) air traffic control officer. Radio communication took place on the 125.325 MHz frequency.

1.1.2 Pre-history

Flight SWR 39 was a scheduled flight from San Francisco (KSFO) to Zurich (LSZH). The flight crew consisted of an augmented flight crew[1], i.e. a commander and two copilots. At the time of the serious incident the commander was pilot not flying (PNF) and copilot 1 was pilot flying (PF). Approximately 20 minutes before the landing, the copilot 2 took the central third occupant seat to monitor the approach in the cockpit.

The glider was a single-seater performance glider. The pilot was on a training flight from the Bohlhof glider airfield.

At the time of the serious incident all five working positions in the Zurich Approach Control (APP) unit were occupied. There were no technical restrictions. According to the air traffic control officer involved (final – FIN) in relation to traffic volume there was inbound rush, the frequency occupancy was high and complexity was not increased.

1.1.3 History of the serious incident

At 02:51:32 UTC on 11 August 2012 the A340-313 aircraft, with the flight plan call sign SWR 39, registration HB-JMN, took off from San Francisco (KSFO) on runway 28R on a scheduled flight to Zurich (LSZH). On board were three pilots, 12 cabin crew members and 215 passengers.

At 12:59 UTC the pilot of the ASW 20 single-seater glider, registration HB-1519 took off by means of aerotow on a training flight from Bohlhof glider airfield. At 13:19:25 UTC he flew north of Birkendorf under TMA LSZH 2 (cf. Annex 2), where he found thermals and climbed to an altitude of over 1450 m AMSL (equal to 4757 ft AMSL). The lower limit of TMA LSZH 2 is 4500 ft AMSL.

After an uneventful flight, the crew of SWR 39 reported to the air traffic control unit Zurich Nord sector ATCO as follows: *"Swiss radar grüezi, Swiss three niner level one six zero maintaining."* At this time the aircraft had an indicated airspeed of 306 KIAS and was decelerating. The air traffic control officer (ATCO) replied: *"Guete Tag Swiss three niner, identified, continue RILAX, descend flight level one five zero, speed two ten."* Four seconds later the crew replied *"Speed two ten, level one five zero, on course RILAX Swiss three niner."* Forty seconds later

[1] Augmented flight crew is the designation used by the operator to describe an extended flight crew. There are two types of augmented flight crew. These are described in Operation Manual (OM) A of the operator (cf. Section 1.7.1.).

the ATCO issued clearance to descend to flight level (FL) 130, which the crew confirmed immediately. At this time the speed was 279 KIAS and still decreasing.

The crew of SWR 39 reported to the Zurich Arrival air traffic control officer (ATCO) at 13:25:26 UTC as follows: *"Zurich arrival grüezi, Swiss three niner heavy, A-three forty, descending level one three zero. We have TANGO, speed two two zero knots."* At this time the aircraft was descending and passing FL 157 at a speed of 267 KIAS and decreasing. According to the commander's statement, his indication "*220 knots*" was intended to make clear that the SWR 39 had received a speed restriction. For the ATCO however it was obvious that SWR 39 was already at that speed. The ATCO immediately replied as follows: *"Swiss three niner Zurich arrival grüezi continue on present heading vectoring for ILS approach runway one four, expect no delay, maintain the speed."* The crew believed this meant that they could maintain their current speed, approximately 260 KIAS at that time. The crew confirmed this immediately as follows: *"Maintaining ah speed and ah one eight zero the heading and descending one three zero Swiss three niner."* The ATCO then informed the crew that they still had a flight path of 48 miles until landing and gave them clearance to descend to FL 100, which was immediately acknowledged by the crew. At this time the aircraft was descending and passing FL 154; the indicated airspeed was 259 KIAS. At 13:29:17 UTC there was a further clearance to descend to FL 80, which the crew confirmed. At 13:29:55 UTC, the ATCO gave the crew of SWR 39 the following heading instruction: *"Swiss three niner turn right heading two four zero."* At 13:30:36 UTC, while the aircraft was descending to FL 80 at 250 KIAS, the crew of SWR 39 received the clearance *"Swiss three niner descend to six thousand feet QNH one zero one niner"*, which they confirmed. At 13:31:03 UTC they were instructed to switch to the Zurich Final frequency.

At 13:31:21 UTC the crew of SWR 39 reported to the Zurich Final air traffic control officer (ATCO) and at 13:31:24 UTC received the clearance: *"Swiss three niner, Final, descend to five thousand feet"*, which was confirmed by the crew. At this time the aircraft was at an altitude of 7450 ft QNH, with a rate of descent (ROD) of 1900 ft/min and a speed of 249 KIAS.

By this time, the glider had reached the southern boundary of TMA LSZH 2 near Krenkingen and at 13:30:33 UTC was at an altitude of approximately 1500 m AMSL (equal to 4921 ft AMSL). The glider pilot later explained the situation as follows [translated from German]: *"While circling I exceeded the permissible altitude of 1376 m* [equal to 4514 ft] *by around 50 to 70 m, because I needed some height for the onward flight."*

At 13:32:04 UTC the ATCO issued the crew of SWR 39 the following clearance: *"Swiss three niner, turn left heading one seven zero, descend four thousand feet, cleared ILS approach runway one four, report established."* The aircraft was at an altitude of 6000 ft QNH, with a rate of descent (ROD) of 2500 ft/min and a speed of 245 KIAS. The commander acting as PNF read this clearance back and at the same time monitored the corresponding entries made by the copilot on the flight control unit (FCU). A few seconds later, at 13:32:23 UTC the ATCO gave the crew of SWR 39 the instruction *"Swiss three niner, reduce minimum clean speed[2] or less".* At this time the aircraft was at an altitude of 5050 ft QNH, with a rate of descent (ROD) of a little over 2700 ft/min and a speed of 254 KIAS. The commander confirmed the ATCO's instruction as follows: *"Minimum clean or less, Swiss three niner."*

[2] In the present case, the minimum speed without flaps (minimum clean speed) was 227 KIAS. This value depends on the type and weight of the aircraft. The air traffic control officer only knows the approximate speed.

At 13:32:25 UTC the glider was circling left in TMA LSZH 2, along the southern boundary with TMA LSZH 1, at an altitude of approximately 1450 m AMSL (equal to 4757 ft AMSL). According to the statement of the glider pilot, he saw the Airbus A340-313 from a distance of approximately 5 to 6 km on the eastern edge of the Steinatal flying south in descent. In order to avoid the Airbus A340-313, the glider pilot initiated a tight right turn at 13:32:32 UTC and then transited TMA LSZH 1 for a short period in a wide right turn in a north-westerly direction (cf. Annex 4).

At approximately the same time, the copilot 2, who was in the central third occupant seat, saw the glider and called out: *"Segelflieger* [Glider]*!"* The copilot 1 and the commander, warned by the copilot's 2 call out in the third occupant seat, detected the glider almost simultaneously. The commander instinctively and vociferously instructed the copilot to respond; he did so simultaneously with a pronounced control input. At this time the aircraft was at an altitude of 4700 ft QNH in the transition to level flight, with a rate of descent (ROD) of 350 ft/min and decreasing, and a speed of 248 KIAS. The recordings from 13:32:40 UTC indicate a maximum bank angle of 36 degrees to the left and an increase in attitude to approximately 5 degrees, which generated a normal acceleration of 1.6 g[3]. According to the recordings of the two flight paths, the two aircraft passed at approximately the same altitude at a lateral distance of approximately 260 m at 13:32:45 UTC.

Immediately after the avoidance manoeuvre performed by the crew of SWR 39, the commander of SWR 39 pressed the event button[4] and reported to the ATCO: *"Swiss three niner, we have a close encounter here with a glider at four thousand seven hundred feet and we are proceeding back to the clearance."* The ATCO thanked him for this information and at 13:33:12 UTC told the crew: "*Swiss three niner, just about two miles north of your position, he was allowed at four thousand five hundred feet, just below the TMA, but then only three thousand feet."* At 13:33:22 UTC the commander intervened as follows: *"No, he was at four thousand seven hundred feet",* to which the ATCO replied five seconds later: *"Ah, Swiss three niner, roger, then we'll file a report about that."*

The crew continued the initiated approach and landed on runway 14 in Zurich at 13:38 UTC.

The glider pilot continued his flight towards Bohlhof glider airfield and landed there at 13:59 UTC.

The Zurich Final ATCO continued his work until the working position closed at approximately 14:30 UTC. At 13:41:49 UTC he issued the crew of SWR 169R, which was arriving from the north within TMA LSZH 2, clearance to 5000 ft QNH and a few seconds later made the crew aware of a reported glider by means of traffic information. The ATCO only issued clearance to 4000 ft QNH once SWR 169R was within TMA LSZH 1 (cf. Annex 16). At 13:46:00 UTC the ATCO issued SWR 1801, which was the subsequent aircraft and also arriving from the north, clearance to descend to 4000 ft QNH while it was still within TMA LSZH 2. SWR 1801 passed the boundary with TMA LSZH 1 at an altitude of approximately 6000 ft QNH (cf. Annex 16).

[3] "g" refers to acceleration due to gravity (approximately 9.81 m/sec^2).

[4] Pressing the event button sets a marker on the flight data recorder (FDR) which makes it possible to quickly find the information in the records and retrieve the data.

1.1.4	Location of the serious incident	
	Position	17 NM north-west of Zurich Airport
	Date and time	11 August 2012, 13:32 UTC
	Lighting conditions	Daylight
	Altitude	4700 ft QNH

1.2 Personnel information

1.2.1	Crew of SWR 39	
1.2.1.1	Commander	
	Person	Swiss citizen, born 1954
	Licence	Airline transport pilot licence aeroplane (ATPL(A)) according to Joint Aviation Requirements (JAR), first issued by the Federal Office of Civil Aviation (FOCA) on 4 January 1994.
	Ratings	Type rating Airbus A330/A340 as pilot in command, valid till 30 September 2013 and 2 March 2013 respectively. Radiotelephony R/T in English. Language proficiency English level 4, valid till 31 March 2014.
	Instrument rating	Instrument rating aeroplane IR(A)
	Last proficiency check	Licence proficiency check (LPC) on 27 February 2012. Operator proficiency check (OPC) on 27 July 2012.
	Medical fitness certificate	Class 1 with restrictions (VML: shall wear multifocal lenses), issued on 8 February 2012, valid till 25 February 2013.
1.2.1.1.1	Flying experience	
	Total	15 020 hours
	of which as commander	11 053 hours
	on the type involved in the incident	1219 hours
	of which as commander	1219 hours
	during the last 90 days	148 hours
	on the type involved in the incident	58 hours
1.2.1.1.2	Crew duty times	
	Duty times before the day of the incident	9 August 2012: off duty 10 August 2012: off duty
	Start of flight duty on the day of the incident	01:35 UTC
	Flight duty time at the time of the serious incident	11:57 hours

1.2.1.2 Copilot 1

Person	Swiss citizen, born 1977
Licence	Airline transport pilot licence aeroplane (ATPL(A)) according to JAR, first issued by the FOCA on 18 February 2002.
Ratings	Type rating Airbus A330/A340 as copilot, valid till 30 November 2012 and 31 May 2013 respectively. Radiotelephony R/T in English. Language proficiency English level 4, valid till 31 May 2017
Instrument rating	Instrument rating aeroplane IR(A)
Last proficiency check	LPC on 23 April 2011 OPC on 10 March 2012
Medical fitness certificate	Class 1 with restrictions (VDL: shall wear corrective lenses), issued on 25 May 2012, valid till 22 June 2013

1.2.1.2.1 Flying experience

Total	9430:36 hours
of which as commander	108:00 hours
on the type involved in the incident	1818:57 hours
during the last 90 days	158:09 hours
of which on the type involved in the incident	142:09 hours

1.2.1.2.2 Crew duty times

Duty times before the day of the incident	9 August 2012: off duty 10 August 2012: off duty
Start of flight duty on the day of the incident	01:35 UTC
Flight duty time at the time of the serious incident	11:57 hours

1.2.1.3 Copilot 2

Person	German citizen, born 1980
Licence	Airline transport pilot licence aeroplane (ATPL(A)) according to JAR, first issued by the FOCA on 18 March 2009
Ratings	Type rating Airbus A330/A340 as copilot, valid till 30 June 2013 and 31 December 2012 respectively Radiotelephony R/T in English Language proficiency English level 5, valid till 31 March 2016 Multi crew cooperation instructor

		MPLI(A)) Simulator flight instructor (SFI)
	Instrument rating	Instrument rating aeroplane IR(A)
	Last proficiency check	LPC on 13 January 2011 OPC on 7 December 2011
	Medical fitness certificate	Class 1, no restrictions, issued on 24 August 2012, valid till 8 September 2013
1.2.1.3.1	Flying experience	
	Total	5206:54 hours
	of which as commander	183:24 hours
	on the type involved in the incident	251:37 hours
	during the last 90 days	148:40 hours
	of which on the type involved in the incident	121:14 hours
1.2.1.3.2	Crew duty times	
	Duty times before the day of the incident	9 August 2012: off duty 10 August 2012: off duty
	Start of flight duty on the day of the incident	01:35 UTC
	Flight duty time at the time of the serious incident	11:57 hours
1.2.1.3.3	Additional information	
	Copilot 2 started his flying career on gliders and at the time of the serious incident had completed 183 hours on gliders.	
1.2.2	Glider crew	
1.2.2.1	Pilot	
	Person	German citizen, born 1936
	Licence	Glider pilot licence according to the ICAO, issued by the FOCA on 3 October 2011, valid till 11 October 2013 and based on the German glider licence, issued by the regional authorities in Kassel, Germany on 6 January 2004.
	Ratings	Class rating for touring motor glider (TMG) acquired on the basis of a glider licence. Authorisation to carry passengers (PAX (glider)). Language proficiency German level 6, unrestricted validity
	Medical fitness certificate	Class 2, restrictions (VDL: shall wear corrective lenses and carry a spare set of spectacles) issued by the aviation au-

	thority of the German Federal State of Baden-Württemberg, Freiburg regional authorities (BWFR) on 21 December 2011, valid till 3 January 2013.

1.2.2.1.1 Flying experience

Total	2253 hours
Number of flights	over 2400
on the type involved in the incident	Unknown
during the last 90 days	08:17 hours
of which on the type involved in the incident	04:23 hours

1.2.2.1.2 Additional information

The glider pilot had been a member of the gliding club "Segelfluggemeinschaft Bohlhof e.V." since 1968 and was familiar with the airspace structure around Bohlhof glider airfield. An analysis of the flights he made between 15 June 2011 and 11 August 2012 indicated that he had flown into the controlled airspaces TMA LSZH 2, TMA LSZH 6 and LSZH TMA 9 without clearance verifiable on at least five flights.

1.2.3 Air traffic control personnel

1.2.3.1 Air traffic control officer

1.2.3.1.1 General

Function	Zurich Final (FIN)
Person	Swiss citizen, born 1982
Duty times on 9 August 2012 Duty times on 10 August 2012 Duty times on the day of the incident	off duty 14:30 – 21:30 UTC 12:00 – 19:00 UTC
Licence	Air traffic control officer licence based on European Community Directive 2006/23, issued by the FOCA on 27 September 2005, valid till 23 May 2013. Language endorsements English level 5, valid till 25 November 2014.

1.2.3.1.2 Additional information

On 31 July 2008 the air traffic control officer was involved in a serious incident on the intersecting runways 16 and 28 at Zurich Airport: he issued take-off clearance to an aircraft on runway 28 shortly after having issued landing clearance to an aircraft approaching on runway 16. The instruction given immediately to the aircraft rolling on runway 28 to abort its take-off was able to defuse the situation.

The investigation of the former Aircraft Accident Investigation Bureau came to the following conclusion [translated from German]:

"The serious incident is attributable to the fact that ATC cleared an aircraft to take off from runway 28, even though an aircraft approaching runway 16 had previously received landing clearance and was about to land."

Following this serious incident, skyguide failed to conduct a debriefing with the air traffic control officer or take any further measures. There was no critical incident stress management (CISM) because the ATCO declined this.

On 15 March 2011 the air traffic control officer was involved in another serious incident on the intersecting runways 16 and 28 in Zurich: he issued take-off clearance to an aircraft on runway 28 shortly after having issued take-off clearance to another aircraft on runway 16; this aircraft was still on its take-off roll. The fact that the crew of the aircraft taking off on runway 28 aborted take-off when they detected the aircraft on runway 16 was able to defuse the situation.

The investigation of the Swiss Accident Investigation Board, Aviation Division (SUST-AD), came to the following conclusion [translated from German]:

"The serious incident is attributable to the fact that the air traffic control officer concerned gave take-off clearance to an aircraft on runway 28 although another aircraft on runway 16, to which he had given take-off clearance shortly before, was still on its take-off roll. The result was that an inadvertent convergence of these aircraft occurred, involving a high risk of collision."

Following this second serious incident, the air traffic control officer was deployed only in the Approach Control (APP) unit at Zurich Airport. After successfully requalifying he was to be redeployed in the Zurich control tower in January 2013.

An analysis of the documents for the selection and training of the air traffic control officer indicated that he was qualified good to very good by skyguide. After acquiring the appropriate license and ratings, the statutory performance reviews take place at skyguide. A classification of the current performance level, i.e. a differentiated qualification, did not take place.

At the ATCO interview regarding this third serious incident on 19 October 2012, he replied to the question of subsequent support by the air navigation services company as follows [translated from German]: *"To me the case was not serious. I therefore did not even complete an OIR* [operational internal report]. *So far skyguide hasn't done anything either."*

The air navigation services company informed the SAIB on 13 August 2012 that a convergence had taken place between SWR 39 and a glider on 11 August 2012. After extensive preliminary clarifications (cf. chapter 1.7.3.2) the investigation regarding a near collsion was opened by the SAIB on 7 September 2012 and skyguide was informed about. Subsequently their media department had to answer several press inquiries to this. The division of the company concerned with air traffic control became aware of the seriousness of the event only after the air traffic control officer was interviewed in October 2012.

1.3 Aircraft information

1.3.1 Aircraft 1

Registration	HB-JMN
Aircraft type	A340-313
Characteristics	Four-jet long-haul commercial aircraft
Manufacturer	Airbus S.A.S., Toulouse, France
Year of manufacture	1997
Owner	Maple Leaf Leasing 8 Limited, Cayman Islands
Operator	Swiss International Air Lines Limited, Switzerland
Relevant equipment	Collins TCAS II (Version 7.0)

1.3.2 Aircraft 2

1.3.2.1 General

Registration	HB-1519
Aircraft type	ASW 20
Characteristics	Single-seater fibre-reinforced plastic (FRP) performance glider
Manufacturer	Alexander Schleicher GmbH & Co., Germany
Year of manufacture	1980
Owner	Private
Operator	Private
Relevant equipment	FLARM collision warning system

1.3.2.2 Cockpit equipment

The ASW 20 glider's instruments were as follows:

Figure 1: HB-1519 instrument panel with:
① FLARM collision warning system
② L-NAV navigation computer
③ GPS navigation system

The glider was equipped, among other things, with a FLARM collision warning system (Hardware Version 6, Firmware Version 4.07), an L-NAV navigation computer (Version 5.8) and an LX 400 GPS navigation system (Version 4.0). There was no transponder fitted.

The navigation computer was coupled with the GPS navigation system, and thus received position data from the GPS navigation system. On 11 August 2012 the navigation computer screen was set for cross-country flights.

Neither the navigation computer nor the GPS navigation system can display electronic maps. These devices did not indicate the vertical and horizontal boundaries of the individual airspaces to the glider pilot. Neither are they capable of warning the pilot when approaching airspace boundaries.

1.4 Meteorological information

1.4.1 General meteorological situation

Switzerland lay on the edge of an area of high pressure centred over the central North Sea. At altitude, a narrow ridge extended from the Balearic Islands to southern Norway.

1.4.2 Weather at the time of the serious incident

The weather was sunny with a moderate Bise wind. In the noon profile, the Stuttgart radiosonde indicated an inversion with a base at 5290 ft AMSL. 1-2/8 fair-weather cumulus clouds with a base at 5900 ft AMSL were observed over Zurich Airport. The relative humidity at the inversion base was nearly 90 percent. At 4700 ft AMSL it was approximately 80 percent.

The inversion base was characterised by a thin layer of damp mist. Above and below this layer, the air was less humid. At Zurich Airport, the visibility was 25 km at both 12:00 and 15:00 UTC. There are hourly observations of visibility from Feldberg in the Black Forest: at 13:00 UTC it was 50 km and at 14:00 UTC it was 55 km.

Weather/cloud	1-2/8 5900 ft AMSL
Visibility	50 km
Wind	from 050 degrees / 10 - 15 kt at 4700 ft AMSL
Temperature/dewpoint	15 °C / 7 °C at 4700 ft AMSL
Atmospheric pressure	1019
Hazards	none

1.4.3 Astronomical information

Position of the sun	Azimuth: 228°	Elevation: 49°
Lighting conditions	Daylight	

1.4.4 Webcam images

Figure 2: Zurich Airport Dock E, looking to the north, 11 August 2012, 13:30 UTC

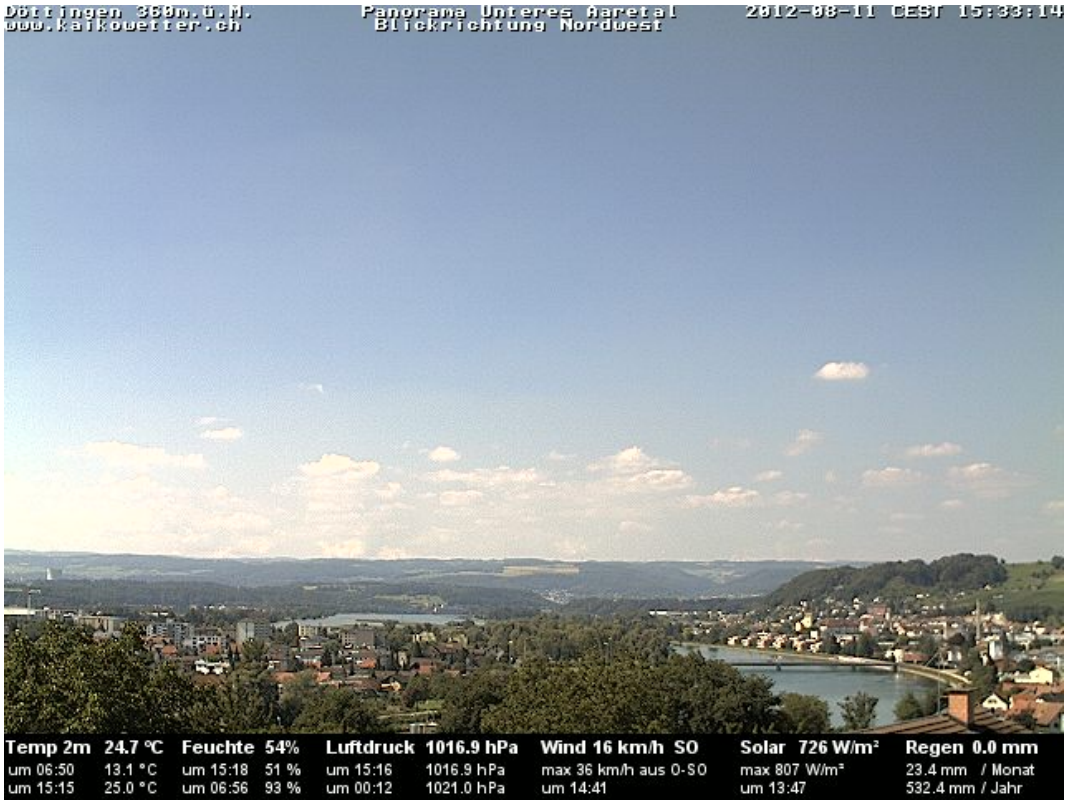


Figure 3: Döttingen, looking to the north-west, 11 August 2012, 13:33 UTC

1.5 Aerodrome information

1.5.1 Airspace structure

1.5.1.1 General

Controlled Swiss airspace (FIR/UIR) is divided into two areas of responsibility (AOR):

- Control area (CTA) Zurich
- Control area (CTA) Geneva

Airspace within the FIR/UIR is divided into four classes (C, D, E and G) and is broadly consistent with ICAO recommendations. The three other ICAO airspace classes (A, B and F), which have also been adopted by Switzerland, are also available, but no area of Swiss airspace is currently assigned to these classes.

Classes C, D and E are controlled airspaces.

Approximately 45% of the airspace managed by the air navigation services company skyguide is over foreign territory. More than 40% of the flights controlled by skyguide take place in this delegated foreign airspace.

1.5.1.2 Zurich Airport

The airspace structure surrounding Zurich Airport comprises a control zone (CTR) and numerous terminal control areas (TMAs), which are numbered accordingly (cf. Annex 6). These TMAs have an upper limit of flight level (FL) 195. The lower limit is 3000, 3500, 4500, 5500, 6500, 7500 or 8500 ft AMSL depending on the TMA.

The serious incident took place in TMA LSZH 2, which has a lower limit of 4500 ft AMSL and is classified as Class C airspace (cf. Annex 7).

In Class C airspace, air traffic control ensures separation of IFR and IFR traffic as well as IFR and VFR traffic. Pure VFR traffic can receive traffic information as an assigned service and avoiding recommendations are sent upon request.

According to skyguide, vertical separation in TMA LSZH 2 (and other TMAs) at Zurich Airport is regulated as recommended in ICAO Annex 11 - Air Traffic Services, Section 2.10.3.1 - Control Areas:

"2.10.3.2.1 The lower limit of a control area should, when practicable and desirable in order to allow freedom of action for VFR flights below the control area, be established at a greater height than the minimum specified in 2.9.3.2.

2.10.3.2.2 When the lower limit of a control area is above 900 m (3000 ft) MSL it should coincide with a VFR cruising level of the tables in Appendix 3 to Annex 2. [This is the semi-circle rule.]"

As TMA LSZH 2 has a lower limit of 4500 ft AMSL (i.e. over 3000 ft AMSL), IFR flights, which are normally only given altitude clearance in thousands of feet, can receive clearance from ATCOs to 5000 ft in TMA LSZH 2, which results in a minimum separation of 500 ft.

The corresponding altitude limits are published as follows in the AIP Switzerland (LSZH AD 2.24.13-1):

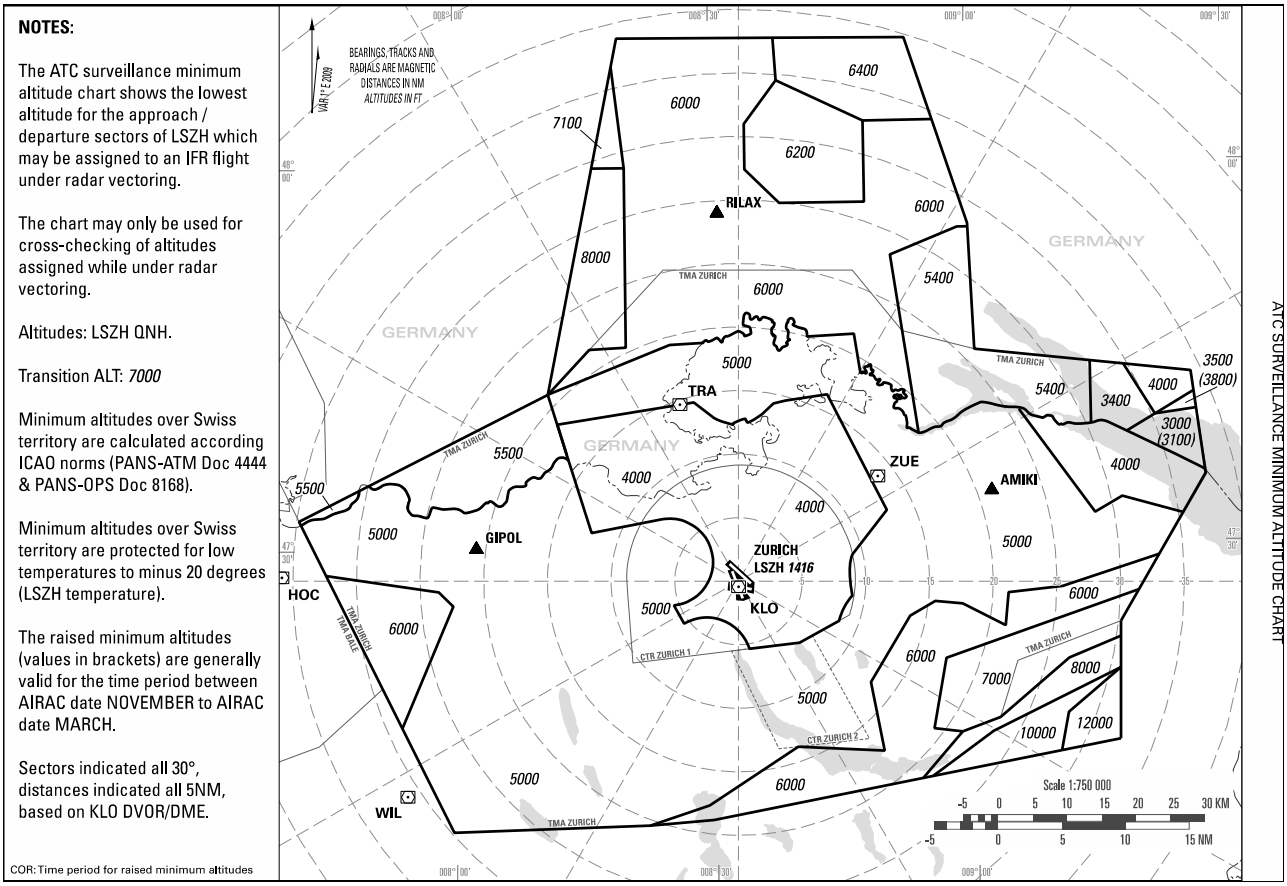


Figure 4: ATC surveillance minimum altitude chart

1.5.1.3 Glider aerodromes below TMA LSZH 1 and TMA LSZH 2

TMA LSZH 1 and TMA LSZH 2 are Class C airspaces. TMA LSZH 1 extends from 3000 ft AMSL to FL 195. TMA LSZH 2 extends from 4500 ft AMSL to FL 195 (cf. Annex 7).

Below TMA LSZH 1 is Bohlhof glider airfield, including TRA LS-T72, a temporary reserved area (TRA) for gliders. TRA LS-T72 extends from the lower limit of TMA LSZH 1 to 3500 ft AMSL and to the north has a boundary with TMA LSZH 2 (cf. Annex 8).

Within TMA LSZH 2, on the boundary with TMA LSZH 1, is Schaffhausen glider aerodrome, including its temporary reserved areas: TRA LS-T70 "SCHAFF-HAUSEN NORTH" and TRA LS-T71 "SCHAFFHAUSEN SOUTH", part of which extends into TMA LSZH 1. TRA LS-T70 extends from the lower limit of TMA LSZH to 6500 ft AMSL, while TRA LS-T71 extends from the lower limit of TMA LSZH to 5000 ft AMSL (cf. Annex 8).

1.5.2 Zurich Air Traffic Control

1.5.2.1 Approach Control

The Approach Control (APP) unit is based in the Zurich Air Traffic Control building in Dübendorf, in the same operations room as skyguide's Area Control (ACC) unit.

The APP Zurich area of responsibility has a vertical limit of FL 125. The lateral limits can be derived from Figure 5.

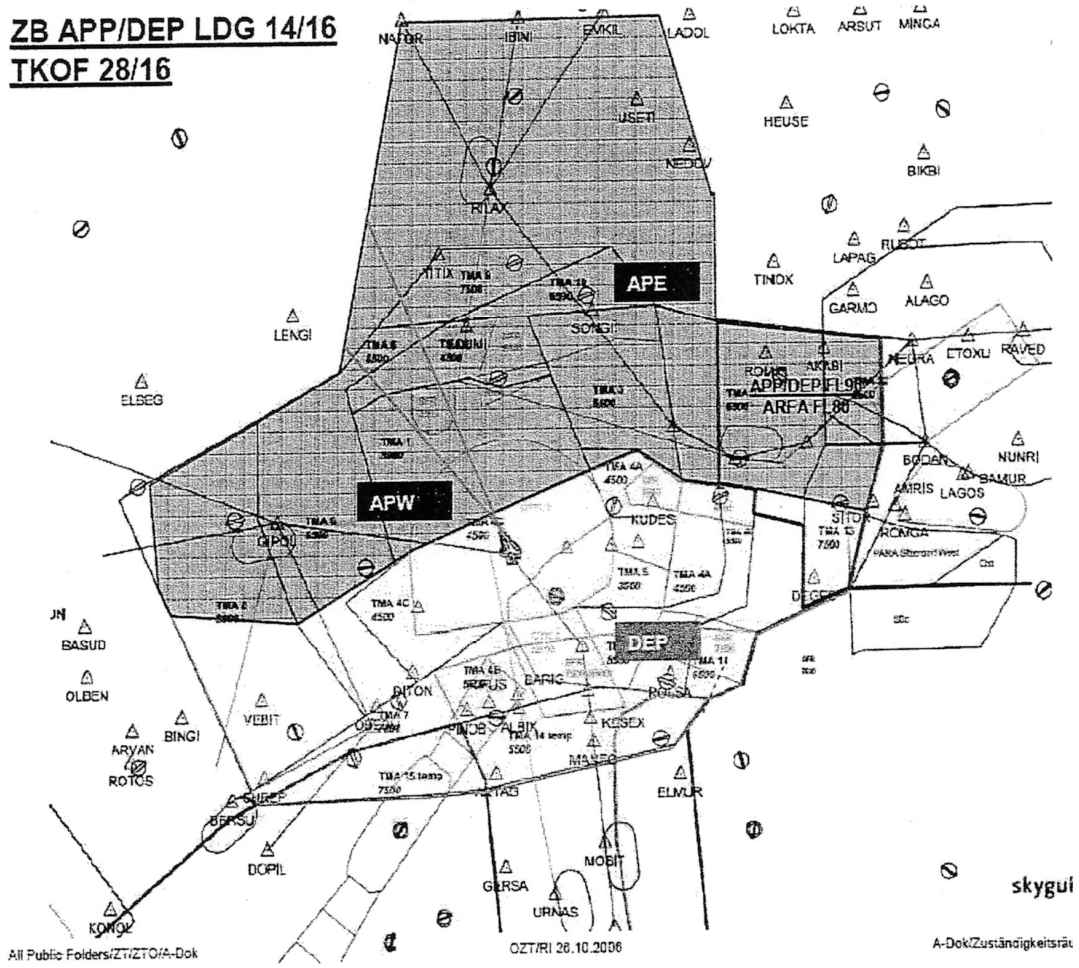


Figure 5: Area of responsibility according to the air traffic management manual (ATMM) Zurich TWR/APP (Section 4 – Approach)

1.5.2.2 Working positions

The five Approach Control working positions are as follows:

- Coordinator Approach (CAP)
- Approach West (APW): responsible for aircraft approaching Zurich Airport via holding point GIPOL
- Approach East (APE): responsible for aircraft approaching Zurich Airport via holding points AMIKI and RILAX
- Departure (DEP): responsible for departing aircraft
- Final (FIN): responsible for aircraft on final approach

The FIN working position is located between the APW (left) and APE (right) working positions.

The most important tasks for the FIN working position include:

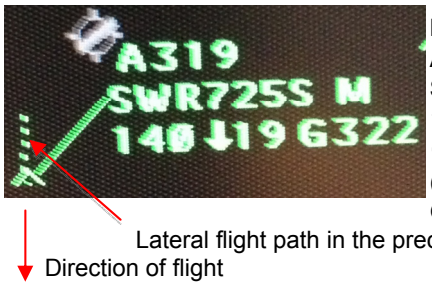
- Air traffic control for all aircraft transferred to it from the APE and APW working positions
- Optimising separation on the final approach
- Transfer of IFR approaches to the next responsible working position (ADC1 or ADC2) according to agreement

1.5.2.3 FIN working position

Destinations are indicated on the radar screen of the FIN air traffic control officer (cf. Annex 9) using a symbol which indicates the current position and a label in green. The lateral flight path for the preceding few seconds is indicated by green dots following the symbol.

The label contains information about the type, call sign and weight category of the aircraft, the flight level or altitude, and with the help of the cursor selectable by the ATCO: by arrow the rate of climb (ROC), rate of descent (ROD) and groundspeed.

Regarding the display on the radar screen the ATCO involved said [translated from German]: "Anticipated clearances will be issued by means of a speed vector that shows us where the aircraft will be in one, two or three minutes. The speed vector shows the actual flight direction straight ahead. With the actual rate of descent I can evaluate where and at what altitude an aircraft will be in one, two or three minutes. I usually use this function to make a prediction for the next minute."



Example of a label:
A319 = aircraft type
SWR725S = flight plan call sign; M = medium weight class
140 = flight level FL 140
↓ 19 = rate of descent in hundreds of feet per minute (1900 ft/min)
G322 = groundspeed in knots 322 kt

Figure 6: Representation of an aircraft on the radar screen

Skyguide records and archives for 30 days all flight movements using the radar recordings (legal recordings) of air traffic. If necessary, the recordings can be stored for longer and retrieved at a later point in time. This meant it was possible to play back and display all the flight movements at the time of the serious inci-

dent in real time. It should be noted that there are differences between the aircraft labels recorded and the original labels. In addition an ATCO can select individual display settings on his screen but they will not be recorded on 'legal recording'. However, altitude, speed and flight plan call sign will always be displayed to the ATCO. The label on the image of the 'legal recording' is displayed as follows:

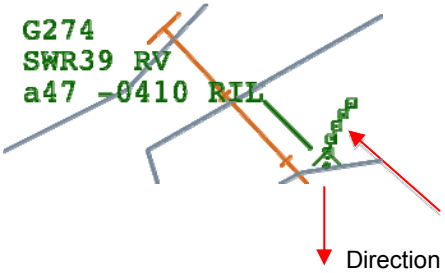


Figure 7: Representation of an aircraft in the legal recording

The displays of flight SWR 39 at the time of the serious incident are set out in Annex 6.

1.6 Warning systems

1.6.1 Aircraft-based warning systems

1.6.1.1 Commercial aircraft

The Swiss International Air Lines HB-JMN aircraft was equipped with a Collins TCAS II (Version 7.0) traffic alert and collision avoidance system (TCAS[5]).

The system is independent of ground-based systems. It transmits signals and on the basis of the radar responses from the transponders of other aircraft determines their relative positions and motion vectors. From this it calculates the closest point of approach (CPA). In the case of convergence with another aircraft, which is capable of communicating using the system in the manner described, an initial aural and visual traffic advisory (TA) is generated and, in the case of more impending, dangerous convergences, an aural and visual resolution advisory (RA) is generated.

As the glider was not equipped with a transponder, it could not be detected by the TCAS on board the A340; the TCAS was therefore unable to generate resolution advisories or traffic advisories.

1.6.1.2 Glider

There is no general obligation for gliders to carry an operational transponder in Swiss or German airspace.

Most gliders are fitted with a FLARM collision warning system on a voluntary basis. In the event of acute risk of collision with another aircraft equipped with a FLARM system, the FLARM system generates an aural and a visual collision warning. Unlike a TCAS, a FLARM system does not generate resolution advisories. It is also unable to detect aircraft equipped with only a transponder.

[5] The basic concept of this collision avoidance system is known as an airborne collision avoidance system (ACAS). The International Civil Aviation Organization (ICAO) uses this term when drawing up the standards with which the system must comply. The traffic alert and collision avoidance system (TCAS) is a concrete implementation of this concept.

1.6.2 Ground-based warning systems

Zurich Air Traffic Control (ACC/APP) is, among other things, equipped with a short-term conflict alert system (STCA). This is based on secondary radar tracking and generates a visual and aural warning when two aircraft violate the safe separation minimum defined in the system within a certain time period.

In the present case, the STCA was at no time able to respond because the glider was not equipped with a transponder and the air traffic control radar system therefore could not detect this aircraft. The system was consequently unable to warn the air traffic control officer.

1.7 Organizational and management information

1.7.1 Operator Swiss International Air Lines

The operator specifies the procedures for the operation of its aircraft, amongst others, in documents including their operations manuals (OM) OM A and OM B.

Chapter 7.1.5.2 of the OM A describes what is to be understood by an "augmented flight crew" as follows:

"A flight crew which comprises more than the minimum number required for the operation of the aircraft and in which each flight crew member can leave his post and be replaced by another appropriately qualified flight crew member.

- *Part augmentation: The crew is augmented by 1 pilot;*
- *Full augmentation: The crew is augmented by 2 pilots"*

With regard to the duties of the additional flight crew member, chapter 4.1.3.3.2. of the OM A states the following:

"The augmented flight crew shall participate at the pre-flight planning and briefing. An augmented flight crew remains together and acts as one crew until the flight duty ends for all together (e.g. flight has landed at destination). An in-flight relieved flight crew member remains in the active crew and must be ready to take over a duty again in case of:

- *sickness of colleague;*
- *intermediate landing;*
- *diversion.*

Therefore, no alcohol shall be consumed by a relieved flight crew member until the duty for the whole crew is terminated."

How mutual replacement or division of labour is provided for in the case of augmented flight crews is not explicitly regulated in the corresponding documents of the operator. This is the responsibility of the respective augmented flight crew. This is also true for the deployment of augmented flight crew members during take-off and landing. However, according to corroborating statements of the crew, it is generally the case that the additional crew member sits in the cockpit in the context of additional monitoring during take-off and landing.

1.7.2 Air navigation services company skyguide

1.7.2.1 Anticipated clearances

During the investigation, the air traffic control officer involved in the serious incident, other traffic control officers and other representatives of the safety division mentioned the so-called "anticipated clearances" principle. Upon request, the persons concerned provided an explanation of this principle which can be demonstrated in the following example: "Anticipated clearance" occurs when an aircraft receives clearance to descend to 4000 ft QNH while still over an area above

which it is only possible to descend to 5000 ft QNH. Issuing clearance to descend to 4000 ft QNH is in this case still possible if it has been established that the relevant aircraft will not violate the valid altitude restriction (in this case 5000 ft QNH) during its descent and will only descend to the cleared altitude (in this case 4000 ft QNH) in airspace where it is permitted. It emerged that the expression "anticipated clearance" is neither contained nor defined in the ATMM Switzerland. Only the term "anticipated separation" is mentioned, and this is in the context of departure and landing clearance (ATMM CH, Section 9, Aerodrome Control, Points 4.9.7 and 4.10.4). Skyguide was also unable to produce training materials on this topic or other guidelines regarding this frequently used working method.

1.7.3 Gliding operations at Bohlhof glider airfield

1.7.3.1 General

Bohlhof glider airfield is in the municipality of Wutöschingen; it is located on a high plateau at an elevation of 569 metres above sea level on the south-eastern edge of the Southern Black Forest Nature Park. The glider airfield is in a good location for flights over the Black Forest and is also regarded as a natural take-off site for regular flights to the Swabian Jura, the Jura Mountains and the Alps.

The temporary reserved area (TRA) for gliders at Bohlhof facilitates approaches and departures below the Zurich TMA.

Operations at Zurich Airport have influenced the operation of Bohlhof glider airfield for quite some time. The first flight restrictions were enacted in 1956. At this time, a maximum flying altitude of 1200 m AMSL was established over the site; this was later revised to 900 m AMSL. In the early 1970s, the Bohlhof TRA was established: it was granted an altitude of 1050 m AMSL (equal to 3445 ft AMSL) for a radius of 1852 m (1 NM) around the airfield. For maps where altitudes are expressed in feet, the upper limit is designated as 3500 ft AMSL.

Location	47°39'06" N / 8°23'15" E
Elevation above sea level	569 m / 1867 ft
Orientation of runway	04 / 22
Length of runway	800 m
Surface	Grass
Bohlhof Info frequency	129.975 MHz
Type of take-off	Aerotow by motorised aircraft or powerful motor glider and winch-launching

The gliding club "Segelfluggemeinschaft Bohlhof" conducted an annual information evening, where safety-related issues were presented and discussed. Participation at this event was mandatory for members.

1.7.3.2 Glider pilot and Segelfluggemeinschaft Bohlhof e.V.

After landing at Bohlhof glider airfield, the glider pilot did not report the serious incident to the authorities or the club management. A few days later, the flight data of all aircraft which had taken off from or landed at Bohlhof glider airfield on 11 August 2012 were inspected by the club management. According to the statement of the pilot of HB-1519, he then informed the club management that he had been involved in the serious incident. The management analysed the flight path of HB-1519; according to the statement of the pilot, he was advised to wait during this time.

During the inquiries by the SAIB and even before the investigation was opened, the Federal Office for Civil Aviation (FOCA) issued a witness appeal, according to

which persons able to provide information about the incident should report to the FOCA's Safety Risk Management Division or the voluntary, anonymous reporting system SWANS. This witness appeal was published on the Segelflugverband der Schweiz (Swiss Gliding Association) website.

Neither the glider pilot himself nor the bodies of the gliding club Segelfluggemeinschaft Bohlhof came forward as a result of the witness appeal.

In the context of the investigation into the serious incident, the German Federal Bureau of Aircraft Accident Investigation (BFU) requested the disclosure of flight path recordings for all aircraft belonging to the Segelfluggemeinschaft Bohlhof which had taken off or landed from the Bohlhof glider airfield on 11 August 2012. In spite of this request the BFU was not provided with the recordings from the FLARM on board HB-1519.

Extensive research on the part of the safety investigation authorities of both Switzerland and Germany was necessary before the glider and the pilot were finally identified. Once contact was made with the glider pilot, he co-operated fully with the SAIB.

These facts led the BFU to again request Segelfluggemeinschaft Bohlhof for the recordings of the FLARM on board the ASW 20. The gliding club then made the recording of the flight of 11 August 2012 available to the BFU. The gliding club no longer had access to other recordings from this aircraft.

In the context of systemic investigations it was possible to evaluate further flights recorded by logger from 2012 and 2013 which had been operated from the Segelfluggemeinschaft Bohlhof (cf. chapter 1.8.4).

1.8 Systemic investigations

1.8.1 General

The investigation of the serious incident, a convergence with a high risk of collision, indicated that the airspace structure around Zurich Airport played a role. The following main points were raised: TMA LSZH has a complicated structure consisting of a number of sectors with different lower limits and vertical boundaries. Furthermore, located below Zurich Airport's TMA are two glider aerodromes, Schaffhausen and Bohlhof, whose temporary reserved areas TRA LS-T70, TRA LS-T71 and TRA LS-T72 extend into TMA LSZH.

In order to facilitate assessment of the airspace structure and its consequences, the investigation examined approaches from the north which transited TMA LSZH 2 before entering TMA LSZH 1.

1.8.2 Approaches by A340 aircraft between 8 and 15 August 2012

26 approaches by the same aircraft type A340, flying from the north and approaching on runway 14, were investigated. All of the flights investigated transited TMA LSZH 2 before they entered TMA LSZH 1 (see Annex 12).

In the majority of the flights investigated it emerged that clearance to the crews to descend to 4000 ft QNH took place in Class C airspace within TMA LSZH 2 (cf. Annex 12), which extends from 4500 ft to FL 195. Flight 21 received clearance to descend to 4000 ft QNH already north of TMA LSZH 2, whereas flights 6, 9, 11 and 17 received clearance only once they were within TMA LSZH 1.

According to the ATMM Switzerland (cf. chapter 1.5.1), the vertical minimum distance to the lower limit of the airspace is 500 ft. The ATCO has to guarantee this minimal distance. This means that the limit below which an aircraft in TMA LSZH 2 may not descend is 5000 ft QNH when flying IFR. If the ATCO issues an air-

craft with an altitude which is lower than this limit, he must monitor the vertical flight path such that the aircraft does not descend below 5000 ft QNH within TMA LSZH 2.

The analysis of the above 26 flights indicates that the lower limit was violated in the case of SWR 39. In all other cases, the actual altitude of the aircraft during the transition from TMA LSZH 2 to TMA LSZH 1 was between 7500 ft QNH and 5000 ft QNH (cf. Annex 13).

1.8.3 Approaches by all aircraft types between 1 and 7 December 2012

All approaches between 1 and 7 December 2012 which entered TMA LSZH 1 from the north were studied on the basis of the radar records of skyguide.

The study calculated the position where the respective flight path first reached 5000 ft QNH for each of the 1714 approaches. The study examined whether these penetration points (at 5000 ft QNH in the horizontal plane) were outside (see Figure 18) or inside (see Figure 19) the lateral boundary of TMA LSZH 2. The results of this study are summarised in the table (Figure 8).

Date	Total approaches	5000 ft outside TMA 2	5000 ft within TMA 2	No penetration point	Within TMA 2 [%]
01/12/2012	199	192	1	6	0.5%
02/12/2012	216	213	3	0	1.4%
03/12/2012	328	311	17	0	5.2%
04/12/2012	161	159	2	0	1.2%
05/12/2012	283	279	3	1	1.1%
06/12/2012	271	264	7	0	2.6%
07/12/2012	256	242	14	0	5.5%
Total	1714	1660	47	7	2.8%

Figure 8: Analysis of the penetration points in the approaches investigated

The seven approaches in the "no penetration point" column were already below 5000 ft QNH within TMA LSZH 1 and did not transit TMA LSZH 2 beforehand. These were not taken into account when calculating the percentage.

For the 47 approaches which first reached 5000 ft QNH within TMA LSZH 2, the altitude when passing over the boundary between TMA LSZH 1 and TMA LSZH 2 was calculated.

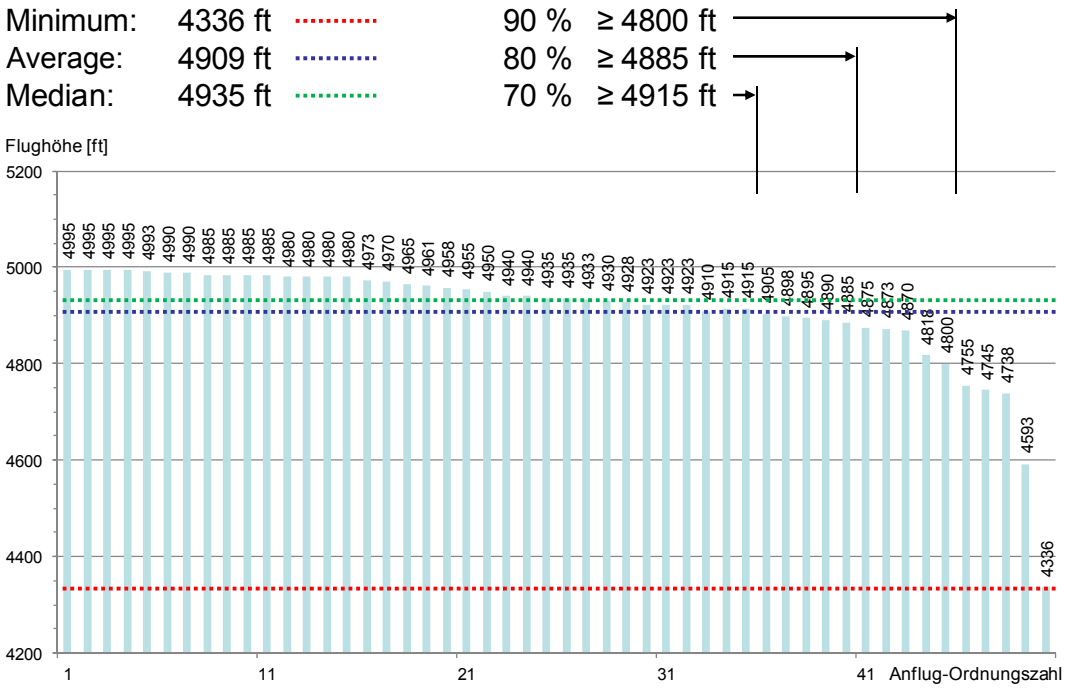


Figure 9: Representation of the analysis of altitudes when passing the boundary between TMA LSZH 2 and TMA LSZH 1 for the 47 approaches which passed below 5000 ft QNH within TMA LSZH 2**.**

1.8.4 Analysis of logger data from other gliders

In the context of the investigation, flight data from gliders belonging to the gliding club Segelfluggemeinschaft Bohlhof for 2012 and 2013 were requested and analysed in order to obtain at least some information as to whether there had been further airspace violations by gliders in the Zurich TMA. 224 flight path files were analysed with the following findings:

- In 2012, there were four airspace violations in the area of TMA 1; the altitude limit of this airspace was exceeded by between 45 and 150 m.
- In 2013, three airspace violations were identified; the affected areas were TMA 1, TMA 2 and TMA 6. There were altitude violations of between 100 and 275 m.

1.8.5 Other dangerous convergences

Various statements in the course of the investigation suggest that this serious incident was not an isolated case. Research has shown that various dangerous convergences in connection with gliders have been recorded in recent years. The following list is limited to known cases within the controlled airspace around Zurich Airport. Several lines of evidence suggest that there are a larger number of unreported cases in addition to these documented cases.

10 May 2008

An Airbus A321 aircraft was approaching runway 14 under radar vectors in TMA LSZH 2. While on a heading of 070 degrees and at an altitude of 6200 ft QNH, the crew sighted a glider 1 to 2 miles away on a collision course at an altitude of 6500 ft QNH. The crew reported as follows: *"(…) no TCAS indication from glider. Too late for any avoiding action (…)."*

25 September 2009

A Boeing B737 was descending to FL 80 under radar vectors in TMA LSZH 8 (cf. Annex 7). The crew reported as follows: *"(…) Passing FL 86 we noticed glider exactly on our right wing (…)."*

21 April 2010

A commercial aircraft was approaching runway 14 under radar vectors in TMA LSZH 2. While on a heading of 060 degrees and at an altitude of 6000 ft the crew was informed that they would be directed via the localiser for reasons of separation. Suddenly, the crew saw a glider directly in front of them. The report states. among other things, the following: *"(…) there was no TCAS information (…) traffic passed on their left side approximately at 100 m at the same altitude (…)"* The event happened so quickly that it was impossible for the crew to react.

22 May 2010

An Airbus A320 aircraft was approaching runway 16 under radar vectors in TMA LSZH 6. At FL 70, the crew reported as follows: *"(…) sighted a glider at our ten o'clock position in a turn towards us. Distance about 400 m at the bottom of the cloud base. The glider tightened the turn and we came close to about 200 m. I was ready to disengage the A/P* [autopilot] *when we observed the glider to turn away (…)."*

03 April 2011

A Cessna on a photography flight in TMA LSZH 4B at an altitude of 6100 ft QNH reported a *"close encounter"* among other things, as follows: *"(…) we saw a glider between Rüschlikon and Thalwil just below us on our right hand side. ... we have estimated the glider to be about 50 metres below and between 50 metres and 100 metres on our right (…)".* The glider was not equipped with a transponder, or at least had not turned it on.

15 April 2011

RJ1H, a commercial aircraft, was on the downwind leg of an instrument approach on runway 14 under radar vectors in TMA LSZH 6. The altitude was 6000 ft QNH. The crew reported the dangerous convergence among other things as follows: *"(…) Two gliders straight ahead at same altitude (…) they probably got aware of us, as they rapidly descended and flew away direction east (…)."*

12 June 2011

A Learjet executive aircraft was in TMA LSZH 6 airspace for an approach on runway 14 when the pilot reported a dangerous convergence with a glider at an altitude of 6000 ft QNH. The glider was not visible on the radar.

15 June 2011

A commercial aircraft was under radar vectors in LSZH TMA 6 airspace. A glider pilot reported a dangerous convergence with this aircraft among other things as follows [translated from German]: *"(...) I found myself between "Schluchsee" Rothaus and Bonndorf; the base was around 2000 - 2100 m. (...) I was circling in thermals at about 1800 m* [5900 ft] *and heading north when I suddenly saw a twin-jet airliner right in front of me, about 200 metres below (...)."*

2 Analysis

2.1 Technical aspects

2.1.1 General

There are no indications of any pre-existing technical defects which might have caused or influenced the serious incident.

2.1.2 Glider equipment

The FLARM traffic and collision warning system with which HB-1519 was equipped has been used since 2004, mainly on gliders. It works exclusively between aircraft which are equipped with a functioning FLARM. It provides the crews of such aircraft with information about the traffic situation and gives aural and visual warnings of approaching aircraft and obstacles to aviation. The TCAS on board the A340 was therefore unable to detect HB-1519, which was equipped only with a FLARM; conversely, the FLARM system was unable to detect the transponder signals of the A340. For some time it has been possible to fit gliders with an additional signal-receiver/decoder for automatic dependent surveillance - broadcast (ADS-B). Such receivers can receive any transponder signal transmitted on 1090 MHz within a radius of up to 250 km. If an ADS-B receiver is coupled with a FLARM system, the signals from Mode S transponders can be processed like FLARM signals. In this case, the convergence of the Airbus A340 would have been displayed by the FLARM system.

HB-1519 was equipped with a navigation computer and an older generation GPS navigation system. In contrast to these systems, modern on-board computers for gliders can display maps, the detail and information of which can be adjusted according to the needs of the pilot. Such systems make it easy for glider pilots to identify both lateral and vertical airspace boundaries. Such on-board computers also give aural and visual warnings when approaching airspace boundaries. In the case of a visual warning, for example, the airspace involved (in this case TMA LSZH 2) is displayed in red and a voice provides an aural warning with the following information: *"one hundred metres below airspace Charlie"*. Such warnings must then be confirmed by the pilot in order not to be constantly repeated. When flying into such an airspace (something that is in other cases quite common with corresponding clearance), it is easy to see that one is within the relevant airspace via the map display on the on-board computer.

Modern on-board computers can also display the traffic situation, as received from the FLARM collision warning system and ADS-B receivers, on the on-screen map. If HB-1519 had been equipped with such an on-board computer coupled with an ADS-B receiver, the glider pilot could have seen the approaching Airbus A340 on his screen together with the relative altitude difference.

In the past, the main problem with using transponders in gliders was power consumption. Modern Mode S transponders are compact, lightweight and have low power consumption. Such systems are suitable for use in gliders. For this reason, gliders owners increasingly equip their gliders with Mode S transponders. If a Mode S transponder had been activated on board HB-1519, the TCAS would have provided the crew of the A340 with a warning regarding the glider on a collision course, the ATCO would have been able to detect the glider on his radar screen, and the STCA would have given the ATCO a conflict warning.

2.2 Human and operational aspects

2.2.1 General information in relation to the "see-and-avoid" principle

The final report BEKLAS (*Bessere Erkennbarkeit kleiner Luftfahrzeuge als Schutz vor Kollisionen* [Improved Detection of Light Aircraft for Collision Prevention]) of the project *"Erkennbarkeit von Segelflugzeugen und kleinen motorisierten Luftfahrzeugen"* [Detection of Gilders and Light Motorised Aircraft] by the German Federal Ministry of Transport, Building and Housing states that the "see-and-avoid" principle for collision avoidance, which is well-known in air traffic, gets at its limits due to the anatomically defined performance of the human eye.

According to the flight path recordings, three seconds before the glider pilot initiated a tight right turn the distance to the Airbus A340-313 was 2.2 km. The glider pilot stated that he had detected the commercial aircraft at a distance of approximately 5 to 6 km. As the commercial aircraft was flying towards the glider at this time (see Annex 5), it was difficult for the glider pilot to estimate the distance to the Airbus A340-313 and its flight path. At 13:32:32 UTC the glider pilot initiated an avoidance manoeuvre. Thirteen seconds later, at the time of the closest point of approach of the two aircraft, the glider was only 250 metres from the position at which the avoidance manoeuvre had been initiated. This clearly indicates that there are few opportunities for action to avoid a collision in a relatively slow-moving aircraft.

It was very difficult for the crew of the commercial aircraft to detect the glider as it is almost impossible to detect small objects with low contrast to their background. In the present case detection of the glider was certainly helped by the fact that it was turning and that its bank angle changed abruptly, as humans can detect moving objects better than stationary ones. The targeted expectations of the observing person are crucial for recognising and detecting other aircraft. In the present case the fact that the second copilot was able concentrate on observing the airspace is likely to have been decisive for the detection of the glider.

Less than 15 seconds passed between the initiation of the avoidance manoeuvre and the closest point of approach. An observation of the flight paths of the two aircraft over this period indicates that neither avoidance manoeuvre in isolation was decisive in avoiding a collision.

2.2.2 Crew of SWR 39

When the crew had reported to Zurich Nord air traffic control they received an instruction from the air traffic control officer (ATCO) to descend to FL 150 and reduce speed to 210 KIAS. At this time the crew had already started to reduce the speed from over 300 KIAS. The additional clearance to descend meant that the reduction in speed was relatively slow. When the crew reported to Zurich Arrival *"... Speed two two zero knots"* approximately one minute later, the aircraft speed was 267 KIAS. With this information the commander wished to state that SWR 39 had previously received a speed restriction. In retrospect, the commander said that a radio communication such as *"reducing speed two two zero knots"* would probably have been clearer. He justified the fact that he had indicated 220 knots rather than the 210 knots ACC Nord had required by stating that the crew wished to avoid extending the flaps at such an early stage. The crew also believed that a deviation of 10 knots was tolerable. When the crew received the clearance from Zurich Arrival *"(...) Expect no delay, maintain the speed (...)"* shortly thereafter, they took this to mean that they could maintain their current speed. This was 260 KIAS and was finally reduced to 250 KIAS when passing FL 100. Neither the Zurich Arrival ATCO nor the Zurich Final ATCO (to whom the crew reported approximately six minutes later) subsequently contested the speed and no other

clearance was issued in this regard. In summary it can be stated that the flight crew of SWR 39 communicated with air traffic control in an unclear manner with respect to speed limits. However, this misunderstanding and the resulting speeds had no influence on the occurrence of the near collision. Approximately 35 seconds before the dangerous convergence the ATCO issued the clearance to descend below the minimum radar vector altitude.

The crew's actions were safety-conscious: they deployed the third pilot in the cockpit as an observer during the approach. The existing resources were therefore used efficiently. At the time of the near collision, the pilot flying and the pilot not flying were primarily focused on the instruments because the aircraft was intercepting the runway 14 ILS. Experience shows that there is a heavy workload in such a phase because the reduction of altitude and speed, the flight guidance system, etc. must be closely monitored. The focus on this work in the cockpit tends to leave little capacity for airspace surveillance.

The attentive monitoring of the airspace and immediate warning by the third pilot allowed the first copilot 1 to react quickly. It is conceivable that the experience of the pilot in the third occupant seat as a glider pilot helped him to detect the glider in good time. The pronounced avoidance manoeuvre was appropriate to the situation and helped to prevent a possible collision. The continued approach and the report of the dangerous encounter indicate that cooperation in the cockpit functioned well despite the spectacular near collision.

2.2.3 Glider pilot

2.2.3.1 Piloting

The glider pilot had been a member of the gliding club "Segelfluggemeinschaft Bohlhof e.V." since 1968. His numerous flights from Bohlhof glider airfield meant that he was well acquainted with the geographical conditions and the complex airspace structure north of Zurich International Airport. In spite of this, verifiable on at least five flights he penetrated without clearance the controlled airspaces TMA LSZH 2, TMA LSZH 6 and TMA LSZH 9 between 15 June 2011 and 11 August 2012.

In the case of the flight on 11 August 2012, which resulted in the dangerous convergence with the Airbus A340, the glider pilot wanted to conduct a local training flight. On his relatively short flight in the vicinity of his home airfield of Bohlhof, the glider pilot was at all times aware of where he was and knew the lateral and vertical airspace boundaries. Upon flying into the controlled airspace TMA LSZH 2 on the northerly boundary of TMA LSZH 1, he probably allowed himself to be seduced by a thermal and climbed above the permissible altitude of 4500 ft AMSL because he did not expect a commercial aircraft approaching at such a low altitude. The additional altitude obtained by entering the controlled airspace was not necessary for the onward flight.

When the glider pilot saw the approaching Airbus A340, he reacted immediately: he stopped circling left and initiated a right turn with a large bank angle. He used this intuitive flight manoeuvre in an attempt to avoid the potential collision point with the A340. This avoidance manoeuvre increased the distance to the flight path of the commercial aircraft. In general, however, the significant difference in speed means that a glider's possibilities for avoiding the danger zone are low.

A few seconds later, when the lateral distance between the A340 and the glider was at its lowest (approximately 260 m) the glider pilot did not see the A340 airliner, because it passed behind him. As a result of the avoidance manoeuvre, HB-1519 flew for a short time within TMA LSZH 1, the lower limit of which is even

lower than that of TMA LSZH 2. However, this fact is not significant in the context of the near collision.

2.2.3.2 Reporting obligation

The near collision with the A340 was a serious event for the 76-year-old glider pilot. Although he did not report the event to anyone after landing at Bohlhof airfield, in retrospect it continued to prey on his mind. From the point of view of flight safety, the glider pilot was required to report the near collision. It should be noted that the legislature expressly stipulates an obligation to report to the safety investigation authority for such serious incidents. While notification via anonymous and voluntary reporting systems may be useful for more minor events, accidents and serious incidents should always be reported to the safety investigation authority.

Only a few days after the incident, as a result of the initial enquiries by the SAIB, during which the flight data of all aircraft at Bohlhof glider airfield were inspected by the club management, the pilot informed the club management of his involvement in the near collision. The fact that even then neither the club management nor the pilot himself reported the incident initially delayed the investigation. Attempting to conceal an incident which is critical in safety terms is problematic with regard to effective prevention.

Once the SAIB eventually managed to identify and contact the glider pilot involved by other methods, he was immediately reasonable and cooperative. The cooperation between the pilot and the SAIB showed that the exchange of information with neutral experts is important for those directly involved in serious incidents; this can also be identified as true in general.

2.2.4 Glider operation

The operation of transponders in gliders has the advantage that gliders can be detected by both aircraft-based warning systems in commercial aircraft and ground-based warning systems in air traffic control units. Furthermore, it has a positive effect on the behaviour of glider pilots with regard to airspace violations, as is the case with flying at gliding championships.

According to the regulations of the Swiss Gliding Championship (as of 1 January 2013) there is a zero tolerance policy towards airspace violations. All flight paths must be recorded by one of the International Gliding Commission's (IGC) homologated loggers and evaluated by the competition management. Airspace violations are measured using the flight path recordings after deduction of a vertical measurement tolerance of 10 metres and a lateral measurement tolerance of 30 metres. Such violations are penalised as follows: In the case of a first-time violation of airspace in a competition, the site where the airspace violation occurred is regarded as the landing location and the maximum punishment is disqualification of the pilot for the corresponding competition day. As such penalties result in an immediate and pronounced fall in ranking, competition pilots are very careful to not commit any airspace violations.

In the popular Online Contest (OLC), where details of thousands of glider flights are voluntarily provided by pilots on the internet, there is a similarly positive effect as in the Swiss Gliding Championship. The fact that anyone can view the flight path and altitude profile of a published flight leads to a certain element of social control, which in turn leads to increased vigilance as regards the prevention of airspace violations. Glider pilots flying with an activated transponder display similarly cautious behaviour since it is possible to analyse the radar recordings at any time.

In order to prevent similar serious incidents, particularly vulnerable airspaces should be surrounded by buffer zones in which only aircraft equipped with a functioning, activated transponder are permitted to manoeuvre. Such transponder mandatory zones (TMZs) should surround control zones and terminal control areas (TMAs) in order to form vertical and lateral buffer zones around these airspaces.

The introduction of TMZs would mean that an increasing number of gliders would be equipped with Mode S transponders. This would also be beneficial outside TMZs. Transponders could be operated according to the situation. For example, when descending from a high altitude via airspace with air traffic flying according to instrument flight rules (IFR) or when flying in the vicinity of a controlled airspace this would significantly reduce the likelihood of dangerous convergence with other aircraft. Wherever the operation of a transponder in a glider is not necessary (e.g. when ridge soaring in mountain valleys) it would not have to remain activated, as modern transponders are operational just moments after they are switched on.

2.2.5 Air traffic control

2.2.5.1 Personality factors of the air traffic control officer

As has been shown in previous investigations, the air traffic control officer involved is characterised by a dedicated approach to work and a cooperative and friendly attitude. This impression was also confirmed in the interviews conducted with him.

The issue is therefore not so much an overly superficial and casual attitude, but rather the fact that it is possible to observe moments or phases in which his attention is somewhat too focused. This is in contrast to "hovering attentiveness", which is characterised by the inability to completely blank out events which effectively take place on the edge of the field of vision or beyond the subjects of interest. This is how humans become aware if the pattern of these events suddenly changes.

Processes which can be predicted with high probability relieve the attention and the effort required for monitoring. Nevertheless, it remains probable, rather than certain and so a certain amount of visual attention is still required even in the case of such processes. If this is lacking, the residual risk is excluded with an unduly optimistic attitude.

It is also required in the case of the "anticipated clearance"[6] which is reportedly used at skyguide.

When the ATCO was questioned he also referred to this practice and was able to plausibly justify it as follows: It would improves the workflow, both for the ATCO and in the cockpit, and it would increases capacity and efficiency.

This implies the attitude that within the meaning of a good service it has to be done so. What was originally intended as a mere recommendation thus suddenly, based on the own aspiration level, comes to the fore. That this working method also entails a certain risk becomes less significant.

The ATCO is concerned about conducting his work as a competent and respected expert, because it is quite in keeping with his nature to be dedicated, friendly and cooperative. It is possible that his history also motivated him to clearly demonstrate his ability.

[6] In his statement, the ATCO constantly refers to "anticipated clearance" cf. Section 1.7.2.1.

Paradoxically, this in itself involves a certain risk of error because it can favour non-situation-specific prioritisation, as this serious incident demonstrates: After anticipating the clearance, the ATCO paid little or no attention to the onward progress of SWR 39, as if this part of his task had already been checked off and completed. This is to some extent based on the assumption that everything is as it would be in the ideal case. As this episode demonstrates, this optimism was misleading.

In summary it can be said that the anticipated clearance applied by the ATCO was at least occasionally accompanied by a lack of situation awareness. This impression is confirmed by his later statement: *"To me the case was not serious (…)".*

This is demonstrated with varying degrees of clarity in the subsequent chapter 2.2.5.2, Actions and Operations. The statements of the ATCO leave questions unanswered and leave the impression that the situational assessment is sometimes incomplete, inaccurate or contradictory. This suggests that neither his general grasp of the circumstances nor his situation awareness was consistent.

2.2.5.2 Actions and operations

Provided that the ATCO had selected the display on his radar screen as he usually did (cf. chapter 1.5.2.3), beside the speed he also had displayed the rate of descent of SWR 39. When he gave the crew of SWR 39 the instruction to reduce speed at 13:32:23 UTC, the ATCO's radar screen was displaying the aircraft's altitude as 5300 ft and the rate of descent as 2700 ft/min. It was therefore foreseeable that the required minimum distance of 500 ft to the lower limit of TMA LSZH 2 (4500 ft) would be violated. Since the ATCO did not respond to this circumstance, it must be assumed that he was not consciously aware of either the altitude or the rate of descent of SWR 39.

When the crew reported the dangerous convergence to the ATCO at 13:32:45 UTC, he thanked them for the information and stated: *"Swiss three niner, just about two miles north of your position, he was allowed at 4500 feet, just below the TMA, but then only 3000 feet."* This response suggests that the ATCO did not realise a dangerous convergence had occurred within TMA LSZH 2. It seemed to him self-evident that the glider pilot had not violated the lower limit of 4500 ft. Both the ATCO's explanation to the crew and his statement served merely to explain the structure of the TMA to the crew. This response did not help the crew and was possibly even misleading, as it gave them the impression that the air traffic control officer had been able to detect the glider on his radar screen.

However, the behaviour of the ATCO in the case of the aircraft approaching shortly after the serious incident indicates that he was at least partially aware of the dangerous convergence. At 13:42:02 UTC he gave the crew of the aircraft which approached afterwards, SWR 169R, corresponding information about the glider; this action was safety-conscious. It is not certain whether this also contributed to the fact that the ATCO issued the crew of SWR 169R clearance to descend to only 5000 ft QNH within TMA LSZH 2. However, the crew of the flight that followed SWR 169R, SWR 1801, received clearance to descend to 4000 ft QNH within TMA LSZH 2 from the ATCO four minutes later (cf. Annex 16). However, the aircraft passed the boundary between TMA LSZH 2 and TMA LSZH 1 above 5000 ft QNH.

2.2.5.3 Systematic aspects

The complex airspace structure around Zurich Airport places exacting requirements on the air traffic control officers who manage this airspace. Management is

further complicated by the glider aerodromes located below TMA LSZH 1 and TMA LSZH 2 because additional temporary reserved areas (TRA LS-T70, TRA LS-T71 and TRA LS-T72) have been defined around these aerodromes. Theses TRAs have an upper limit which is above the lower limit of the Class C airspace of TMA LSZH 1 and TMA LSZH 2. An additional factor is the fact that aircraft manoeuvring below the lower limit of TMA LSZH 1 and TMA LSZH 2 do not require a transponder. They cannot therefore be detected by ATCOs and cannot be caught by secondary radar.

The investigation indicated that 23 of the 26 evaluated Airbus A340 approaches and flight SWR 39 received clearance to descend to 4000 ft QNH within TMA LSZH 2, which is Class C airspace and has a lower limit of 4500 ft QNH. With the specified vertical height of minimal 500 ft, the lowest permissible altitude in this airspace would thus be 5000 ft QNH. Early clearance to descend to 4000 ft QNH is not a contradiction, insofar as it reflects the ATCO's concept of service to approaching crews, who wish to receive clearance to descend early enough to make a continuous descent whenever possible. The ATCO's concept of service allows optimum traffic flow on the one hand, but requires increased monitoring of the approaching aircraft on the other.

It is in this context that the concept of "anticipated clearance" should probably be viewed. It is, however, important to first note that "anticipated clearance" does not mean that the clearance is anticipated; it is clearance for an anticipated vertical flight path. Furthermore, it was noticed that the concepts of the individual air traffic control officers at the company differ with respect to this type of clearance. Although it is unsurprising, issuing "anticipated clearance" is not described anywhere in skyguide's working rules and regulations. Skyguide was also unable to produce training materials or other binding information regarding this procedure. Apart from a prevailing vague idea at the air navigation services company regarding this method, the serious incident which is the subject of the investigation and the radar data of the other flights discussed below indicate that issuing clearance on the basis of an anticipated flight path is in certain cases not safely controlled by air traffic control officers.

Furthermore, it should be noted that in contrast to an ATCO, who has the airspace structure on his screen, the crew of an approaching commercial aircraft is not usually aware of this. It is also not usually displayable on the navigation screen in the cockpit and also not on all Swiss aircraft in service for the time being. The only restriction for approaching crews is therefore the cleared altitude, which must not be violated.

The investigation has further shown that, with the exception of SWR 39, none of the 26 flights studied which received clearance to 4000 ft QNH within TMA LASZH 2 violated the minimal vertical height of 500 ft, i.e. a minimum altitude of 5000 ft QNH. It should be noted that flights 6, 9, 11 and 17 received an altitude restriction of 5000 ft QNH from the duty ATCO within TMA LSZH 2 and clearance to 4000 ft QNH only occurred once they had passed over the boundary with TMA LSZH 1 (cf. Annexes 7 and 8).

Furthermore, the A340 approaches studied indicate that the vertical distance was 1000 ft or more for 20 of these 26 flights. These flights would have therefore also complied with the ICAO standard vertical separation minimum (VSM) of 1000 ft (cf. Annex 13).

Of the 1714 approaches by different aircraft types between 1 and 7 December 2012, 47 approaches (2.8%) descended below 5000 ft QNH within the lateral boundaries of TMA LSZH 2. With regard to this proportion it must be taken into account that the altitude when passing over the boundary from TMA LSZH 2 to

TMA LSZH 1 was over 4900 ft QNH for 74.5% of these 47 approaches. Assuming 100 ft altitude difference as a measurement error tolerance, 12 (0.7%) of the 1714 approaches studied were directed too low within TMA LSZH 2.

It is not possible to estimate the probability of a collision between a directed aircraft on an approach and another aircraft in TMA LSZH 2 on the basis of only using the percentage of approaches which were flown too low. However, the documented dangerous convergences with gliders alone indicate that a collision is possible. If one also considers the many other convergences with motorised aircraft and paragliders, the violation of a minimal vertical height of 500 ft relating to the lower limit of the TMA due to issuing a clearance which is too low represents a significant safety risk. The fact that this was apparently never detected by the air navigation services company probably contributed to the situation whereby the air traffic control officer in question and some of his colleagues were accustomed to issuing clearance to descend in such a way that the minimum radar vectoring altitude in TMA LSZH 2 was occasionally violated by IFR traffic.

In the case of airspace violations by aircraft without transponders neither air traffic control nor the crews of the directed aircraft have technical support for the detection of impending collisions. Pilots of gliders without a functioning transponder in particular must therefore do everything within their power to respect the lower limits of controlled airspace without fail. The vast majority of glider pilots are responsible and can easily comply with this on their own using modern technical aids. Gliding associations, clubs and aerodromes should therefore take accompanying measures to identify pilots with poor risk awareness. The random inspection of loggers and collision warning systems by gliding organisations is feasible with reasonable effort and presents no inconvenience to responsible pilots.

3 Conclusions

3.1 Findings

3.1.1 Technical aspects

- The HB-JMN commercial aircraft was licensed for VFR/IFR transport.
- The investigation produced no indications of any pre-existing technical defects which might have caused or influenced the serious incident.
- The A340-313 aircraft was equipped with a TCAS II, which can generate resolution advisories (RA).
- The ASW 20 glider was equipped with a collision warning system FLARM. The FLARM cannot generate resolution advisories (RA).
- The TCAS II and FLARM systems are not compatible.

3.1.2 Crews

- The pilots of HB-JMN were in possession of the necessary licences for the flight.
- The pilot of the glider was in possession of the necessary licences for the flight.
- There are no indications of the pilots involved suffering any health problems during the flights involved in the serious incident.

3.1.3 Air traffic control personnel

- The air traffic control officer was in possession of the licences necessary to exercise his activities.
- There are no indications of the air traffic control officer suffering any health problems at the time of the serious incident.

3.1.4 History of the serious incident

- The commercial aircraft HB-JMN, an A340-313, was in the approach on runway 14 at Zurich Airport.
- The crew received clearance to descend to 4000 ft QNH from the Zurich Final (FIN) air traffic control officer (ATCO) at 13:32:04 UTC.
- At this time the commercial aircraft was in Class C airspace in Zurich Airport terminal control area (TMA) LSZH 2 at an altitude of 6000 ft QNH, with a rate of descent (ROD) of 2500 ft/min and a speed of 245 KIAS.
- When the crew of the commercial aircraft confirmed this clearance four seconds later, the aircraft was at an altitude of 5800 ft QNH with an ROD of 3170 ft/min.
- When at 13:32:23 UTC the ATCO instructed the crew of the commercial aircraft to reduce speed, the aircraft was at an altitude of 5050 ft QNH, with an ROD of just over 2700 ft/min and a speed of 254 KIAS.
- An ASW 20 glider, which had taken off from the Bohlhof glider airfield on a training flight, was located on the southern boundary of TMA LSZH 2 at an altitude of just over 4700 ft QNH.
- While turning onto the localiser axis, the third pilot of the A340-313, who was in the central third occupant seat in the cockpit, suddenly saw the glider, which

was at the same altitude on a collision course, and warned the two other pilots.

- A pronounced avoidance manoeuvre was initiated by the crew of the A340-313 at 13:32:35 UTC. The recordings show a maximum bank angle of 36 degrees to the left and an increase in attitude to approximately 5 degrees, which generated a normal acceleration of 1.6 g.
- At this time the A340-313 was still in Class C airspace in TMA LSZH 2 at an altitude of 4700 ft QNH, with an ROD of 350 ft/min and a speed of 248 KIAS.
- The glider pilot had also seen the A340-313 shortly before and initiated three seconds before, at 13:32:32 UTC, an abrupt right-hand turn as an avoidance manoeuvre.
- According to the recordings of the two flight paths, the two aircraft passed at approximately the same height at a lateral distance of approximately 260 m at 13:32:45 UTC.

3.1.5 General conditions

- The ATCO responsible for separation in Class C airspace was unable to detect the glider as it did not have a transponder and could not be detected by the secondary radar. The primary radar stations were also unable to detect the glider.
- The TCAS II on board the Airbus A340 was unable to generate a resolution advisory as the glider was not equipped with a transponder.
- The short-term conflict alert system (STCA) was unable to warn the ATCO of the dangerous convergence of the two aircraft as the glider was not equipped with a transponder.
- Application of the ICAO recommendations allows a vertical separation minimum of 500 ft between IFR and VFR traffic in TMA LSZH 2. In contrast, the vertical separation minimum (VSM) between two IFR flights is usually at least 1000 ft.
- The weather conditions had no influence on the serious incident.

3.1.6 Organisational aspects

- It was common practice at the air navigation services company to issue commercial aircraft in TMA LSZH 2 clearance to descend below the lowest permissible altitude for instrument flights (minimum radar vector altitude). Skyguide refers to this procedure as "anticipated clearance", but it is not documented anywhere.
- A study of 1714 approaches on runway 14 indicated that the minimum radar vector altitude in TMA LSZH 2 was violated by more than 100 ft in 0.7% of cases. Violations of up to 660 ft were identified.

3.2 Causes

The near collision is attributable to the fact that a glider, without a respective clearance, was in airspace class C in which a commercial aircraft was directed below the minimum radar vector altitude.

The following factors were identified as the direct cause of this near collision:

- Lack of risk awareness on the part of the glider pilot.
- The ATCO issued a descend clearance to an altitude which was, in the airspace in which the clearance was given, below the minimum radar vector altitude for instrument flights, without monitoring a possible violation.

The following factor was identified as a systemic cause:

- The absence of a compatible safety system for gliders, commercial aircraft and air traffic control which could have warned of the dangerous convergence.

The following was identified as a contributing systemic factor:

- The air navigation services company did not realise that the minimum radar vector altitude was occasionally violated when clearance to descend was issued.

The following factors were identified neither as causal nor as contributory but as systemic factors to risk:

- The airspace structure around Zurich airport is complex, make it demanding for crews to use and for air traffic control officers to manage.
- The airspaces around Zurich airport are, regarding their vertical dimension, designed in a way that also relatively small mistakes can already lead to dangerous situations.

4 Safety recommendations and measures taken since the serious incident

According to the provisions of Annex 13 of the ICAO, all safety recommendations listed in this report are intended for the supervisory authority of the competent state, which has to decide on the extent to which these recommendations are to be implemented. Nonetheless, any agency, any establishment and any individual is invited to strive to improve aviation safety in the spirit of the safety recommendations pronounced.

Swiss legislation provides for the following regulation regarding implementation in the Ordinance on the Investigation of Aircraft Accidents and Serious Incidents:

"Art. 32 Safety recommendations

[1] DETEC, on the basis of the safety recommendations in the SAIB reports and in the foreign reports, shall address implementation orders or recommendations to the FOCA.

[2] The FOCA shall inform DETEC periodically about the implementation of the orders or recommendations pronounced.

[3] DETEC shall inform the SAIB at least twice a year on the state of implementation by the FOCA."

4.1 Safety recommendations

4.1.1 General

When the essential elements of the factual information were available, the SAIB together with the assigned representative of Federal Republic of Germany arranged in March 2013 extensive discussions with the stakeholders that were affected either by the serious incident or directly or indirectly by possible measures taken to improve flight safety. The following organisations participated:
Aerocontrol, Airport Zurich AG, Civil Aviation Safety Officer (CASO) of the Federal Department of the Environment, Transport, Energy and Communications (DETEC), Federal Office of Civil Aviation (FOCA), German Aeroclub, 'Segelfluggemeinschaft Bohlhof', 'Schweizerischer Segelflugverband', Skyguide, Swiss Air Line Pilots Association, Swiss International Airlines Ltd.

This meeting was also intended for consultation of the involved stakeholders in relation to possible safety recommendations, as stipulated in art. 17 section 1 of the legal ordinance (EU) Nr. 996/2010 of the European Parliament and the Council, dated 20 October 2010 regarding the investigation and prevention of accidents and disturbances in civil aviation and to abolition of guideline 94/56/EG, which was also implemented by the Federal Office of Civil Aviation (FOCA) on 1 February 2013. Subsequently an interim report with safety recommendations 466 to 468 (cf. chapter 4.1.2 to 4.1.3) was sent to the FOCA. The intention of the interim report with its safety recommendations as well as the information given to the involved stakeholders was to make it possible for involved organisations to take measures for improvement regarding flight safety already immediately and not only after the final report has been published.

After closing the investigation two more safety deficits were determined, leading in association with reasonable proposals by the involved stakeholders, to safety recommendations 483 and 484 (cf. chapter 4.1.4 and 4.1.5).

4.1.2 Safety recommendations in relation to airspace structure and transponders

4.1.2.1 Safety deficit

On 11 August 2012 a commercial aircraft, an Airbus A340-313, registration HB-JMN, was on a scheduled flight from San Francisco to Zurich. After an uneventful flight, the crew received clearance to descend to 4000 ft QNH from the Zurich Final (FIN) air traffic control officer at 13:32:04 UTC. At this time the aircraft was in Class C airspace in terminal control area (TMA) LSZH 2 at an altitude of 6000 ft QNH, with a rate of descent (ROD) of 2500 ft/min and an indicated airspeed of 245 KIAS (knots indicated airspeed). Class C airspace in TMA LSZH 2 extends from 4500 ft AMSL to FL 195.

At the same time, an ASW 20 glider, registration HB-1519, which had taken off from the Bohlhof glider airfield on a training flight at 12:59 UTC, was located on the southern boundary of TMA LSZH 2 at an altitude of just over 4700 ft QNH.

While turning onto the localiser axis, the third pilot of the A340-313, who was in the central third occupant seat in the cockpit, surprisingly caught sight of the glider, which was at the same altitude on a collision course. He warned the two pilots conducting the flight and a pronounced avoidance manoeuvre was initiated. The recordings show a maximum bank angle of 36 degrees to the left and an increase in attitude to approximately 5 degrees, which generated a normal acceleration of 1.6 g. At this time the aircraft was still in Class C airspace in TMA LSZH 2 at an altitude of 4700 ft QNH, with a rate of descent (ROD) of 350 ft/min and a speed of 248 KIAS.

According to the recordings of the two flight paths, the two aircraft passed at approximately the same height at a lateral distance of approximately 260 m.

The traffic alert and collision avoidance system (TCAS) on board the A340-313 was unable to either generate traffic advisories (TA) or resolution advisories (RA) as the glider was not equipped with a transponder.

The air traffic control radar system was unable to detect the glider for the same reason, which meant that firstly, the air traffic control officer (ATCO) was unable to detect the glider at any point and secondly, the air traffic control short-term conflict alert system (STCA) was unable to warn the ATCO of the dangerous convergence.

4.1.2.2 Safety Recommendation No. 466

"Das Bundesamt für Zivilluftfahrt sollte gegebenenfalls in Zusammenarbeit mit den Aufsichtsbehörden von Nachbarstaaten um die Schweizer Flughäfen herum Lufträume festlegen, in denen sich ausschliesslich Luftfahrzeuge bewegen dürfen, die mit einem funktionsfähigen und eingeschalteten Transponder ausgerüstet sind (transponder mandatory zones – TMZ). Diese TMZ sollten die Kontrollzonen und Nahkontrollbezirke umfassen und gegenüber diesen Lufträumen vertikale oder horizontale Pufferzonen bilden."

[The Federal Office for Civil Aviation should, if applicable in cooperation with the supervisory authorities of neighbouring countries in the vicinity of Swiss airports, establish airspaces in which only aircraft equipped with a functioning, activated transponder are permitted to manoeuvre (transponder mandatory zones - TMZs). These TMZs should include the control zones and terminal control areas and create vertical or horizontal buffer zones above or around these airspaces.]

4.1.3 Safety recommendations for dealing with airspace violations

4.1.3.1 Safety deficit

On 11 August 2012 a commercial aircraft, an Airbus A340-313, registration HB-JMN, was on a scheduled flight from San Francisco to Zurich. After an uneventful flight, the crew received clearance to descend to 4000 ft QNH from the Zurich Final (FIN) air traffic controller at 13:32:04 UTC. At this time the aircraft was in Class C airspace in terminal control area (TMA) LSZH 2 at an altitude of 6000 ft QNH, with a rate of descent (ROD) of 2500 ft/min and an indicated airspeed of 245 KIAS (knots indicated airspeed). Class C airspace in TMA LSZH 2 extends from 4500 ft AMSL to FL 195.

At the same time, a ASW 20 glider, registration HB-1519, which had taken off from the Bohlhof glider airfield on a training flight at 12:59 UTC, was located on the southern boundary of TMA LSZH 2 at an altitude of just over 4700 ft QNH.

While turning onto the localiser axis, the third pilot of the A340-313, who was in the central third occupant seat in the cockpit, surprisingly caught sight of the glider, which was at the same altitude on a collision course. He warned the two pilots conducting the flight and a pronounced avoidance manoeuvre was initiated. The recordings show a maximum bank angle of 36 degrees to the left and an increase in attitude to approximately 5 degrees, which generated a normal acceleration of 1.6 g. At this time the aircraft was still in Class C airspace in TMA LSZH 2 at an altitude of 4700 ft QNH, with a rate of descent (ROD) of 350 ft/min and a speed of 248 KIAS.

According to the recordings of the two flight paths, the two aircraft passed at approximately the same height at a lateral distance of approximately 260 m.

In the context of the investigation the following safety-critical findings were made:

- In recent years, airspace violations in relation to approaches to runways 14 and 16 at Zurich Airport by general aviation aircraft equipped with a transponder have been regular and relatively large in number.
- The air navigation services company informed the SAIB on 13 August 2012 that a convergence had taken place between SWR 39 and a glider on 11 August 2012. After extensive preliminary clarifications the investigation regarding a near collsion was opened by the SAIB on 7 September 2012 and skyguide was informed about. Subsequently their media department had to answer several press inquiries to this. The division of the company concerned with air traffic control paid no attention to the near collision and became aware of the seriousness of the event only after the air traffic control officer was interviewed by the SAIB in October 2012.
- In the case of previous flights made by the glider pilot involved, as well as flights made by other glider pilots which were conducted in the terminal control area and the control zone of Zurich Airport, there had been airspace violations which were revealed only in the context of this investigation.
- The gliding club in which the glider pilot involved in the near collision was a member did not systematically record airspace violations made by its members and did not report events which were known to it to the appropriate authorities.
- A systematic assessment of airspace violations as is the case for aircraft which are equipped with a transponder does not take place in the case of gliders and other aircraft which do not require a transponder. It can thus be

assumed that there have been a considerable number of similar unreported airspace violations whose causes therefore cannot be determined.

These deficits should be resolved by the following safety recommendations.

4.1.3.2 Safety Recommendation No. 467

"Das Bundesamt für Zivilluftfahrt sollte gemeinsam mit den massgeblichen Luftfahrtverbänden und gegebenenfalls in Zusammenarbeit mit den Aufsichtsbehörden von Nachbarstaaten insbesondere im Bereich von grösseren Schweizer Flughäfen wirksame Massnahmen ergreifen, die sicherstellen, dass Piloten der allgemeinen Luftfahrt die Grenzen von kontrollierten Lufträumen konsequent respektieren."

[The Federal Office of Civil Aviation should, together with the relevant aviation associations and if appplicable in cooperation with the supervisory authorities of neighbouring countries (particularly those in the vicinity of major Swiss airports), take effective measures to ensure that general aviation pilots consistently respect controlled airspaces.]

4.1.3.3 Safety Recommendation No. 468

"Das Bundesamt für Zivilluftfahrt sollte gemeinsam mit der Flugsicherung Skyguide, den massgeblichen Luftfahrtverbänden und gegebenenfalls in Zusammenarbeit mit den Aufsichtsbehörden von Nachbarstaaten Massnahmen entwickeln, die sicherstellen, dass auch Luftraumverletzungen von Luftfahrzeugen, die nicht mit Transponder ausgerüstet sind, systematisch erfasst und die damit verbundenen Risiken verringert werden können."

[The Federal Office of Civil Aviation should together with the air navigation services company skyguide, the relevant aviation associations and if applicable the supervisory authorities of neighbouring countries, develop measures to ensure that airspace violations by aircraft not equipped with a transponder can be systematically recorded so that the associated risks can be minimised.]

4.1.4 Safety recommendation to a working method by skyguide

4.1.4.1 Safety deficit

On 11 August 2012 a commercial aircraft, an Airbus A340-313, registration HB-JMN, was on a scheduled flight from San Francisco to Zurich. After an uneventful flight, the crew received clearance to descend to 4000 ft QNH from the Zurich Final (FIN) air traffic controller at 13:32:04 UTC. At this time the aircraft was in Class C airspace in terminal control area (TMA) LSZH 2 at an altitude of 6000 ft QNH, with a rate of descent (ROD) of 2500 ft/min and an indicated airspeed of 245 KIAS (knots indicated airspeed). Class C airspace in TMA LSZH 2 extends from 4500 ft AMSL to FL 195.

At the same time, a ASW 20 glider, registration HB-1519, which had taken off from the Bohlhof glider airfield on a training flight at 12:59 UTC, was located on the southern boundary of TMA LSZH 2 at an altitude of just over 4700 ft QNH.

While turning onto the localiser axis, the third pilot of the A340-313, who was in the central third occupant seat in the cockpit, surprisingly caught sight of the glider, which was at the same altitude on a collision course. He warned the two pilots conducting the flight and a pronounced avoidance manoeuvre was initiated. The recordings show a maximum bank angle of 36 degrees to the left and an increase in attitude to approximately 5 degrees, which generated a normal acceleration of 1.6 g. At this time the aircraft was still in Class C airspace in TMA

LSZH 2 at an altitude of 4700 ft QNH, with a rate of descent (ROD) of 350 ft/min and a speed of 248 KIAS.

According to the recordings of the two flight paths, the two aircraft passed at approximately the same height at a lateral distance of approximately 260 m.

In the context of the investigation it has been determined that it was quite common practise within the air navigation services company skyguide to issue so called 'anticipated clearances'. However it has to be clarified that with this, not a clearance will be anticipated respectively predicted or expected but a clearance will be issued that is based on an expected or predicted flight path. As a result, in the serious incident which is the subject of the investigation, as well as in general it happened that sometimes, based on assumption of a certain flight path, a descent clearance was issued that led to an undershooting of the lowest permissible altitude for IFR flights within TMA LSZH 2. The concept of 'anticipated clearances' was nowhere described, neither in the operating documents of the navigation services company nor in the training documents. According skyguide this was not necessary since this was a working method only and not a procedure. This led to a different management respectively different view of the concept by the individual air traffic control officers. The serious incident investigated as well as the analysed radar data of other flights as part of the investigation show, that issuing a clearance based on an expected flight path only is not under control by all air traffic control officers in certain cases.

4.1.4.2 Safety recommendation No. 483

"Das Bundesamt für Zivilluftfahrt sollte gemeinsam mit dem Flugsicherung Skyguide das Konzept der "anticipated clearances" prüfen und Massnahmen treffen, die sicherstellen, dass Flüge nach Instrumentenflugregeln, unter Einhaltung einer Freigabe, nicht auf Höhen oder in Lufträume gelangen, die für sie nicht vorgesehen sind."

[The Federal Office of Civil Aviation should together with the air navigation services company skyguide audit the 'anticipated clearance' concept and develop measures to guarantee that IFR flights adhere to a clearance given do not get on altitudes or airspaces where they do not belong to.]

4.1.5 Safety recommendation to the airspace structure around Zurich airport

4.1.5.1 Safety deficit

On 11 August 2012 a commercial aircraft, an Airbus A340-313, registration HB-JMN, was on a scheduled flight from San Francisco to Zurich. After an uneventful flight, the crew received clearance to descend to 4000 ft QNH from the Zurich Final (FIN) air traffic controller at 13:32:04 UTC. At this time the aircraft was in Class C airspace in terminal control area (TMA) LSZH 2 at an altitude of 6000 ft QNH, with a rate of descent (ROD) of 2500 ft/min and an indicated airspeed of 245 KIAS (knots indicated airspeed). Class C airspace in TMA LSZH 2 extends from 4500 ft AMSL to FL 195.

At the same time, a ASW 20 glider, registration HB-1519, which had taken off from the Bohlhof glider airfield on a training flight at 12:59 UTC, was located on the southern boundary of TMA LSZH 2 at an altitude of just over 4700 ft QNH.

While turning onto the localiser axis, the third pilot of the A340-313, who was in the central third occupant seat in the cockpit, surprisingly caught sight of the glider, which was at the same altitude on a collision course. He warned the two pilots conducting the flight and a pronounced avoidance manoeuvre was initiated. The recordings show a maximum bank angle of 36 degrees to the left and an in-

crease in attitude to approximately 5 degrees, which generated a normal acceleration of 1.6 g. At this time the aircraft was still in Class C airspace in TMA LSZH 2 at an altitude of 4700 ft QNH, with a rate of descent (ROD) of 350 ft/min and a speed of 248 KIAS.

According to the recordings of the two flight paths, the two aircraft passed at approximately the same height at a lateral distance of approximately 260 m.

In the context of the investigation it has been determined that not only relating to the serious incident investigated but also in general correlation to airspace violations that the airspace structure around Zurich airport make high demands to flight crews as well as to air traffic control officers. The fragmenting of the airspace leads to numerous vertical and horizontal airspace borders that are difficult to adhere to even with careful mode of operation by all parties involved. With it the airspace structure is a systemic risk factor because it finally is based on an error-free working method and that is related to normal human limits a wrong assumption. As the serious incident which is the subject of the investigation shows the airspaces are designed in a way that already relatively small lapses can lead to dangerous situations. That shows a little fault-tolerant concept.

4.1.5.2 Safety recommendation No. 484

"Das Bundesamt für Zivilluftfahrt sollte gegebenenfalls in Zusammenarbeit mit den Aufsichtsbehörden von Nachbarstaaten und unter Einbezug der betroffenen Verkehrskreise die Luftraumstruktur um den Flughafen Zürich prüfen und Massnahmen treffen, welche die Luftraumstruktur und die Nutzung des Luftraumes vereinfachen bzw. fehlertoleranter machen."

[The Federal Office of Civil Aviation should if applicable together with the supervisory authorities of neighbouring countries and under comprehension of the stakeholders involved audit the airspace structure around Zurich airport and develop measures that make use of airspace easier respectively more fault-tolerant.]

4.2 Measures taken since the serious incident

4.2.1 By Segelfluggemeinschaft Bohlhof

In addition to the existing measures regarding violations of the Zurich TMA and CTR, the gliding club "Segelfluggemeinschaft Bohlhof" introduced the following regulations in Spring 2013 [translated from German]:

- *"There will be random, unannounced logger inspections on all aircraft flying at Bohlhof.*
- *If airspace violations are identified the relevant pilot will have to undergo refresher training and his logger will in future be inspected after every flight. A second airspace violation will result in a ban on flights from Bohlhof as pilot in command.*
- *The establishment of an "anonymous" reporting system to facilitate the reporting of incidents."*

In a further letter, dated 18 March 2014 the 'Segelfluggemeinschaft Bohlhof' states that the aircraft had been equipped in such a way that in the year 2014 all glider flights departing from Bohlhof can be controlled by logger recordings.

4.2.2 By the air navigation services company skyguide

In a letter, dated 18 February 2013 the air navigation services company states that based on the serious incident the following measures have taken place [translated from German]:

1. *"This incident was taken as an example in the Tower/Approach Refresher briefing (9.9.-27.9.2013). Based on this subject 'anticipated clearances' and MVA were discussed.*
2. *The incident was also discussed together with Swiss International Airlines. A first discussion took place on 2 April 2013. Swiss and skyguide exchanged their internal investigation reports in order to use them for their own training area. Skyguide used the pilots information on this subject in their above mentioned refresher.*
3. *In addition in all operational units of skyguide where 'anticipated clearances' are adopted a respective analysis had been made. In cases where work without using 'anticipated clearances' does not have a negative effect regarding workload, a change will be made regarding the actual work practices. In cases where work without using 'anticipated clearances' have a negative effect regarding workload a change in actual work practices will be checked and aimed for if possible."*

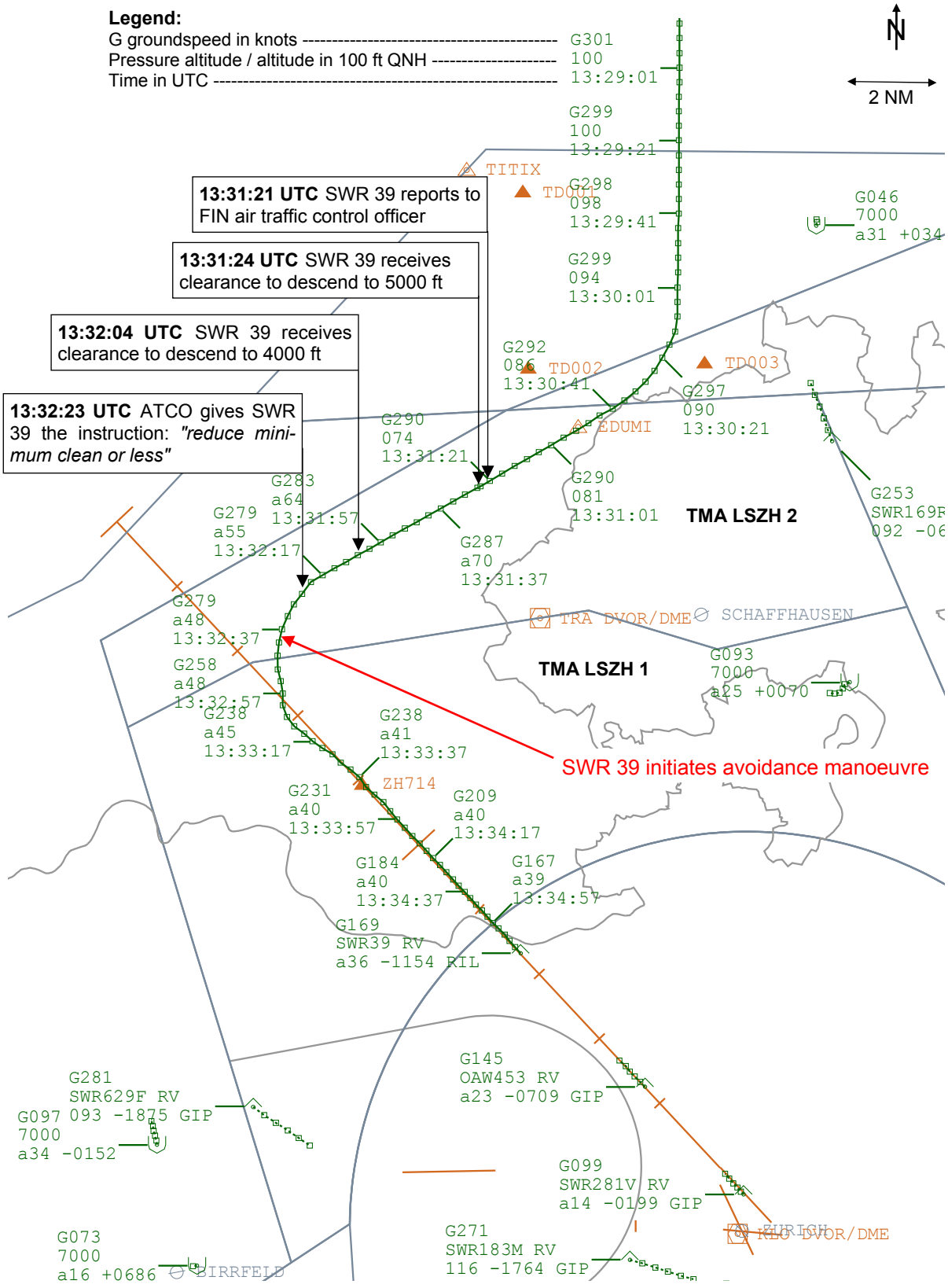
Payerne, 19 August 2014 Swiss Accident Investigation Board

This final report was approved by the management of the Swiss Accident Investigation Board SAIB (Art. 3 para. 4g of the Ordinance on the Organisation of the Swiss Accident Investigation Board of 23 March 2011).

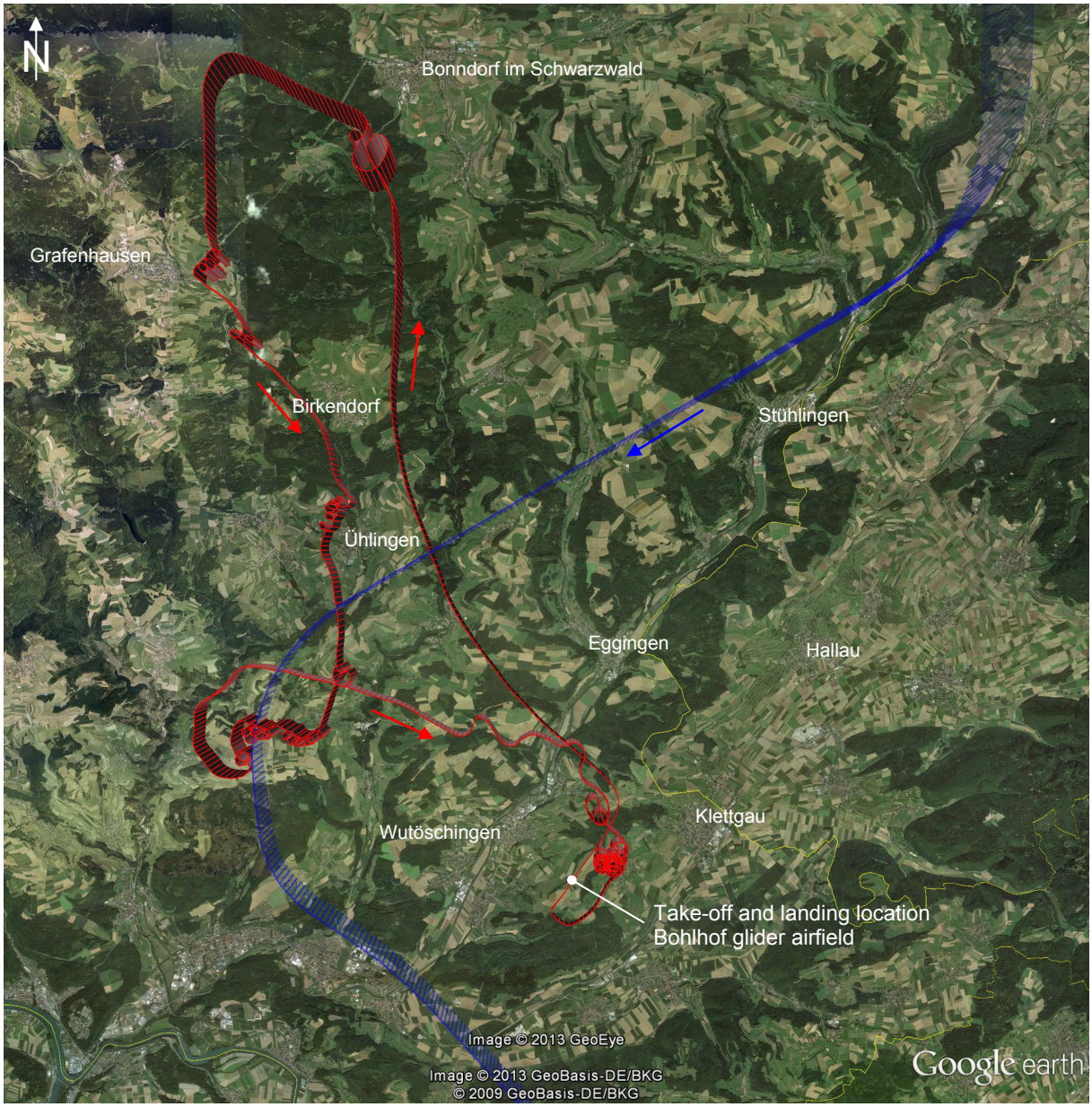
Berne, 14 August 2014

Annexes

Annex 1: Flight path radar recordings for SWR 39



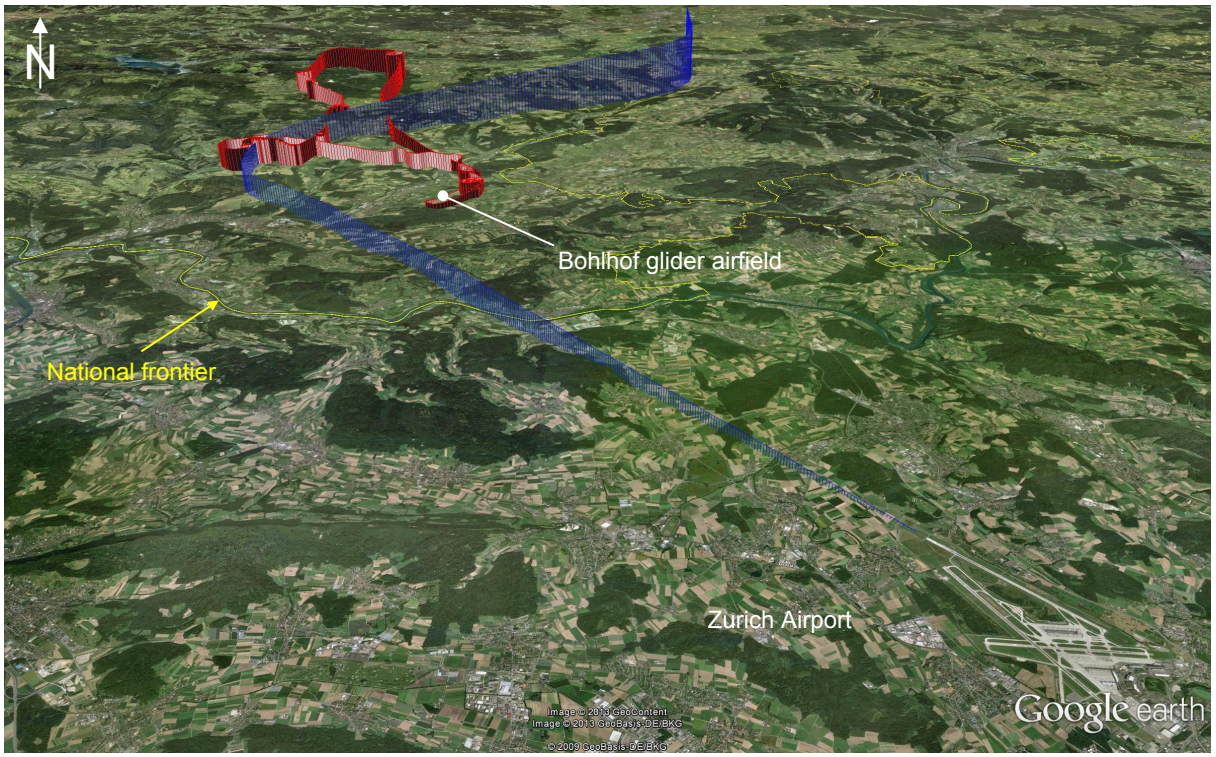
Annex 2: Flight paths of the two aircraft



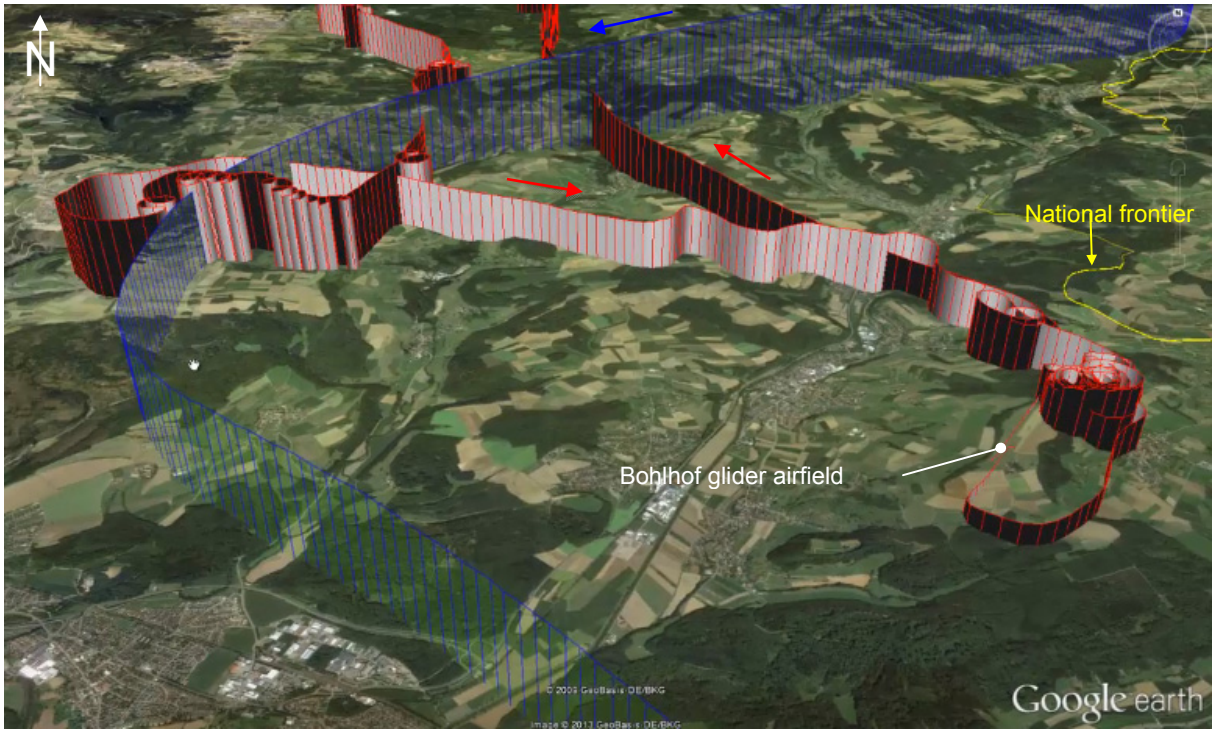
Flight path of the HB-1519 glider (take-off: 12:59:21 UTC, landing: 13:59:37 UTC)

Flight path of the A340-313 HB-JMN on the approach phase, from the north

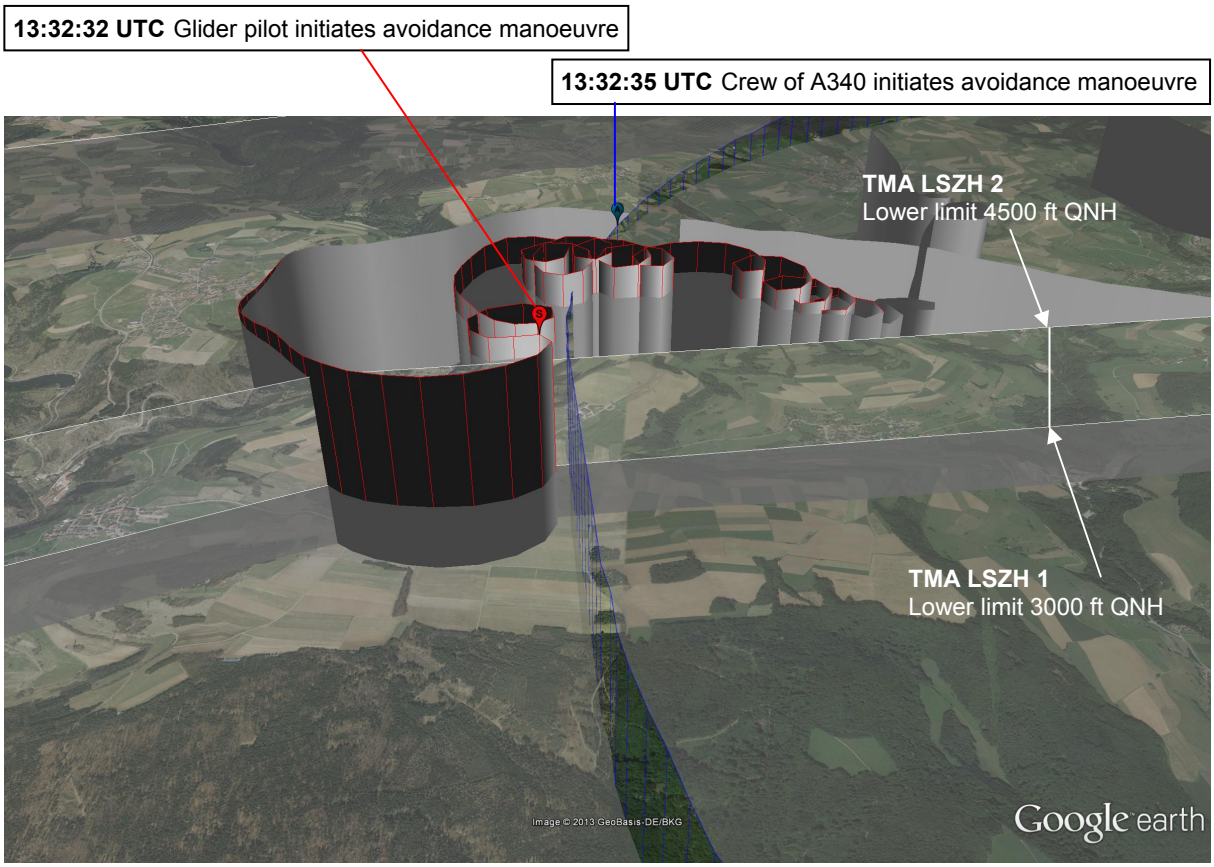
Annex 3: Three-dimensional flight paths of the two aircraft involved



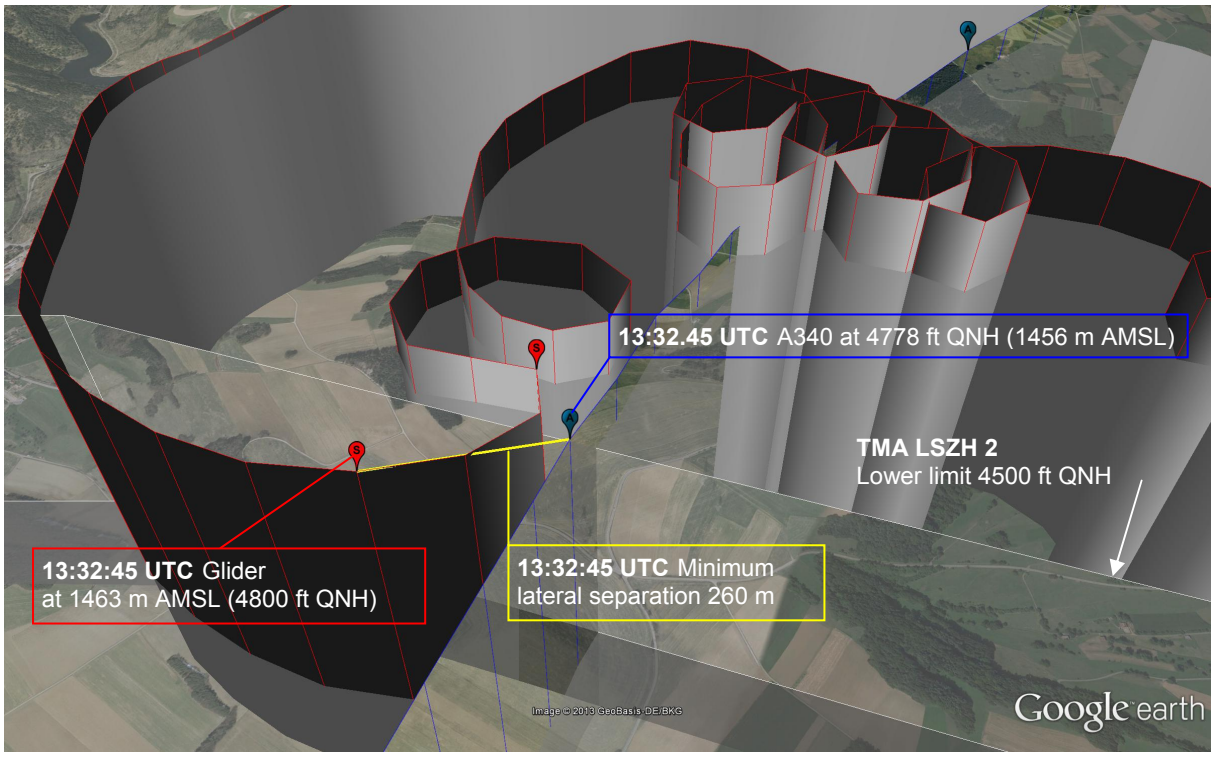
Flight path of the HB-1519 glider
Flight path of the A340-313, registration HB-JMN



Annex 4: Dangerous Convergence



Flight path of the HB-1519 glider
Flight path of the A340-313, registration HB-JMN
Violation of TMA lower limit



Annex 5: Aircraft visibility

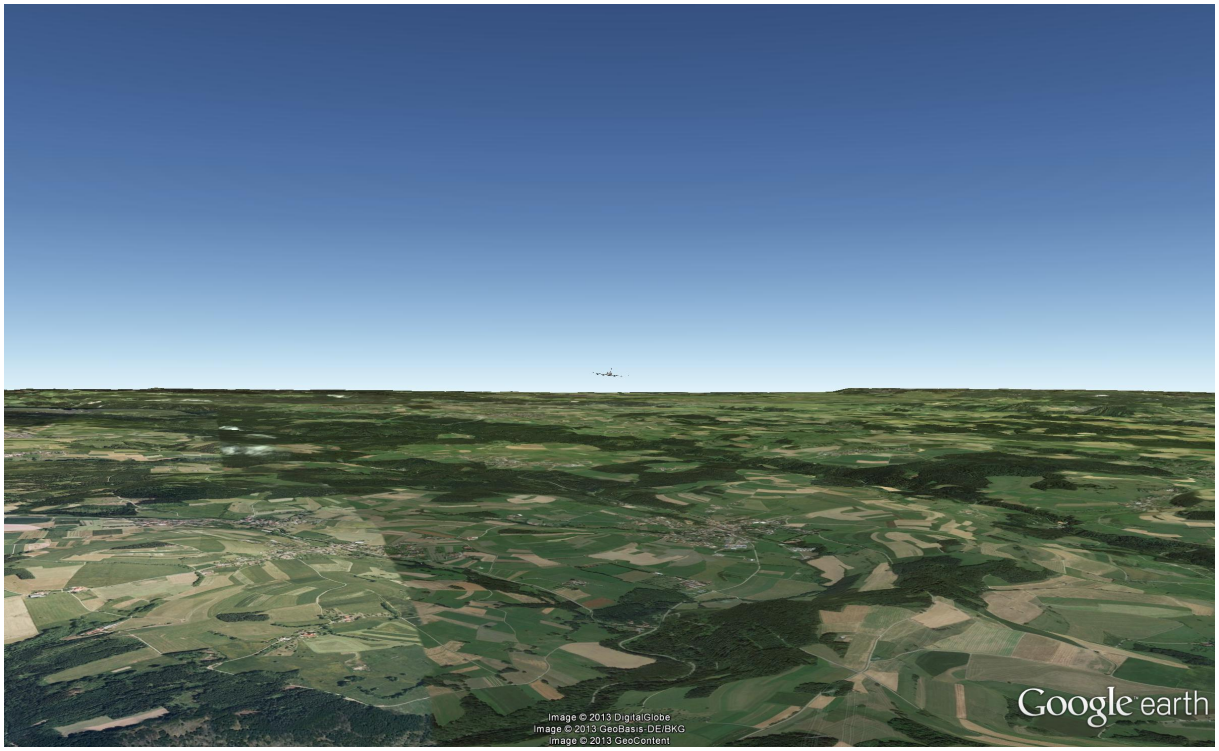


Figure 10: Probable view of the Airbus A340-313 from the position of the glider at 13:32:32 UTC

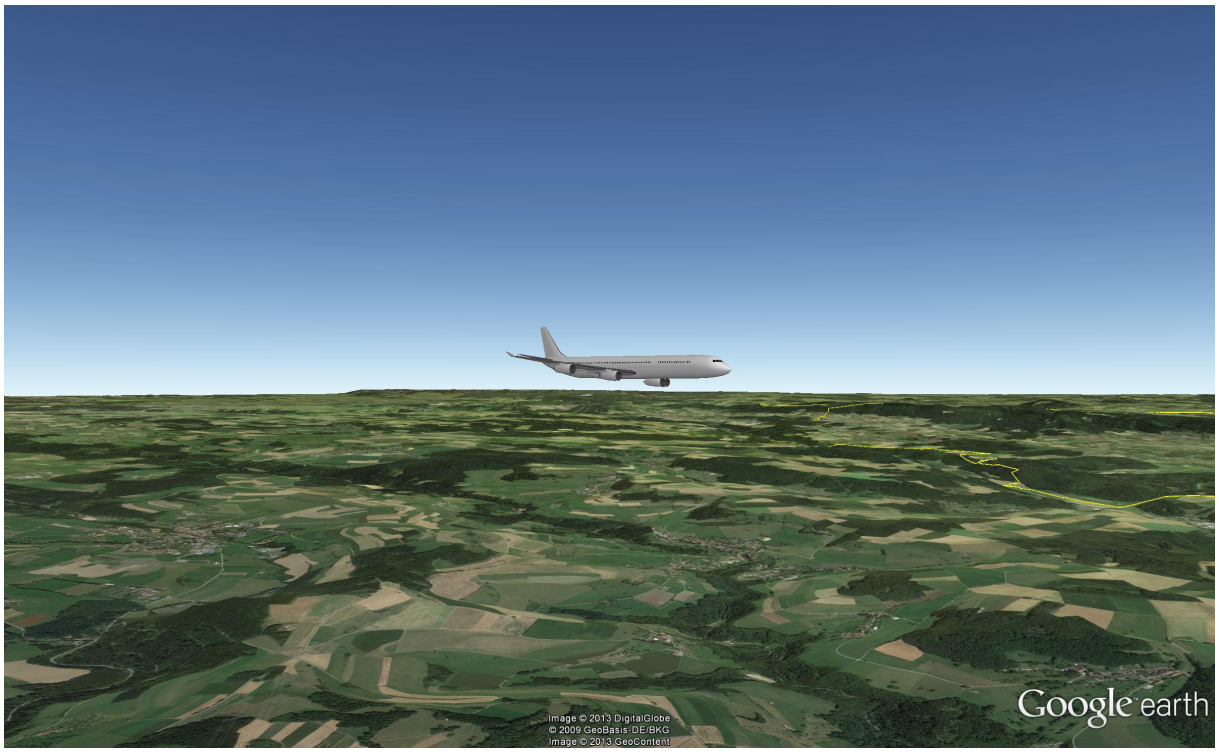
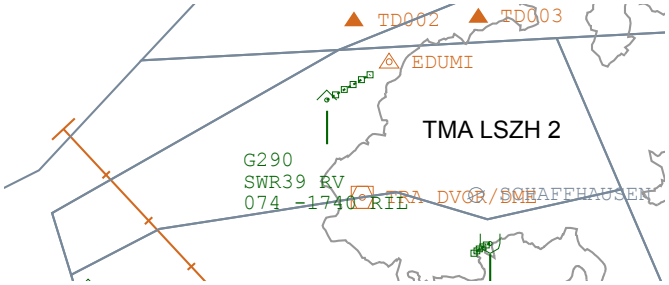


Figure 11: Probable view of the Airbus A340-313 from the position of the glider at 13:32:45 UTC

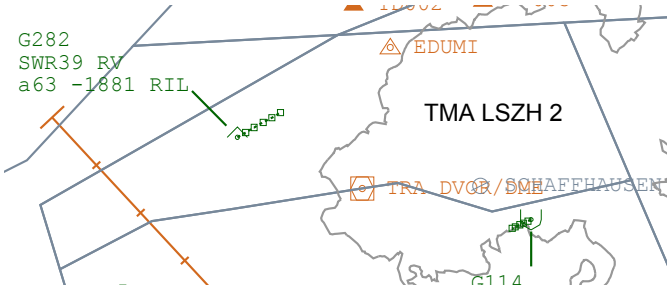
Annex 6: Radar data recording of SWR 39 during the approach



Radar screen at 13:31:22 UTC

SWR 39 reported to the ATCO at 13:31:21 UTC and received clearance to descend to 5000 ft at 13:31:24 UTC

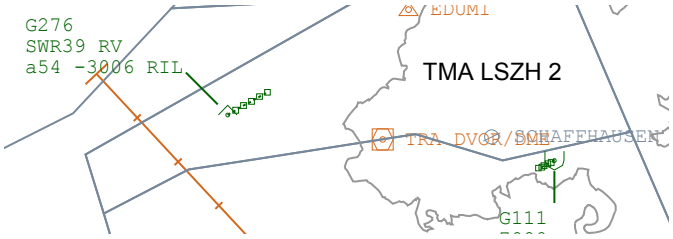
Groundspeed 290 kt
FL 74
1740 ft/min ROD



Radar screen at 13:32:04 UTC

SWR 39 receives a heading instruction and clearance to descend to 4000 ft from the ATCO.

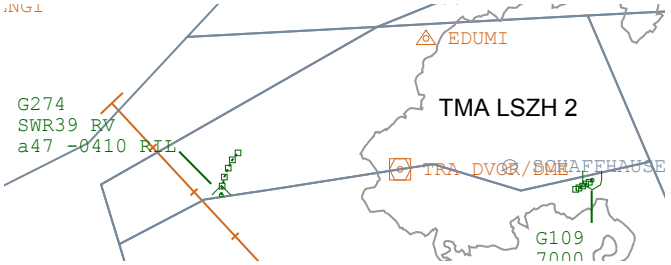
Groundspeed 282 kt
6300 ft QNH
1881 ft/min ROD



Radar screen at 13:32:21 UTC

SWR 39 receives the instruction to reduce speed to "*minimum clean*" from the ATCO at 13:32:23 UTC.

Groundspeed 276 kt
5400 ft QNH
3006 ft/min ROD



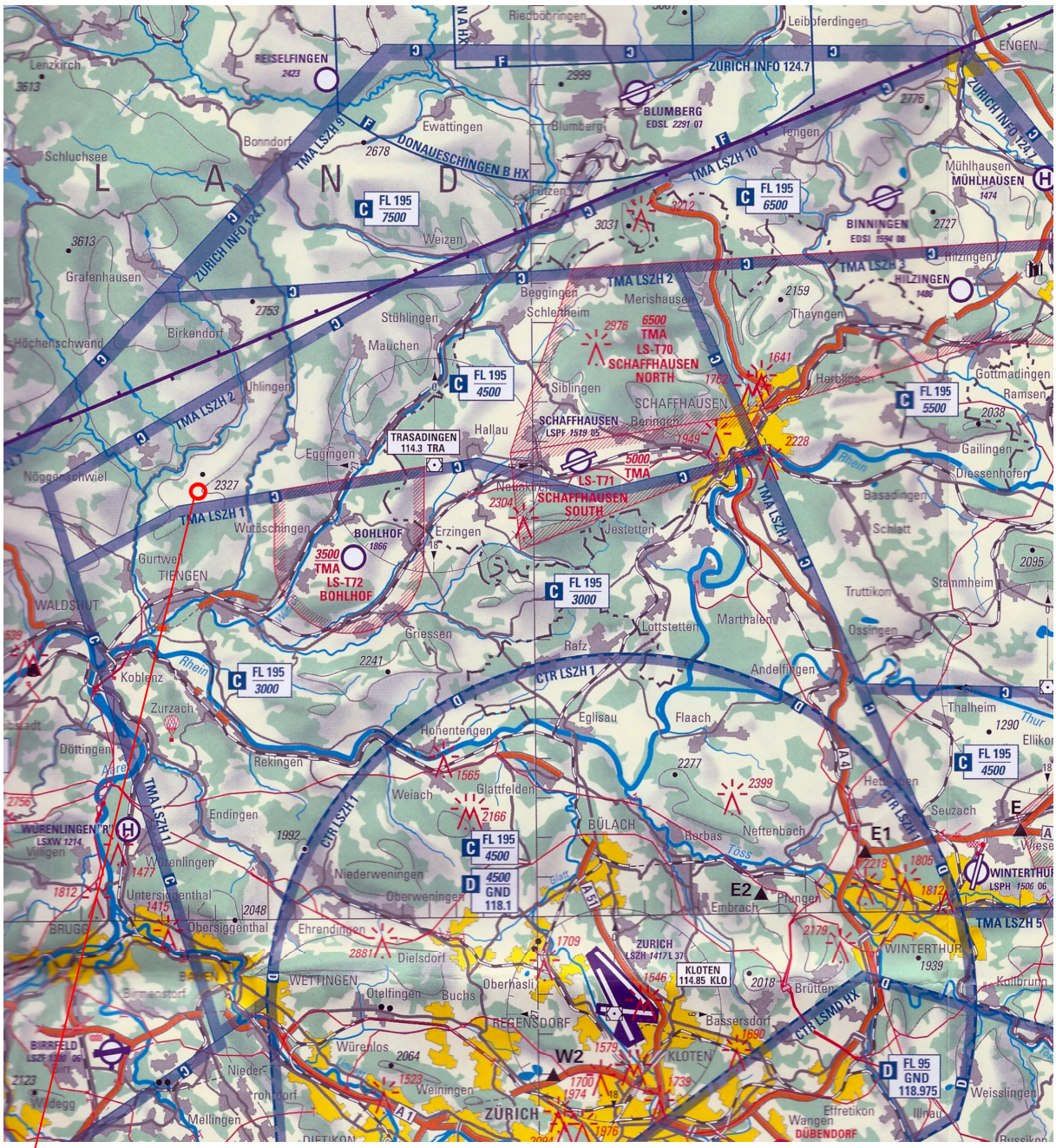
Radar screen at 13:32:45 UTC

SWR 39 reports the dangerous encounter to the ATCO after initiating an avoidance manoeuvre

Groundspeed 274 kt
4700 ft QNH
410 ft/min ROD

Annex 7: Control zone and terminal control area (TMA) around Zurich

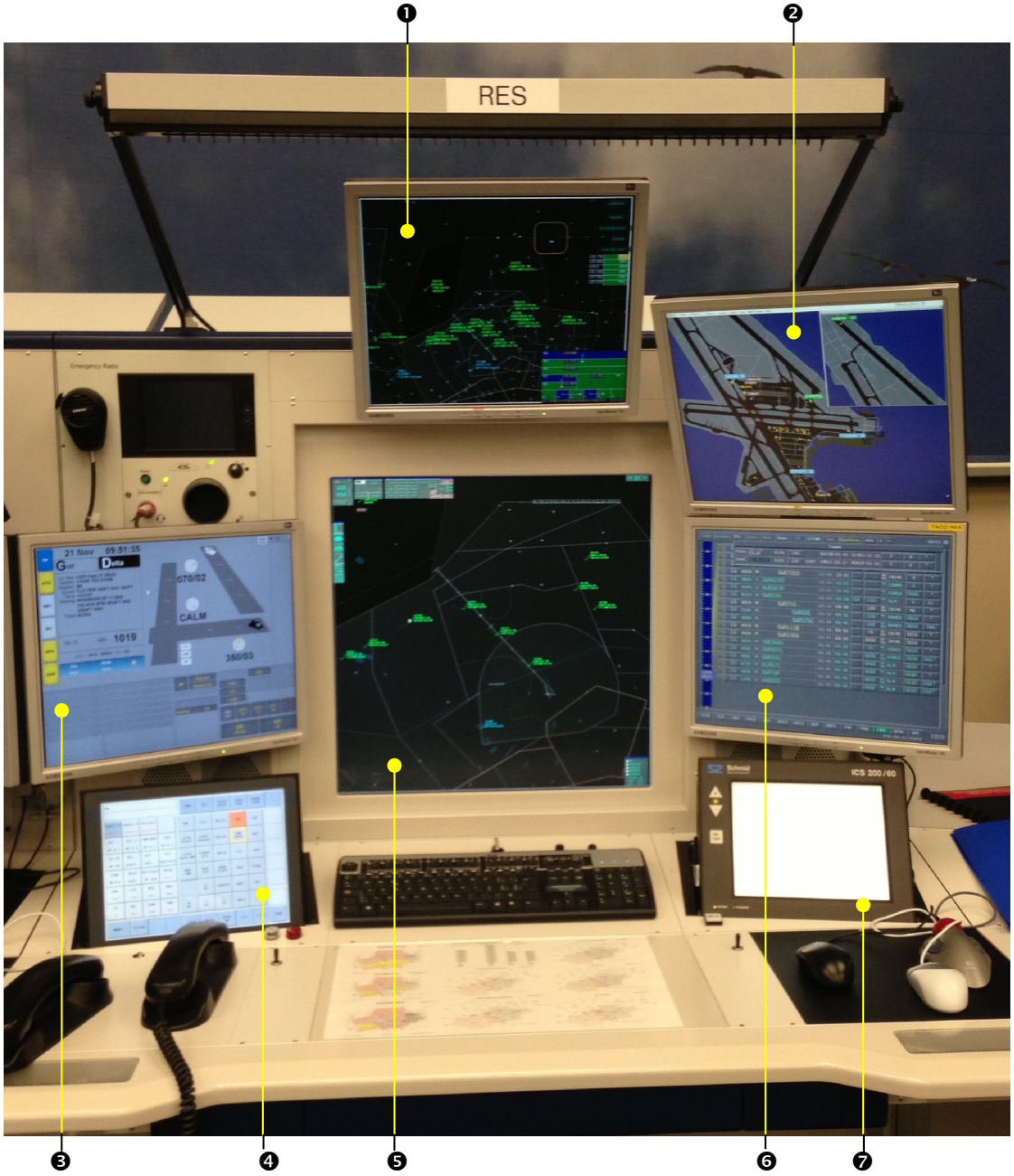
Annex 8: Division of the Zurich control zone



Copy of the AREA CHART ICAO, 2012 MAR 08, 3rd edition

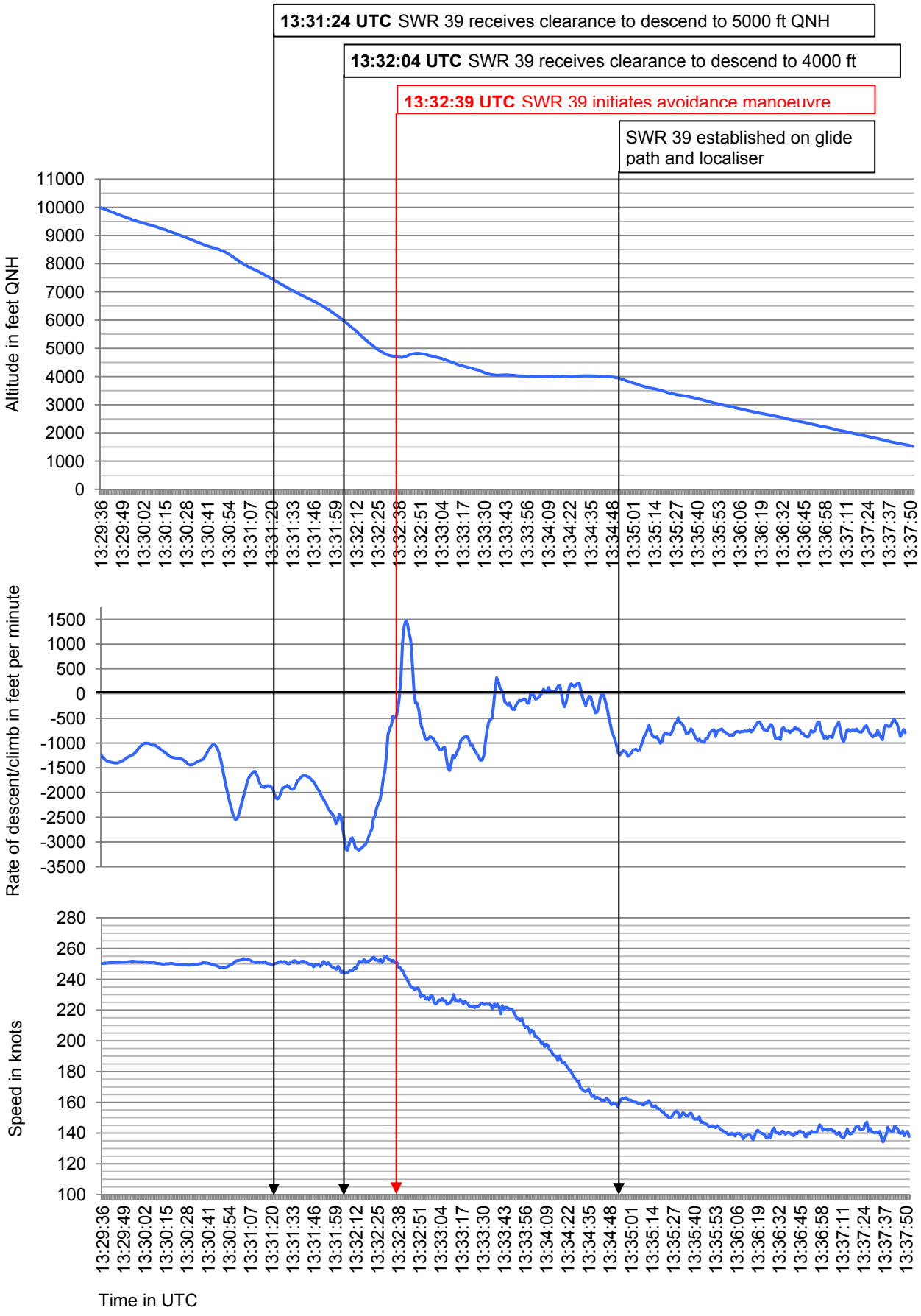
Location of the serious incident

Annex 9: Reserve working position in APP (identical to FIN working position)

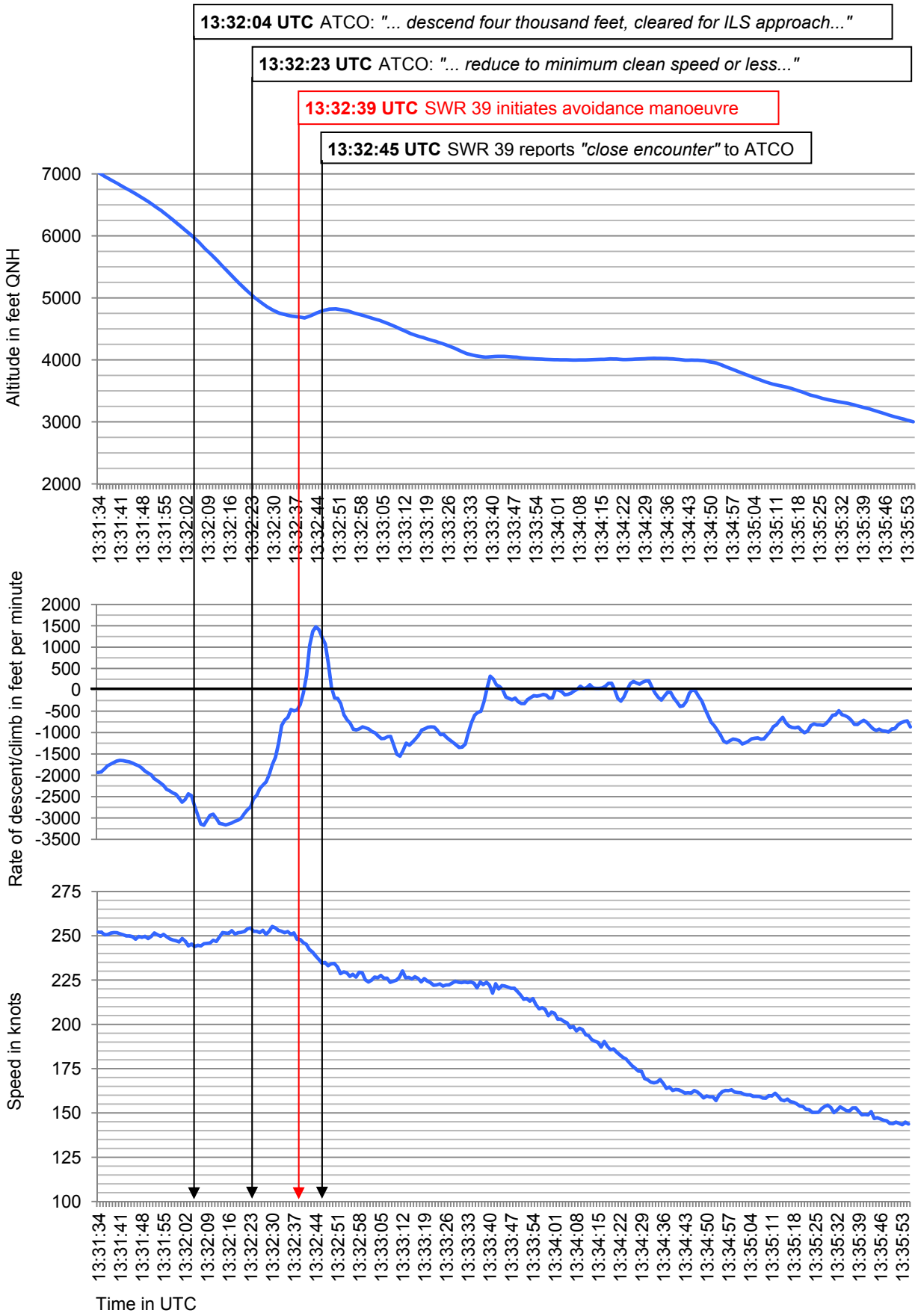


No.	Device	Function/use
❶	Upper radar screen	Radar image of the air situation (range selectable by ATCO)
❷	SAMAX	(Swiss Airport Movement Area Control System) Ground radar with integrated RIMCAS
❸	INCH	(Information System Schweiz) Representation of weather, runway conditions, time, etc.
❹	Telephone	Coordination with various units e.g. APE, TWR, apron, etc.
❺	Main radar screen	Radar image of final approach sector (range selectable by ATCO)
❻	TACO	(Tower and Approach Coordination System) Electronic representation of all flight plans
❼	Radio frequency selector	Selection of the frequencies used

Annex 10: Vertical flight path of SWR 39 from FL 100



Annex 11: Vertical flight path of SWR 39 between 7000 and 3000 ft QNH



Annex 12: Clearance to descend to 4000 QNH

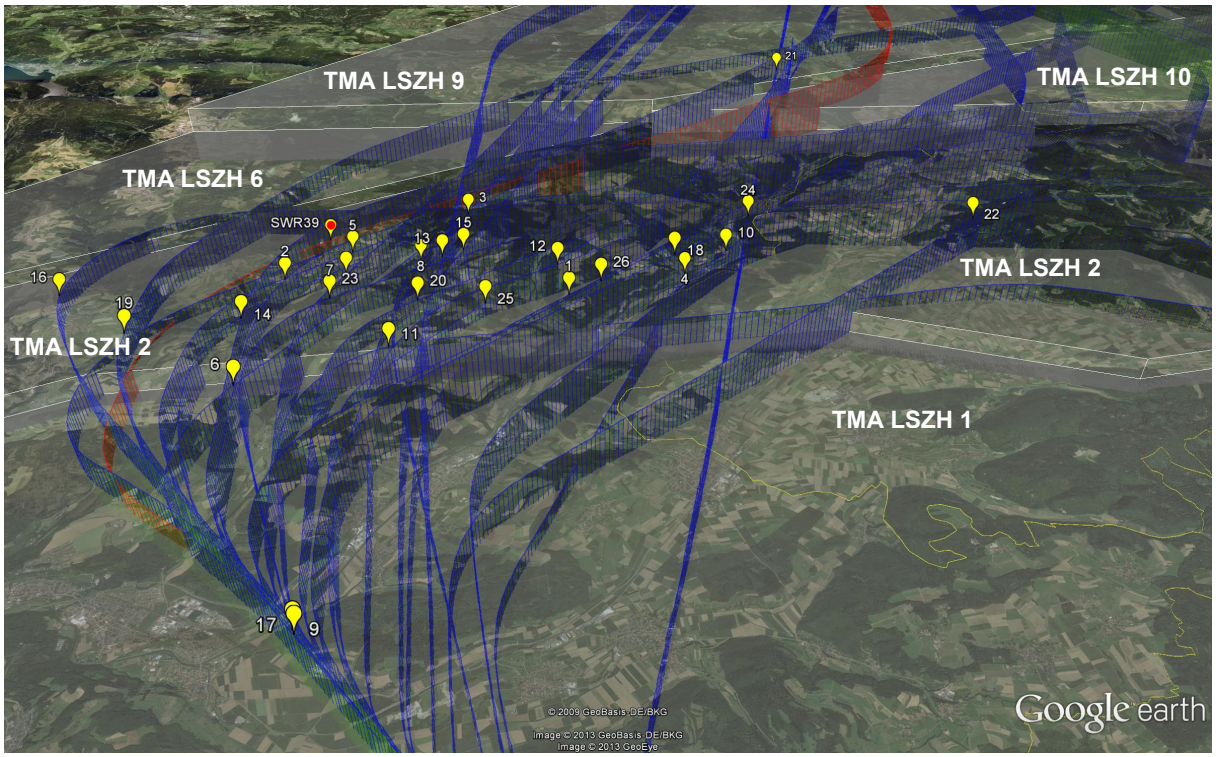


Figure 12: On the corresponding three-dimensional display of the flight path the yellow beads indicate the flight number and the position at which the crew selected the altitude of 4000 ft QNH after having received corresponding clearance. Flight 21 received clearance to 4000 ft QNH north of TMA LSZH 2, while flights 6, 9, 11 and 17 received clearance within TMA LSZH 1.

The following table shows the respective altitudes (ALT), rates of descent (ROD) and knots indicated airspeed (KIAS) for the aircraft upon receiving clearance to descend to 4000 ft QNH.

Flight	ALT ft QNH	ROD ft/min	KIAS
SWR 39	6000	2500	245
1*)	6100	2000	229
2*)	6300	1300	210
3*)	6600	2600	250
4*)	5400	1600	235
5*)	6100	550	199
6	5500	500	206
7*)	6500	900	210
8*)	6300	1500	216
9	5000	250	177
10*)	6900	1000	223
11	5000	200	179
12*)	6700	700	222
13*)	6900	1600	211

Flight	ALT ft QNH	ROD ft/ min	KIAS
14*)	6100	1400	216
15*)	7200	1600	225
16*)	6000	300	185
17	5000	0	172
18*)	7800	800	226
19*)	6300	800	184
20*)	6000	0	178
21	8200	1200	233
22*)	7200	1300	220
23*)	6300	1200	191
24*)	7100	1100	235
25*)	5400	400	190
26*)	6800	1500	220

*) Clearance to descend received within TMA LSZH 2.

Annex 13: Vertical flight path of SWR 39 and 26 other aircraft

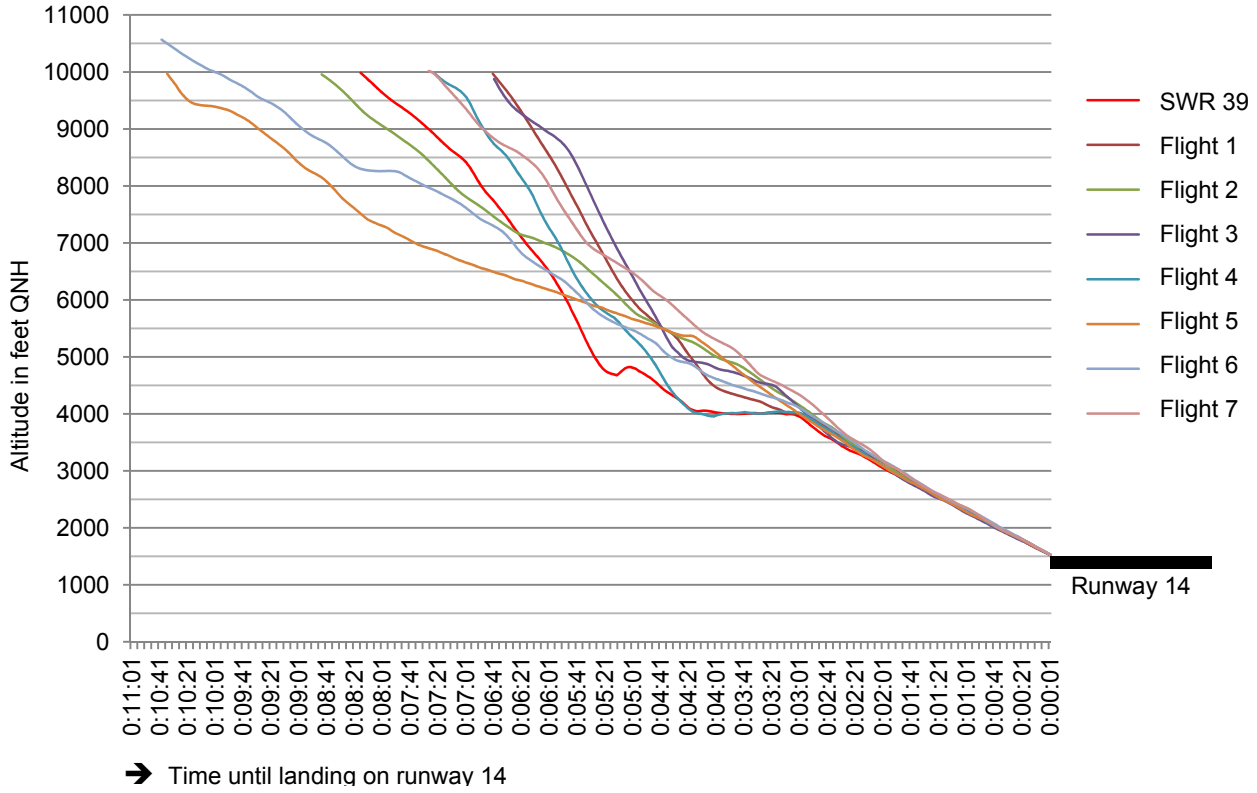


Figure 13: SWR 39 (red) and flights 1 to 7. Flights 2, 4 and 5 have a steeper rate of descent than flight SWR 39.

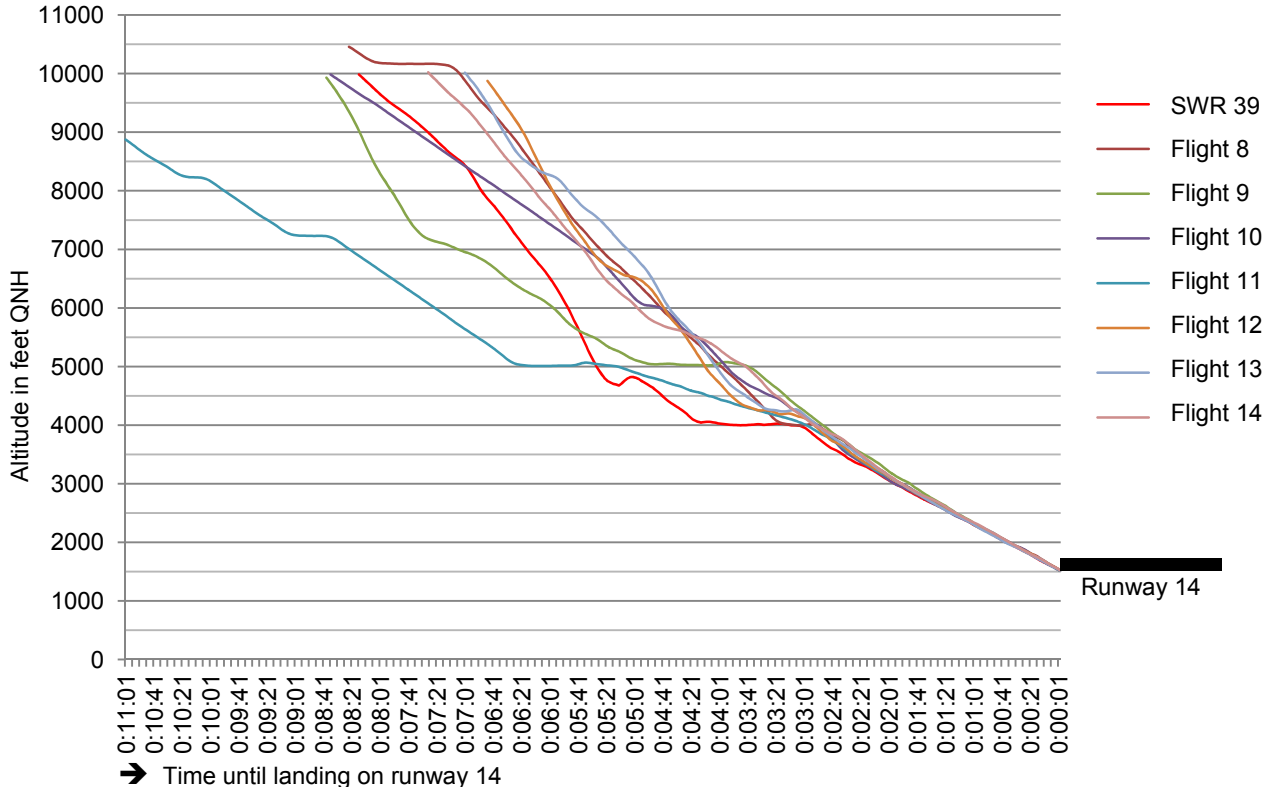


Figure 14: SWR 39 (red) and flights 8 to 14. Flights 9 and 11 only received clearance to 5000 ft QNH within TMA LSZH 2.

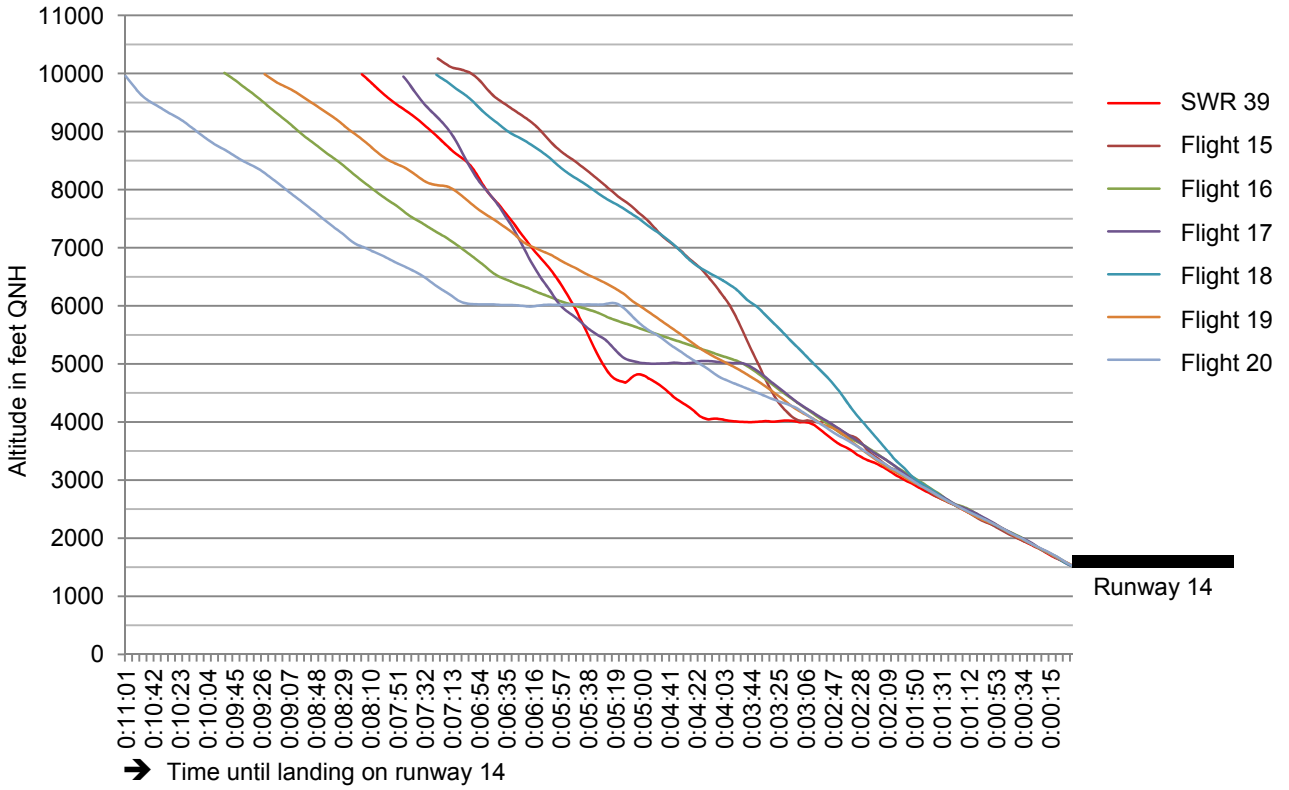


Figure 15: SWR 39 (red) and flights 15 to 20. Flight 20 had clearance to 4000 ft QNH, but remained in level flight at 6000 ft until the glide path of the instrument landing system (ILS) had been acquired.

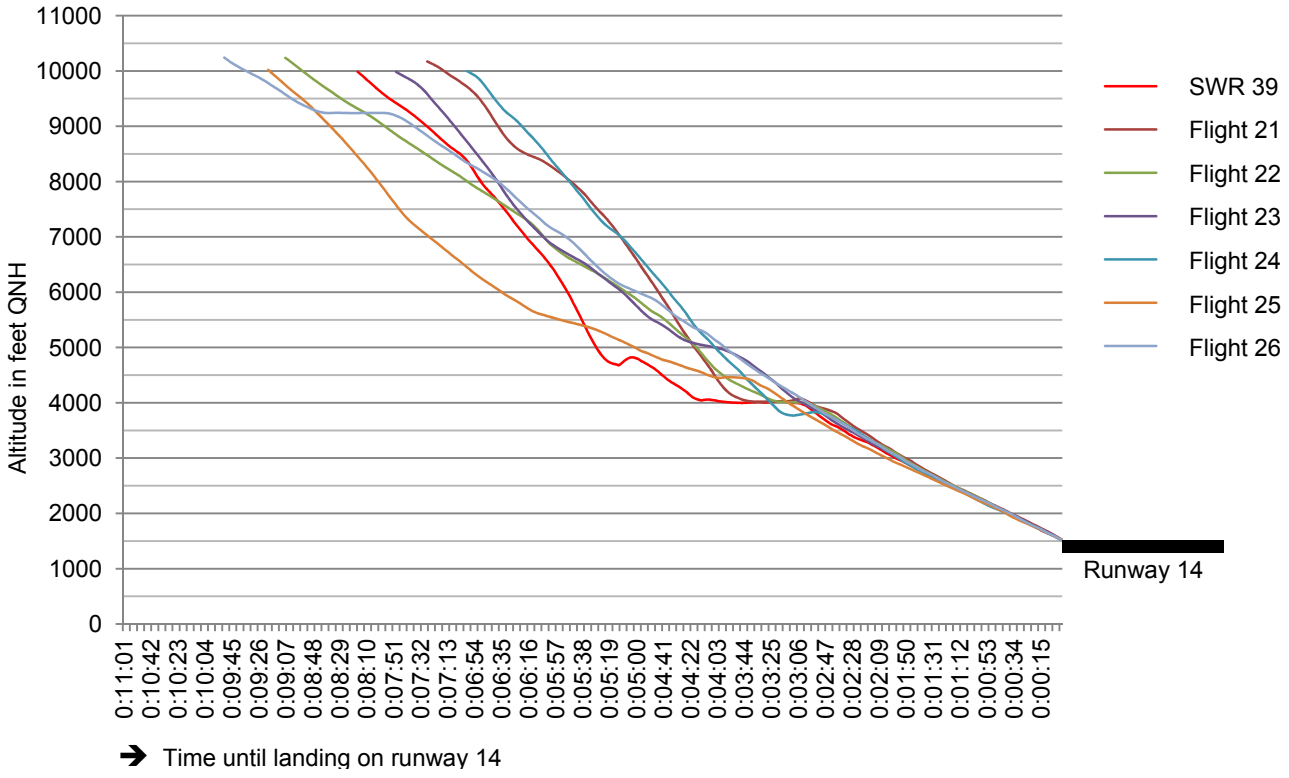


Figure 16: SWR 39 (red) and flights 21 to 26. Flight 21 has a virtually identical descent profile to SWR 39.

Annex 14: Altitudes of the 26 flights when passing from TMA LSZH 2 to TMA LSZH 1

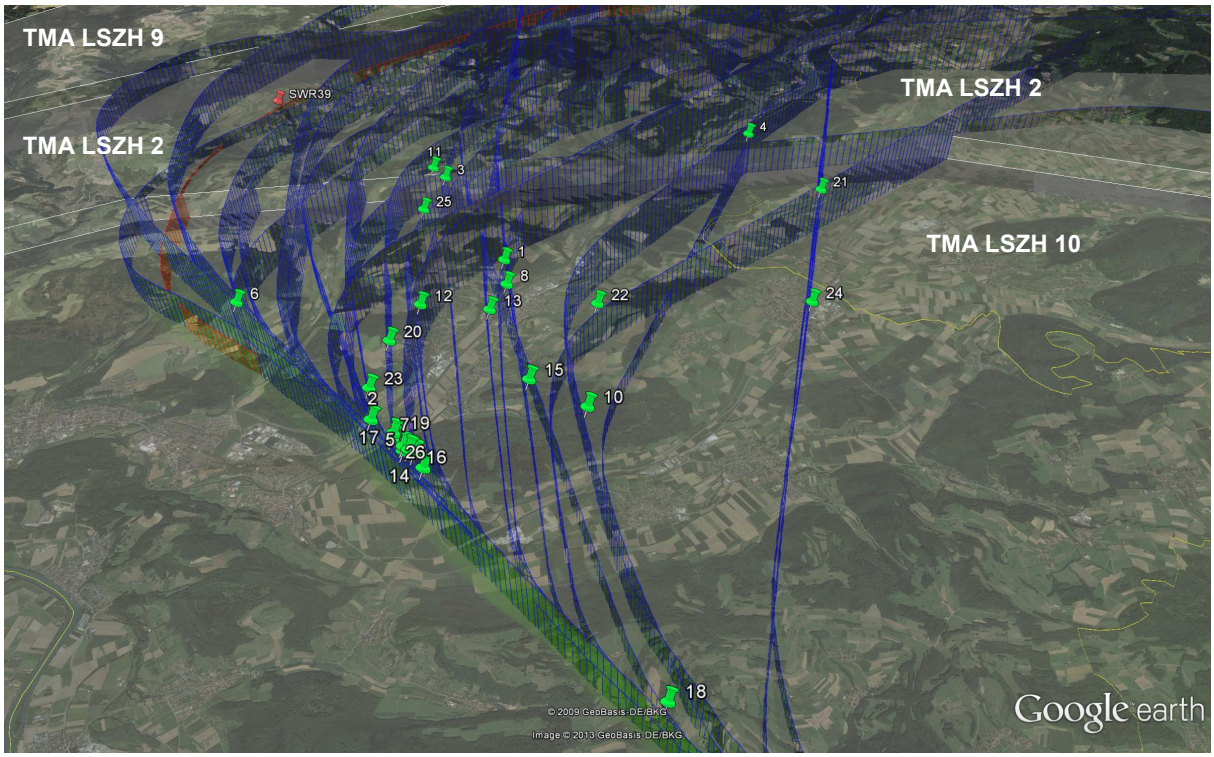


Figure 17: On the corresponding three-dimensional display of the flight path the green pin indicates the flight number and the position where the aircraft passed 5000 ft QNH while descending. With the exception of SWR 39 every flight passed 5000 ft QNH within TMA LSZH 1 and were therefore above 5000 ft QNH in TMA LSZH 2.

The following table shows the respective altitudes (ALT), rates of descent (ROD) and knots indicated airspeed (KIAS) for aircraft when passing from TMA LSZH 2 to TMA LSZH 1. The data has an accuracy of ±100 ft.

Flight	ALT ft QNH	ROD ft/min	KIAS
SWR 39	4831	1860	253
1*)	5778	1792	229
2*)	5942	1352	209
3*)	5206	2764	249
4*)	5039	1684	234
5*)	5833	588	199
6	5638	1008	227
7*)	6223	1208	207
8*)	5762	1628	213
9	5121	840	223
10*)	6303	1632	222
11	5164	1092	223
12*)	6346	280	219
13*)	6246	2188	205

Flight	ALT ft QNH	ROD ft/ min	KIAS
14*)	5939	1140	218
15*)	6842	1232	221
16*)	5737	752	176
17	5224	856	229
18*)	7456	952	225
19*)	6369	696	188
20*)	5971	24	180
21	5391	2348	230
22*)	6409	816	210
23*)	6160	1256	193
24*)	6087	1820	227
25*)	5291	408	189
26*)	6470	1608	222

*) Clearance to descend to 4000 ft QNH received within TMA LSZH 2.

Annex 15: Flight altitudes of the 1714 flights studied

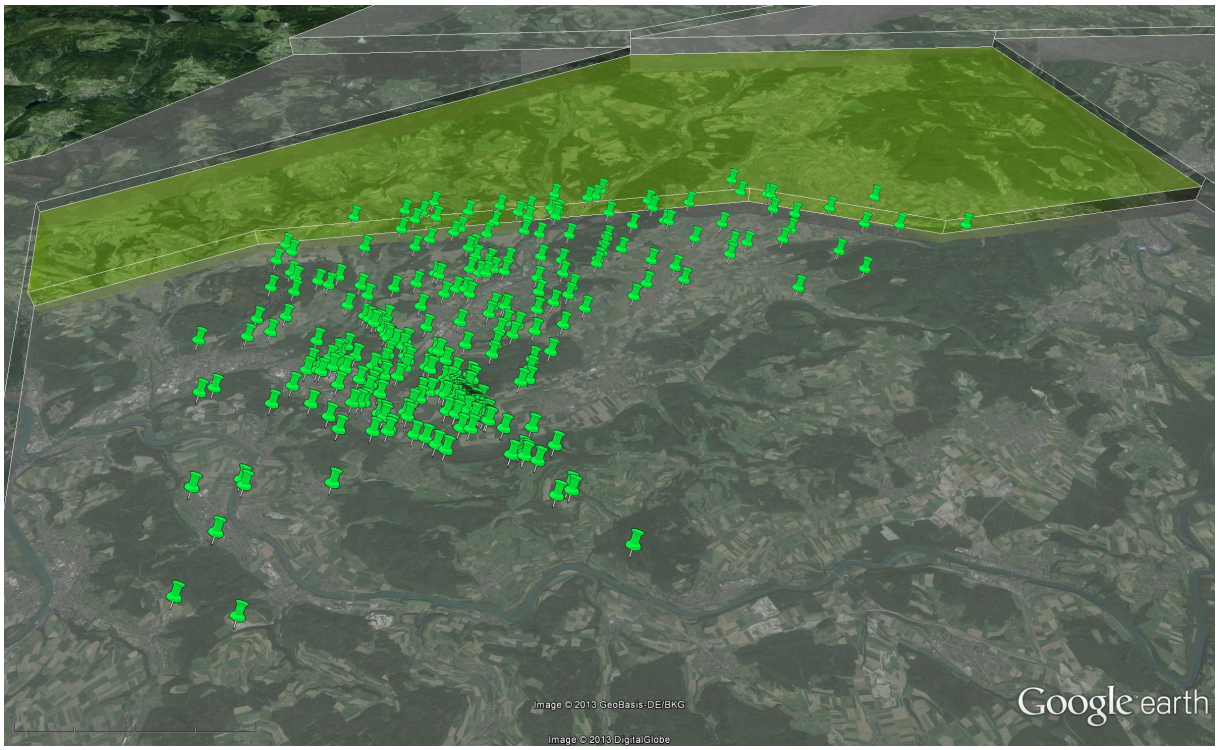


Figure 18: 311 approaches on 3 December 2012 with positions outside TMA LSZH 2 when passing below 5000 ft QNH for the first time.

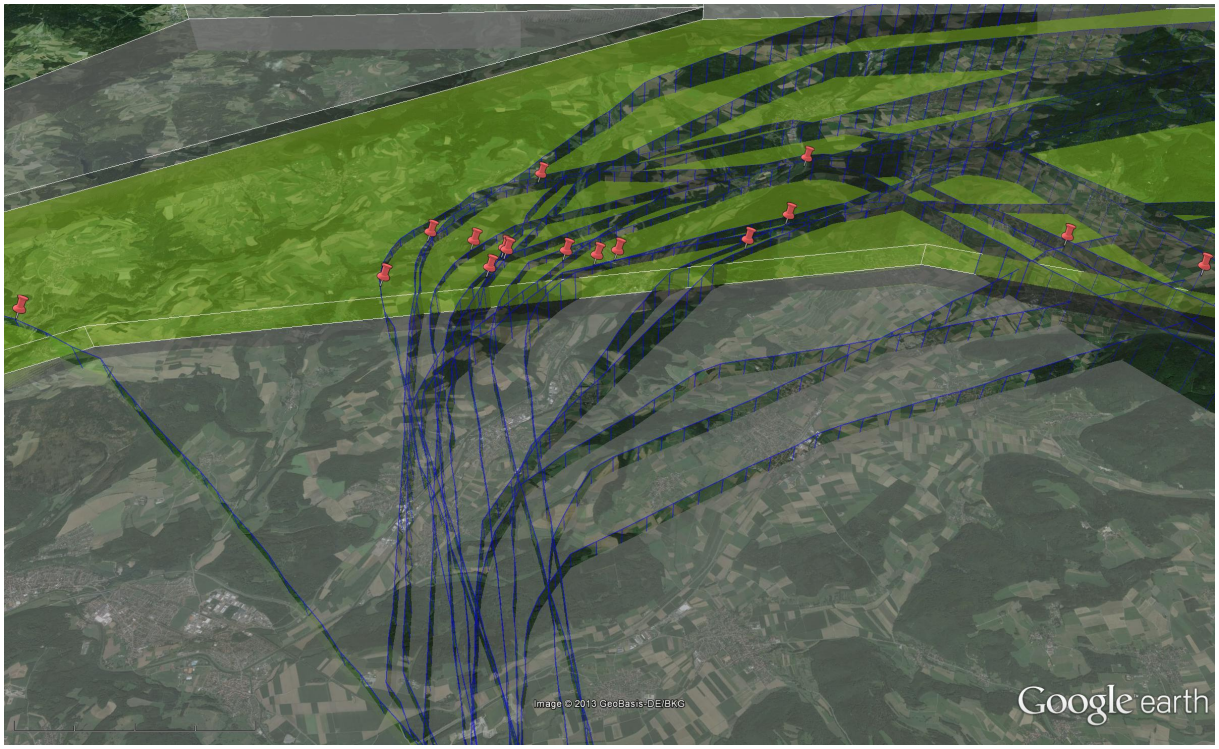


Figure 19: 17 approaches on 3 December 2012 with positions within TMA LSZH 2 when passing below 5000 ft QNH for the first time.

Figure 20: Example flight path from the investigation with a position when passing below 5000 ft QNH for the first time within TMA LSZH 2 (red pin) and the altitude when passing the boundary between TMA LSZH 1 and TMA LSZH 2 (yellow bead)

Annex 16: Lateral flight paths of SWR 169R and SWR 1801

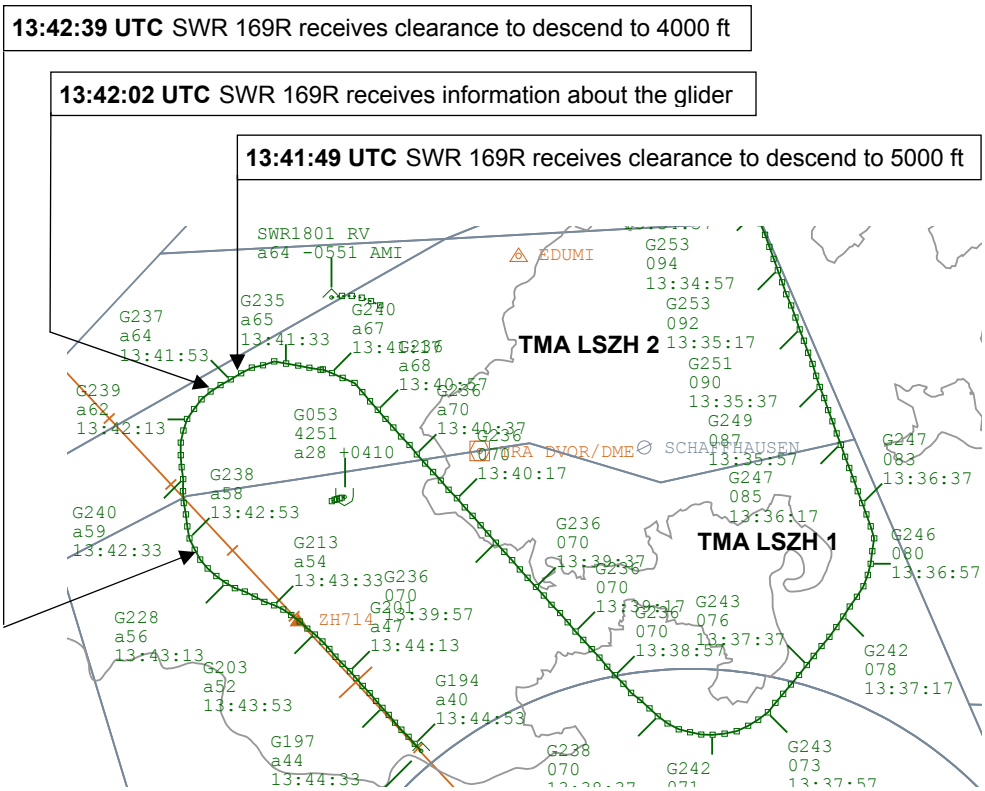


Figure 21: Lateral flight path of SWR 169R

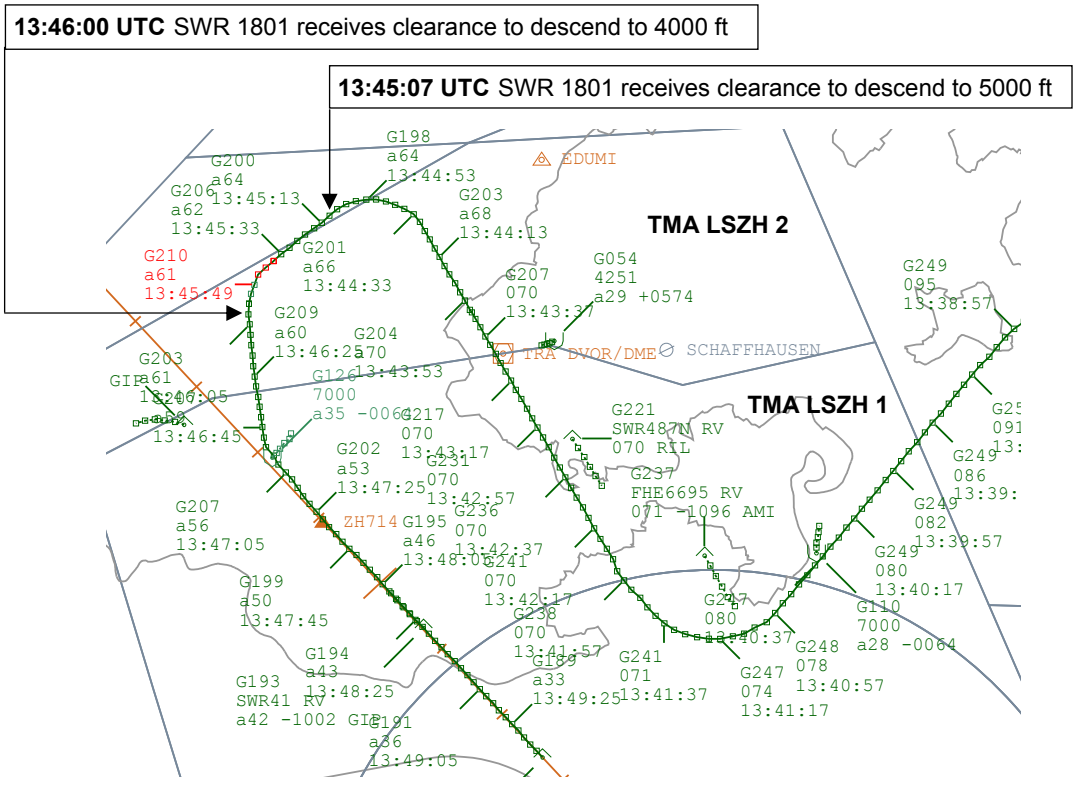


Figure 22: Lateral flight path of SWR 1801