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Swiss Transportation Safety Investigation Board STSB

Final Report No. 2325 by the Swiss Transportation Safety Investigation Board STSB

Concerning the serious incident (near-collision)

involving the commercial aircraft Fokker 50, OO-VLF,

operated by Vlaamse Luchttransportmaatschappij N.V. (VLM) under the flight plan call sign VLM 22TX

and the Piper PA-28RT-201T aircraft, OK-ELL,

on 21 April 2016

approximately 10 NM north-east of Friedrichshafen airport (EDNY), Germany

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General information on this report

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

In accordance with 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 prevention, due consideration shall be given to this circumstance.

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

All information, unless otherwise indicated, relates to the time of the accident.

All times in this report, unless otherwise indicated, are stated in coordinated universal time (UTC). At the time of the incident, Central European time (CET) applied as local time in Switzerland. The relation between LT, CET and coordinated universal time (UTC) is:
LT = CET = UTC + 2 hour.

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Final Report

Synopsis

Aircraft 1	
Owner	Jetstream Aviation Capital, Miami Florida
Operator	Vlaamse Luchttransportmaatschappij N.V. (VLM), Antwerpen, Belgium
Manufacturer	Fokker Aircraft B.V., Amsterdam, Netherlands
Aircraft type	F27 Mk050, Marketing designation „Fokker 50“
Country of registration	Kingdom of Belgium
Registration	OO-VLF
Flight number	VG 322
Flight plan call sign	VLM 22TX
Radio call sign	Rubens Two Two Tango Xray
Flight rules	Instrument flight rules (IFR)
Type of operation	Scheduled flight
Departure point	Berlin-Tegel (EDDT), Germany
Destination	Friedrichshafen (EDNY), Germany
Aircraft 2	
Owner	SATIKO s.r.o., Brno, Czech Republic
Operator	Icarus Aviation Group s.r.o., Brno, Czech Republic
Manufacturer	Piper Aircraft Inc., Vero Beach, USA
Aircraft type	Piper PA-28RT-201T (Marketing designation „Turbo Arrow“)
Country of registration	Czech Republic
Registration	OK-ELL
Radio call sign	Oscar Kilo Echo Lima Lima
Flight rules	Visual flight rules (VFR)
Type of operation	Private flight
Departure point	Brno-Tuřany (LKTB), Czech Republic
Destination	Friedrichshafen (EDNY), Germany
Location	Approximately 10 NM north-east of Friedrichshafen airport (EDNY), over German territory
Date and time	21 April 2016, 08:14:54 UTC
ATS unit	Area control center (ACC) Zurich, regional sector ARFA[1]
Airspace class	Class E
Closest point of approach between the two aircraft	0.5 NM horizontally and 100 ft vertically
Minimum prescribed separation	IFR to VFR traffic: None Traffic information are given as far as is practical.
Airprox category	ICAO category A

[1] Sector ARFA: Area Control Center Friedrichshafen (EDNY) and St. Gallen-Altenrhein (LSZR).

Investigation

The serious incident took place on 21 April 2016 at 08:14:54 UTC. The notification was received on 25 April 2016 at 08:01 UTC from the Belgian investigating authority, Air Accident Investigation Unit (AAIU), by the Swiss Transporation Safety Investigation Board (STSB). After preliminary clarifications, which are typical for this type of serious incident, the investigation was opened on 26 April 2016.

The STSB reported the serious incident to the Belgian, German and Czech investigation authorities, who in turn nominated authorized representatives, that assisted with the investigation. Since the serious incident took place in an airspace over Germany that was administrated by the air traffic control Skyguide (delegated services), Germany delegated the investigation to Switzerland.

The following elements were available for the investigation:

- The recordings of the radiotelephony and radar data;
- The stored data of the quick access recorder (QAR);
- The statements made by the pilots and air traffic controllers

Procurement of documentation from the air navigation service provider (ANSP) in charge of the aerodrome control at Friedrichshafen airport turned out to be laborious.

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

Summary

On 21 April 2016, the second day of the aviation exhibition „AERO-Friedrichshafen“, the pilot of the pistoned-engine Piper PA-28RT-201T, registration OK-ELL, with three passengers on board, made initial contact at 08:03:27 UTC with the Friedrichshafen (EDNY) aerodrome control on frequency 120.075 MHz for landing. The pilot notified the air traffic controller that he had passed Kempten and was going to descend to 4000 ft QNH.

At the aerodrome control of Friedrichshafen Airport two air traffic controllers' workstations were allotted with the descriptions VFR Pick-up, respectively PL-Main. After initial contact, the pilot of OK-ELL was instructed by the VFR Pick-up controller to fly directly towards the waypoint OSCAR, north-west of the airport, thereby remaining outside of the control zone (CTR).

Roughly four minutes later, the crew of the commercial aircraft Fokker 50 with the flight plan call sign VLM 22TX and 33 passengers on board, made initial contact with the radar executive (RE) air traffic controller of the approach control (APP). The latter then issued a heading and a descent clearance with the intention of guiding VLM 22TX via a right-hand base towards a waypoint situated on the extended centreline of runway 24 and approximately 11 NM from the threshold for an instrument approach.

When OK-ELL was roughly 20 NM east of the airport at an altitude of 4000 ft AMSL, the pilot was cleared by the VFR Pick-up aerodrome controller to join the final approach leg of runway 24.

At 08:12:49 UTC, the flight crew of flight VLM 22TX was cleared by the RE air traffic controller to descend to 5000 ft QNH. Half a minute later, they were cleared to turn to a heading of 150 degrees for the base leg, coupled with the clearance to descend to 4000 ft QNH.

After having been transferred to the PL Main air traffic controller, the pilot of OK-ELL called on frequency 134.300 MHz at 08:13:44 UTC on long final to runway 24. At 08:13:58 UTC, the PL Main aerodrome controller instructed the pilot of OK-ELL to turn right towards the waypoint OSCAR and to remain outside of the CTR.

At 08:14:06 UTC the ground based short term conflict alert (STCA) generated an alarm between VLM 22TX and OK-ELL, followed ten seconds later at 08:14:16 UTC by a traffic information provided to the flight crew of VLM 22TX by the RE air traffic controller concerning an unknown VFR traffic. He then provided a second traffic information at 08:14:37 UTC.

Despite good visual meteorological conditions, the visibility through the flight deck windows of VLM 22TX was impaired by the reflection and position of the sun, which is why the flight crew could only identify and follow the intruding traffic at the same altitude with the information displayed by their traffic alert and collision avoidance system (TCAS). The commander subsequently decided to initiate an avoidance manoeuvre by turning 90 degrees to the right.

At approximately the same time, following the traffic information, the pilot of OK-ELL reported that he had visual contact with the Fokker 50.

During the avoidance manoeuvre of VLM 22TX, the two aircraft crossed at an altitude of approximately 4000 ft AMSL. The closest point of approach at 08:14:54 UTC was 0.5 NM horizontally und 100 ft vertically.

Both aircraft continued their approach without further events.

Causes

The serious incident is attributable to a dangerous convergence of two aircraft flying on a converging course in airspace class E during an aviation exhibition, during which time the commercial aircraft flying under instrument flight rules was in contact with the approach control, while the light aircraft flying under visual flight rules was in radio contact with the aerodrome control.

The dangerous convergence arose from the concurrence of the following factors in chronological order:

- The operational concept consisting of the simultaneous approach of traffic under visual and instrument flight rules during the trade fair entailed systemic risks.
- The pilots of both aircraft were not in radio contact with the same air traffic control unit.
- The traffic guidance within the aerodrome control service concerning the light aircraft approaching under visual flight rules was coordinated inadequately.
- The traffic alert and collision avoidance system on board the commercial aircraft did not generate a resolution advisory due to a lateral avoidance manoeuvre.
- The traffic information provided by the aerodrome control to the pilot of the light aircraft was given too late.
- The pilots of both aircraft only acquired a late visual contact of each other.

The current classification of the airspace, in which the dangerous convergence took place, contributed to the occurrence of the serious incident.

Safety recommendations and safety advices

One safety recommendation was issued in the framework of this investigation.

1 Factual information

1.1 Flight preparations and history of the serious incident

1.1.1 General

The scheduled flight VLM 22TX was conducted under instrument flight rules (IFR). The commander was pilot flying (PF) and the co-pilot was pilot monitoring (PM) during the entire flight.

The flight of aircraft OK-ELL was conducted under visual flight rules (VFR).

The management of the airspace over the region of Friedrichshafen is divided among several air navigation service providers (ANSP): the German air traffic control service *Deutsche Flugsicherung GmbH* (DFS) has delegated the air traffic control services for the airspace sector over German territory around the control zone (CTR) Friedrichshafen to Skyguide. However, Austro Control GmbH (ACG) is responsible for the air traffic control service within the CTR of Friedrichshafen and for the related processes. The Federal Air Traffic Controlling Office (*Deutsche Bundesaufsichtsamt für Flugsicherung* – BAF) is responsible for the supervision over the civil air navigation service organisations.

At the time of the serious incident, Zurich Arrival of Skyguide was in charge of the sector ARFA[2] and supervised IFR arrivals and departures at Friedrichshafen Airport over German territory as well as St. Gallen-Altenrhein airport (LSZR) over Swiss territory.

At Friedrichshafen Airport, ANSP Austro Control GmbH (ACG) had staffed two worksations for the aerodrome control during the serious incident.

The serious incident occured over German territory in airspace E (cf. chapter 1.7.2).

The yearly aviation exhibition „AERO-Friedrichshafen“ took place from 20 to 23 April 2016 (cf. chapter 1.7.5).

There were no indications of technical restrictions, neither for the air traffic control equipment nor for the two aircraft.

1.1.2 Pre-flight history

The temporary directives for the event „AERO-Friedrichshafen“ published in the aeronautical Information publication supplement (AIP SUP) for IFR and VFR traffic contained detailed descriptions of the operational limitations and the general conditions for arriving and departing traffic at Friedrichshafen Airport (cf. chapter 1.7.6). The related notice to airmen (NOTAM) was published in due time. A prior authorisation (prior permission required – PPR) was necessary during the exhibition for both VFR and IFR traffic, with the exception of scheduled line and charter flights, VFR departures and arriving or departing helicopters.

The air traffic controllers (ATCO) at workstation ARFA had been trained prior to the event during a one day refresher course in the simulator with high traffic volume (heavy traffic refresher) (cf. chapter 1.10.1.3). At the same time, they were introduced to the unusual „two-man OPS“ procedures and had complied with the guidelines of the associated list of duties (cf. chapter 1.10.1.3).

The radar executive (RE) air traffic controller on duty assessed both the traffic volume and the complexity at the time of the serious incident as medium to high. The

[2] Sector ARFA : Area Control Center Friedrichshafen (EDNY) and St. Gallen Altenrhein (LSZR)

radar coordinator (RC) air traffic controller shared this view and added that his tour of duty during the 2014 „AERO-Friedrichshafen“ were more intense than the preceeding year.

The pistoned-engined aircraft, a Piper PA-28RT-201T registered OK-ELL was conducting a private VFR flight from Brno-Tuřany (LKTB) to Friedrichshafen (EDNY). Other than the pilot, three passengers were on board. Following the flight preparation and the study of the NOTAM, he knew the particular operational conditions for arriving and departing traffic during the exhibition at Friedrichshafen Airport. (cf. chapter 1.7.6). During the serious incident, the pilot of OK-ELL was first in radio contact with the aerodrome controller in charge of the worksation internally designated as VFR Pick-up on frequency 120.075 MHz, and then with the aerodrome controller in charge of the workstation internally designated as PL Main on frequency 134.300 MHz.

The scheduled flight of the Belgian operator VLM Airlines from Berlin-Tegel (EDDT) to Friedrichshafen was conducted with a Fokker 50, registration OO-VLF, with the radio call sign *Rubens Two Two Tango Xray*. On board the commercial aircraft were two pilots, one cabin crew member and 33 passengers. During the serious incident, the flight crew of VLM 22TX was in radio contact with ARFA on frequency 119.925 MHz.

1.1.3 History of the serious incident

On 21 April 2016, the pilot of OK-ELL made initial contact at 08:03:27 UTC with the Friedrichshafen aerodrome control on frequency 120.075 MHz. He reported that he had passed Kempten and was about to start descending to an altitude of 4000 ft QNH. He was then instructed by the VFR Pick-up aerodrome controller to proceed towards the waypoint OSCAR (cf. figure 1) and was asked if he wished to land on the paved runway. The pilot then replied that he was going to fly directly to the final approach of runway 24. The aerodrome controller immediately corrected the reply of the pilot and told him that he was to remain north of the Friedrichshafen CTR. The pilot of OK-ELL read back the instruction correctly.

At 08:07 UTC VLM 22TX, which was following the standard arrival route (STAR) GARMO 1P, arrived in the area controlled by the sector ARFA. After initial contact with the RE air traffic controller at 08:07:50 UTC, the flight crew was instructed to descend to flight level (FL) 90 and to turn to a heading (HDG) of 135 degrees. The intention of the air traffic controller RE was, with this heading instruction, to guide the Fokker 50 towards a point situated approximately 11 NM from the threshold and on the extended axis of runway 24. He activated the speed vector on his radar display, that provided the instantaneous direction information for this traffic.

Approximately two minutes later, at 08:08:58 UTC, the flight crew of VLM 22TX received a clearance to descend to an altitude of 6000 ft QNH, with the information that 35 track miles could be expected until landing from their actual position. After an additional two minutes, VLM 22TX was instructed to turn to a heading of 120 degrees by the RE air traffic controller.

At this moment, the recorded radar data showed several VFR tags[3] north-northwest of Friedrichshafen Airport, some isolated tags dispersed east and south of St. Gallen-Altenrhein (LSZR) aerodrome and three more VFR tags between 14 and 17 NM in the final approach area of the instrument landing system (ILS) of runway 24. These three VFR tags showed various flight directions and, in each case, an altitude below 4000 ft above mean sea level (AMSL).

[3] Radar tags contain information and are attached to the aircraft symbol.

At 08:09:33 UTC and once again at 08:09:48 UTC, the VFR Pick-up aerodrome controller instructed the pilot of OK-ELL to proceed via the waypoint ETREM[4] to the final approach of runway 24. The name ETREM was thereby spelled twice by the ATCO. At this point in time, OK-ELL was about 20 NM east of the airport at an altitude of 4000 ft AMSL. The clearance was acknowledged by the pilot of OK-ELL approximately 20 seconds later with "*turning final 24 OLL*".

At 08:12:49 UTC the radar executive controller cleared VLM 22TX to descend to an altitude of 5000 ft QNH. The clearance was followed approximately half a minute later by an instruction to turn on a heading of 150 degrees for the base leg, associated with a descent clearance to 4000 ft QNH. The clearance was read back correctly by the flight crew. At approximately the same time, the VFR tag of an aircraft flying in the final approach area of runway 24 and 12 NM from its threshold could be seen, with an apparent south-westerly direction and an altitude value decreasing from 3800 ft to 3700 ft AMSL. This was OK-ELL which had been transferred to the frequency 134.300 MHz at 08:13:25 UTC by the VFR Pick-up aerodrome controller to his collegue at workstation PL Main. The pilot called the PL Main air traffic controller at 08:13:44 UTC, as he was on long final.

In the period of time between the first call made by the flight crew of VLM 22TX at 08:07:50 UTC and the instruction at 08:13:26 UTC, the RE air traffic controller was engaged with two departing aircraft from St. Gallen-Altenrhein, one departing jet on a scheduled flight from Friedrichshafen and two arriving aircraft to Friedrichshafen. He was able to solve, at an early stage, a potential conflict situation between two departing traffics, one from St. Gallen-Altenrhein and one from Friedrichshafen.

There was no coordination (tower check) in connection with the IFR approach of VLM 22TX between the approach control and the aerodrome control (cf. chapter 1.10.3).

The PL Main aerodrome controller instructed the pilot of OK-ELL at 08:13:58 UTC to turn right in the direction of the waypoint OSCAR and to remain outside the CTR. The clearance was read back correctly by the pilot of OK-ELL. At 08:14:10 UTC, the VFR tag on the radar plot clearly indicated that a right turn had been initiated in a north-westerly direction at an altitude of approximately 3900 ft AMSL.

The RE air traffic controller was in contact with another aircraft as the alarm of the short term conflict alert (STCA) between VLM 22TX and OK-ELL was triggered at 08:14:06 UTC (cf. chapter 1.10.1.5). At 08:14:16 UTC, the RE air traffic controller provided the flight crew of VLM 22TX with the following traffic information concerning an unknown VFR flight: *„Rubens Two Two Tango Xray, there is a known unknown VFR traffic on your uh one o'clock three and a half miles at 3900 feet coming opposite now, confirm you have him insight?“.*

The RC air traffic controller heard both the STCA and the subsequent transmission of a traffic information to VLM 22TX by the RE air traffic controller and, at 08:14:23 UTC, proceeded with an additional coordination conversation with the aerodrome controller of St. Gallen-Altenrhein.

The flight crew of VLM 22TX later declared that they could see a traffic at the same altitude on the indication of their traffic alert and collision avoidance system (TCAS). They were awaiting further instructions from the air traffic control when the TCAS triggered a traffic advisory (TA). Both the commander and the co-pilot expected an imminent resolution advisory (RA) from the system, but the latter was never generated.

[4] ETREM: a GPS waypoint for the area navigation (RNAV), also defined as Final Approach Point of the ILS approach for runway 24 in Friedrichshafen (cf. figure 5 in chapter 1.7.4).

The flight crew of VLM 22TX replied at 08:14:32 UTC that they did not have visual contact with the reported traffic. Thereupon, the RE air traffic controller began issuing an instruction with the words *„Two Two Tango Xray, turn uh uh disregard“* and, after a short interruption, continued at 08:14:37 UTC with the words *„Rubens Two Two Tange Xray, turn right uh disregard the traffic is now crossing right to left one mile in front same altitude“.*

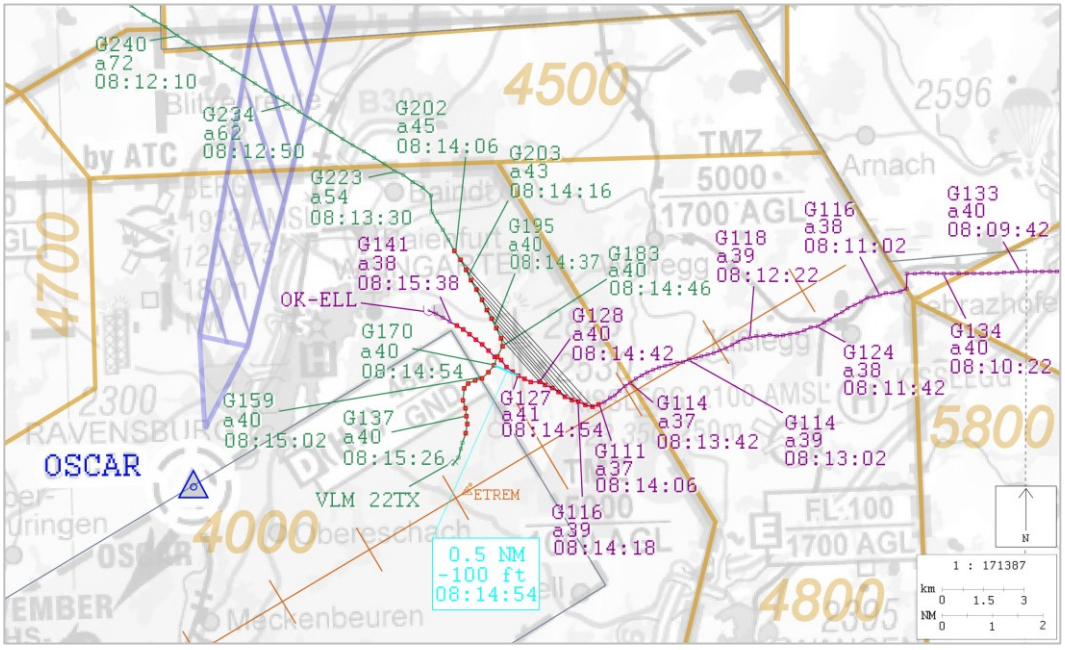

Figure 1: Flight paths of VLM 22TX (green) and OK-ELL (magenta) during the dangerous convergence according to the recorded radar data, with information of speed (G) relative to the ground in knots, altitudes (a) in hundreds of feet QNH and time in UTC. All positions during the STCA from 08:14:06 UTC until 08:15:34 UTC are illustrated in red, the closest point of approach having taken place at 08:14:54 UTC (cyan). In the period of time between 08:14:18 UTC and 08:15:38 UTC, the altitude readings of OK-ELL increased from 3900 ft to 4100 ft and then decreased again to 3800 ft. The following superimposed information are shown: the areas with the respective minimum vectoring altitudes (MVA) (orange), the VFR approach corridor to the reporting point OSCAR (blue) and the connecting lines (black) between the positions of the two aircraft with a constant angle (constant bearing).

The commander of VLM 22TX later stated that the visual meteorological conditions (VMC) were good, but that the visibility from the flight deck had been degraded due to the glare resulting from the position of the sun.

At 08:14:42 UTC, the radar plot indicated a first change of course of VLM 22TX to the right. At the same time, OK-ELL changed his own course to the left, followed by another change of course to the right four seconds later. The RE air traffic controller later declared that he had been surprised by the left turn of the VFR traffic, because the speed vector had pointed shortly and unexpectedly towards VLM 22TX. Based on the observed altitude and heading fluctuations of the VFR traffic involved (cf. figure 1), the RE air traffic controller determined that neither a reliable heading instruction nor a descent clearance were possible, as the aircraft was already flying at the minimum vectoring altitude (MVA) of 4000 ft AMSL.

At 08:14:48 UTC and again two seconds later, the recorded data at the workstation of the RE air traffic controller show that the push-to-talk button was pressed for a short time.

The convergence could be continuously observed on the TCAS display by the flight crew of VLM 22TX, without ever being able to establish visual contact with the VFR

traffic. Consequently, the commander decided to initiate an avoidance manoeuvre and turned 90 degrees to the right.

Approximately at the same time, at 08:14:50 UTC, the PL Main aerodrome controller provided the pilot of OK-ELL with a traffic information regarding VLM 22TX: *„OKELL traffic is a Fokker 50 on, eh, being established on the ILS a moment ahead of you".* A few seconds later, the pilot of OK-ELL reported that he had visual contact with the traffic.

During the avoidance manoeuvre of VLM 22TX, the trajectories of both aircraft crossed each other at an altitude of 4000 ft AMSL (cf. figure 1). The closest point of approach was at 08:14:54 UTC 0.5 NM horizontally and 100 ft vertically.

At 08:15:05 UTC, the commander of VLM 22TX announced over the radio that he had performed an avoidance manoeuvre and, while doing so, had seen a single engine, low wing aircraft, flying by. He reckoned that the VFR traffic had been on a collision course and estimated the shortest distance between the two aircraft to have been between 300 m to 500 m.

The commander of VLM 22 TX also concluded that the right turn had avoided a collision.

The co-pilot later said he had never seen the VFR traffic and had only realized the seriousness of the situation by the commander's reaction. The flight crew could observe a relative height value of +100 ft on the TCAS during the right turn.

The pilot of OK-ELL stated to have seen the underside of the Fokker 50 reckoned 500 ft to 1000 ft above and estimated the horizontal separation to be approximately one kilometre.

Following the event, the commander of VLM 22TX reported clear of conflict. The RE air traffic controller cleared VLM 22TX for the ILS approach 24 and, the radar service being terminated, handed them over to the aerodrome control of Friedrichshafen. The approach and the landing of VLM 22TX were uneventful.

The remainder of the flight of OK-ELL was uneventful and the pilot landed some 10 minutes later on runway 24 in Friedrichshafen.

After landing, the commander of VLM 22TX contacted the operational control center (OCC) of the airline per telephone and requested the safeguarding of the cockpit voice recorder (CVR) so that the event could be investigated.

When the Belgian Air Accident Investigation Unit requested the CVR on behalf of the STSB, they were informed that the recordings had been overwritten. When questioned after the event, the airline declared in a written statement that there had been no other CVR available at the time and that the afternoon flight should have been cancelled. Furthermore, it was thought that the CVR did not record the radiotelephony conversations and would therefore not provide any pertinent information.

1.1.4 Location and time of the serious incident

Geographical Position	Approximately 10 NM north-east of Friedrichshafen Airport (EDNY), over German territory
Date and time	21 April 2016, 08:14:54 UTC
Lighting conditions	Daylight
Coordinates	N 047° 46' 55.30" E 009° 42' 58.00" (WGS84)
Altitude above sea level	4000 ft AMSL

1.2 Personnel information

1.2.1 OO-VLF

1.2.1.1 Commander

Person	Dutch citizen, born 1976	
Licence	Airline transport pilot licence aeroplane ATPL(A)) according to European Aviation Safety Agency (EASA), issued by the Civil Aviation Authority of the Netherlands	
Training on ACAS[5]	Initial training on 17 November 2000	
Flying experience	Total	7000 h
	On the type involved in the incident	6500 h
	During the last 90 days	122 h
	Of which on the type involved in the incident	122 h

All information available indicates that the commander started his duty rested and healthy. There are no signs that at the time of the serious incident fatigue played a role.

1.2.1.2 Co-pilot

Person	Dutch citizen, born 1987	
Licence	Commercial pilot licence aeroplane (CPL(A)) according to EASA, issued by the Civil Aviation Authority of the Netherlands	
Training on ACAS	Initial training on February 2015 refresher acquired through VLM Airlines on 5 April 2016	
Flying experience	Total	750 h
	On the type involved in the incident	550 h
	During the last 90 days	170 h
	Of which on the type involved in the incident	170 h

All information available indicates that the co-pilot started his duty rested and healthy. There are no signs that at the time of the serious incident fatigue played a role.

1.2.2 OK-ELL

Person	Czech citizen, born 1971
Licence	CPL(A) according EASA, issued by the Civil Aviation Authority of the Czech Republic
Training on ACAS	None

[5] ACAS: The name of the basic concept of the collision prevention system is airborne collision avoidance system (ACAS). The International Civil Aviation Organization (ICAO) uses this term when laying down the standards with which the system must comply. The traffic alert and collision avoidance system (TCAS) is a concrete implementation of this concept.

Flying experience	Total	831:55 h
	On the type involved in the incident	47:00 h
	During the last 90 days	88:35 h
	Of which on the type involved in the incident	05:10 h

All information available indicates that the pilot started his flight rested and healthy. There are no signs that at the time of the serious incident fatigue played a role.

1.2.3 Air traffic control personnel

1.2.3.1 Air traffic controller RE

1.2.3.1.1 General

Function	Sector ARFA, radar executive controller (RE)
Person	French citizen, born 1980
Duty days before the day of the incident	20 April 2016, 05:30 – 13:00 UTC: sector ARFA
Start of duty on the day of the incident	05:30 UTC
Simulation training	18. April 2016, 07.00 – 15.30 UTC: ARFA-Simulation (heavy traffic refresher)
Licence	Air traffic controller licence based on European Community Directive 2011/805, issued by the FOCA

All information available indicates that the air traffic control officer started his duty rested and healthy. There are no signs that at the time of the serious incident fatigue played a role.

1.2.3.1.2 Education and professional career

The licencing at the workstation ARFA took place on February 2015. The air traffic controller performed his first duty on the occasion of the „AERO Friedrichshafen“. He stated that it had been a positive experience.

1.2.3.2 Air traffic controller RC

1.2.3.2.1 General

Function	Sector ARFA, radar coordinator controller (RC)
Person	Swiss citizen, born 1977
Duty days before the day of the incident	20 April 2016, Ruhetag
Start of duty on the day of the incident	05:30 UTC
Simulation training	18. April 2016, 07.00 – 15.30 UTC: ARFA-Simulation (heavy traffic refresher)
Licence	Air traffic controller licence based on European Community Directive 2011/805, issued by the FOCA

All information available indicates that the air traffic control officer started his duty rested and healthy. There are no signs that at the time of the serious incident fatigue played a role.

1.2.3.2.2 Education and professional career

The licencing at the workstation ARFA took place on December 2013.

1.2.3.3 Aerodrome controller 1

1.2.3.3.1 General

Function	Aerodrome control (ADC), PL Main
Person	German citizen, born 1961
Duty days before the day of the incident	19 and 20 April 2016
Start of duty on the day of the incident	07:00 UTC (actual start at 07:20 UTC)
Licence	Air traffic controller licence, based on European Community Directive 805/2011, issued by the Federal Air Traffic Controlling Office, in accordance with the ICAO standards

All information available indicates that the aerodrome controller started his duty rested and healthy. There are no signs that at the time of the serious incident fatigue played a role.

1.2.3.3.2 Education and professional career

The aerodrome controller had over 15 years of experience with assignments during the “AERO Friedrichshafen”.

1.2.3.4 Aerodrome controller 2

1.2.3.4.1 General

Function	Aerodrome control (ADC), VFR Pick-up
Person	No information[6]
Duty days before the day of the incident	18, 19 and 20 April 2016
Start of duty on the day of the incident	05:40 UTC (actual start at 06:00 UTC)
Licence	Austro Control GmbH stated that the licence was valid and was renewed in 2016 for one year with all the authorizations for Friedrichshafen Airport (EDNY) (without restrictions)

1.2.3.4.2 Education and professional career

The aerodrome controller had over 15 years of experience with assignments during the “AERO Friedrichshafen”.

[6] Numerous enquiries on the part of the STSB remained unanswered.

1.3 Aircraft information

1.3.1 VLM 22TX

1.3.1.1 General

Aircraft type	F27 Mk050, marketing designation „Fokker 50“
Characteristics	Twin-engined turboprop regional commercial aircraft, constructed as a cantilever high-wing monoplane in all-metal construction with retractable undercarriage in nose-wheel configuration
Owner	Jetstream Aviation Capital, Miami Florida
Operator	Vlaamse Luchttransportmaatschappij N.V. (VLM), Antwerpen, Belgien
Relevant equipment	TCAS Type: Honeywell TPU 67B Software-Standard: TCAS 7.1 Transponder Mode S

1.3.1.2 Traffic alert and collision avoidance system

After its delivery in 1991, the Fokker 50 registered OO-VLF, was originally operated without a traffic alert and collision avoidance system, the installation of such systems not being required then. According to information from the air carrier, the aircraft was modified in 1998 by the previous operator with the installation of such a system.

Figure 2: Flight deck of a Fokker 50. The yellow arrow shows the installation location of the commander’s variometer. The copilot’s instrument is concealed by the right control column.

The information of the traffic alert and collision avoidance system are presented on an integrated vertical speed indicator (IVSI), found in place of the existing VSI, to the right of the commander’s and copilot’s navigation displays (ND) (cf. figure 2).

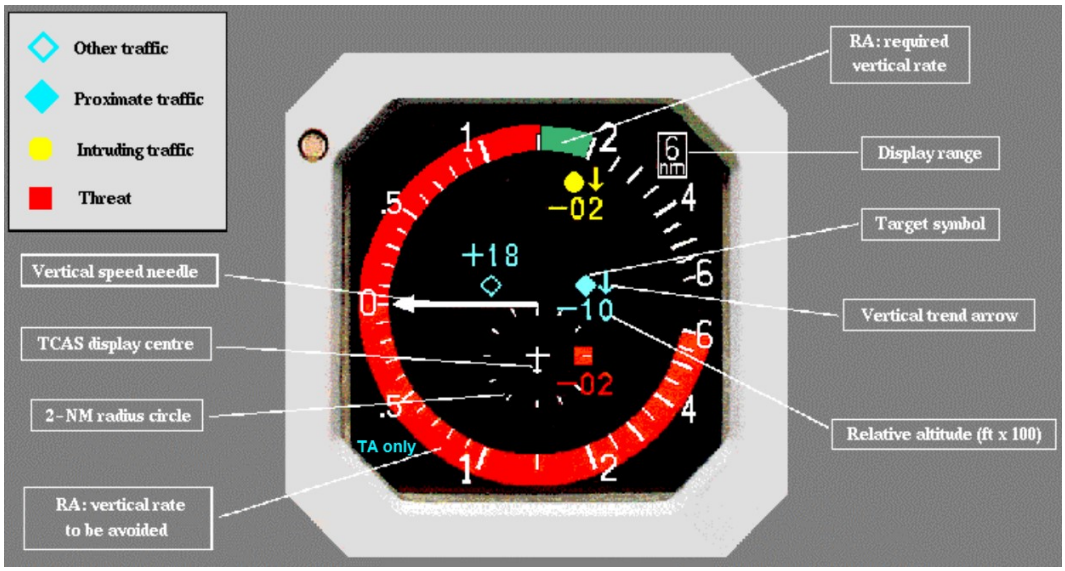

Figure 3: Illustration of the working principle of an integrated vertical speed indicator with a display function for the traffic alert and collision avoidance system. The relative altitudes of the other aircraft equipped with a transponder transmitting altitude data are indicated in hundreds of feet. The „TA only“ (blue) message appears in the lower left corner of the instrument display if the TCAS is in the mode „traffic advisories (TA) only“.

If a resolution advisory (RA) is triggered on board a Fokker 50, the flight crew must change the attitude of the aircraft to such an extent that the resulting vertical speed indicated by the variometer remains in the green band. In the example shown in Figure 3, a rate of climb of 1500 to 2000 ft/min is required.

The signals emitted by the transponder of OK-ELL could be detected by the TCAS on board OO-VLF. The TCAS test performed before the flight was successful.

1.3.2 OK-ELL

Aircraft type	Piper PA-28RT-201T, “Turbo-Arrow IV”
Characteristics	Piston, single-engined low-wing aircaft of all-metal construction, with four seats and retractable landing gear in nose-wheel configuration
Owner	Satiko s.r.o., Brno, Czech Republic
Operator	Icarus Aviation Group s.r.o., Bmo, Czech Republic
Equipment	No equipment for collision avoidance installed Transponder Mode S

1.4 Meteorological information

1.4.1 General weather situation

The surface map showed a flat col between anticyclones over the North Atlantic and the the Balkans. In the middle troposphere a narrow ridge extended from Southern Italy to Ireland. Hence subsidence stabilized the anticyclonic weather over Switzerland and South-western Germany.

1.4.2 Weather at the time and location of the serious incident

Dry and sunny weather prevailed. The boundary layer over Lake of Constance and its surroundings was misty up to 3000 ft AMSL. Above this layer the air was dry with a visibility up to 60 km. In Constance the observer reported a met visibility of 25 km.

Weather/clouds	CAVOK[7]	
Visibility	60 km	
Wind	190 degrees, 6 knots	
Temperature/Dew point	10°C / 1°C	
Atmospheric pressure (QNH)	1023 hPa, pressure reduced to sea level, calculated using the values of the ICAO standard atmosphere	
Hazards	None	

1.4.3 Astronomical information

Lighting conditions	Daylight	
Position of the sun	Azimuth: 117°	Elevation 37°

1.5 Aids to navigation

All navigation aids were fully available at the time of the incident.

1.6 Communication

Radio communication was conducted in English and without any technical restrictions.

1.7 Aerodrome and airspace information

1.7.1 Friedrichshafen Airport

The airport is located on lake Constance, approximately 4 km north-east of the city limits of Friedrichshafen.

Runway 24 is equipped with a category III instrument landing system (ILS). At the time of the incident, 2150 m of runway length were available for landing.

1.7.2 Airspace structure

The control zone (CTR) around Friedrichshafen Airport protects the arriving and departing traffic from the ground extending up to an altitude of 4500 ft AMSL. This airspace is classified as class D. IFR traffic flying in this zone are separated from each other and are provided with VFR traffic information. VFR traffic are not separated from each other and are only provided with traffic information concerning other traffic.

Furthermore, there are two transponder mandatory zones (TMZ) classified as class E (cf. figure 4):

- EDNY A: with a lower limit of 1000 ft above ground level (AGL) and with an upper limit of FL 100;
- EDNY B: covering a wider area and with a lower limit of 1700 ft AGL and with an upper limit of FL 100.

In the German airspace classified as class E, the VFR conditions are defined as follows:

- Maximum indicated airspeed below 10 000 ft: 250 Kt;

[7] CAVOK: ceiling and visibility okay: Meteorological visibility 10 km or more, no clouds below 5000 ft or below the highest minimum sector altitude (MSA), if this is higher than 5000 ft above aerodrome level (AAL); No cumulonimbus (CB) or towering cumulus (TCU) at any altitude. No significant weather phenomena.

- Lowest visibility: 8 km;
- Distance to the clouds: vertically: 300 m; horizontally: 1500 m

In airspace E, VFR traffic in radio contact with a flight information service (FIS) can be provided with an information if the situation permits.

Figure 4: Aeronautical map of Switzerland and Liechtenstein of 31 March 2016 with the two transponder mandatory zones (TMZ) EDNY A and EDNY B, source: Swiss federal office of topography (Swisstopo)

1.7.3 Areas of responsability

1.7.3.1 General

The responsabilities for the aerodrome control at Friedrichshafen Airport and for the airspace over the region of Lake Constance are shared between various air traffic control providers.

1.7.3.2 Aerodrome control Friedrichshafen

The air navigation service provider (ANSP) Austro Control GmbH (ACG) is responsible for the Friedrichshafen aerodrome control.

A letter of agreement between Austro Control and Skyguide regulates the procedures and responsabilities between the Friedrichshafen aerodrome control, the sector ARFA, Zurich approach and Zurich area control center (ACC).

1.7.3.3 Airspace over the region of Lake Constance

An agreement between the German air traffic control service *Deutsche Flugsicherung GmbH* (DFS) and Skyguide exists for the airspace ARFA over German territory.

In this agreement, Skyguide is in charge of air traffic control, information and alarm service. The airspace structures, their classification and applicable procedures are defined by the DFS.

1.7.4 Approach procedures in Friedrichshafen

1.7.4.1 Instrument approaches

The approach route for the ILS approach of runway 24 starts from the initial approach fix MOKOP until reaching the limits of the CTR in airspace E. This is also the case when approaching under radar vectoring from the air traffic control.

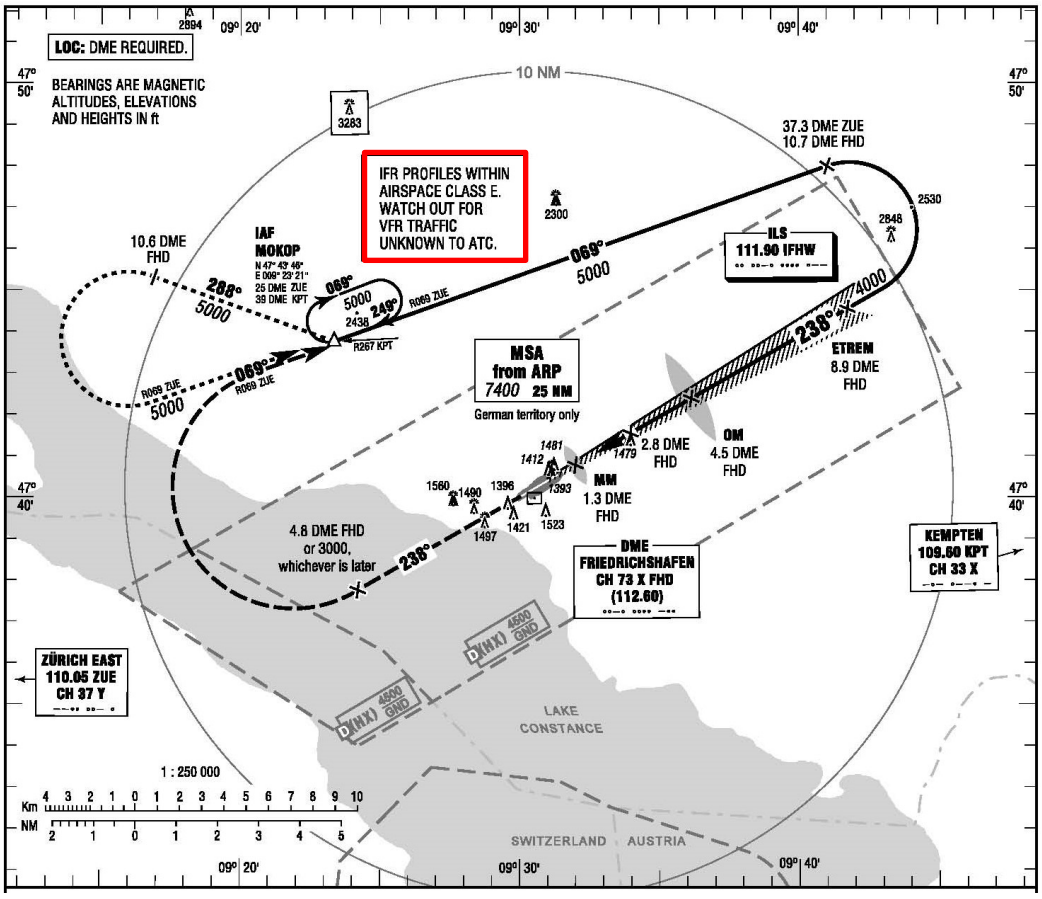

Figure 5: ILS approach to runway 24 in Friedrichshafen according the German AIP with a note (red frame), stating that the approach leads partly through airspace E and therefore unknown VFR traffic is to be expected.

The airspace E is designated as controlled airspace, since an air traffic control clearance is required for IFR traffic, which is separated from other IFR traffic. Traffic information concerning VFR traffic is only provided to IFR traffic when indicated and the situation permits. A traffic separation between IFR and VFR traffic is not provided in airspace E. Advice for collision avoidance are only provided upon request of the flight crew.

1.7.4.2 Visual approach chart

The visual approach chart for Friedrichshafen Airport, as published in the aeronautical information publication (AIP) for Germany, contains defined flight routes over the VFR reporting points OSCAR, NOVEMBER, WHISKEY and SIERRA. Also, a maximum flight altitude of 3000 ft AMSL is prescribed for arrival and departure (cf. figure 6). The arrival and departure routes over the reporting points NOVEMBER and SIERRA are almost perpendicular to the runway axis.

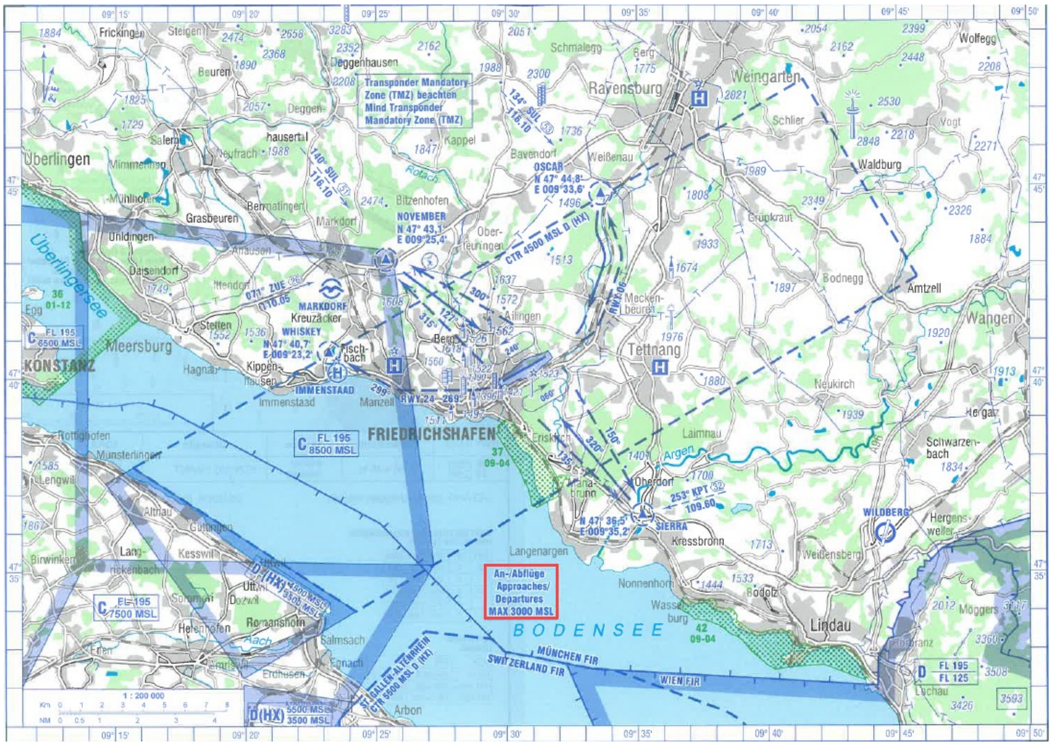

Figure 6: Visual approach chart for the airport of Friedrichshafen as per the aeronautical information publication (AIP) for Germany with a maximum flight altitude of 3000 ft AMSL for arrivals and departures (red frame)

1.7.5 Aviation exhibition „AERO Friedrichshafen“

The „AERO Friedrichshafen“ is a trade fair for general aviation that takes place every year on the exhibition site as well as at neighbouring Friedrichshafen Airport. In 2016, the exhibition was held from 20 to 23 April 2016.

A prior authorisation (prior permission required – PPR) for both VFR and IFR traffic was necessary during the event „AERO Friedrichshafen“, with the exception of scheduled line and charter flights, VFR departures and arriving or departing helicopters. In order to relieve Friedrichshafen, the neighboring airfields of Markdorf and Mengen were available for landing; these airfields did not require any prior authorisation.

1.7.6 Publications relevant to the “AERO Friedrichshafen”

1.7.6.1 General

On the occasion of the exhibition “AERO Friedrichshafen“, the German air traffic control service *Deutsche Flugsicherung GmbH* (DFS) published the AIP SUP IFR 07/16 (cf. chapter 1.7.6.2) on 31 March 2016 and the AIP SUP VFR 07/16 (cf. chapter 1.7.6.3) on 14 April 2016 with detailed information, general conditions and recommendations for the forthcoming exhibition.

A notice to airmen (NOTAM) pertaining to the event was duly published.

The information sheet „*VFR Pilot Info 01/2016 Luftraum E*“ published by the DFS, provided facts and recommendations for the use of airspace E and clearly stated that IFR flights did not have the right-of-way, even when under radar vectoring.

1.7.6.2 Documentation relevant to the IFR traffic

The PPR rules, with their exceptions and issuance, the valid temporary procedures with the associated changes of flight rules from VFR to IFR and vice-versa and the

possible refusal to provide an ATC clearance were all described in the comprehensive one page document „*AERO 2016 in Friedrichshafen (EDNY)*“

In addition, it calls attention to the increased number of VFR flights from and to Friedrichshafen as follows [translated from German]: : *“During the instrument approach and/or instrument departure from/to EDNY, the pilots must continually monitor the airspace (see and avoid principle) due to the expected high volume of VFR flights from/to EDNY in visual meteorological conditions (VMC”).*

1.7.6.3 Documentation relevant to the VFR traffic

The AIP documents valid during the „AERO Friedrichshafen“ consist of eight pages: The first four, written in German and English, cover various procedures, PPR, arrival and departure rules. The next two pages each include a chart and are dedicated to the operation concept for runways 24 and 06. A chart shows in detail the course directions towards the VFR reporting points OSCAR, NOVEMBER, WHISKEY und SIERRA. The last page shows a ground chart with the information valid during the „AERO Friedrichshafen“.

These documents show that when runway 24 is in use, the flights on approach to the paved runway are to proceed via the compulsory reporting point OSCAR and recommend following the red shaded arrival corridor (cf. figure 7). The radio contact with the aerodrome control is to be established latest ten minutes before reaching OSCAR, in any case no later than when overflying the 18 NM radius line around the airport reference point as shown on the chart. The CTR must be avoided when approaching the compulsory reporting points.

It is recommended to fly the approach to the compulsory reporting points at a maximum altitude of 4000 ft AMSL; NOVEMBER, WHISKEY and OSCAR cannot be flown over at an altitude higher that 3000 ft AMSL.

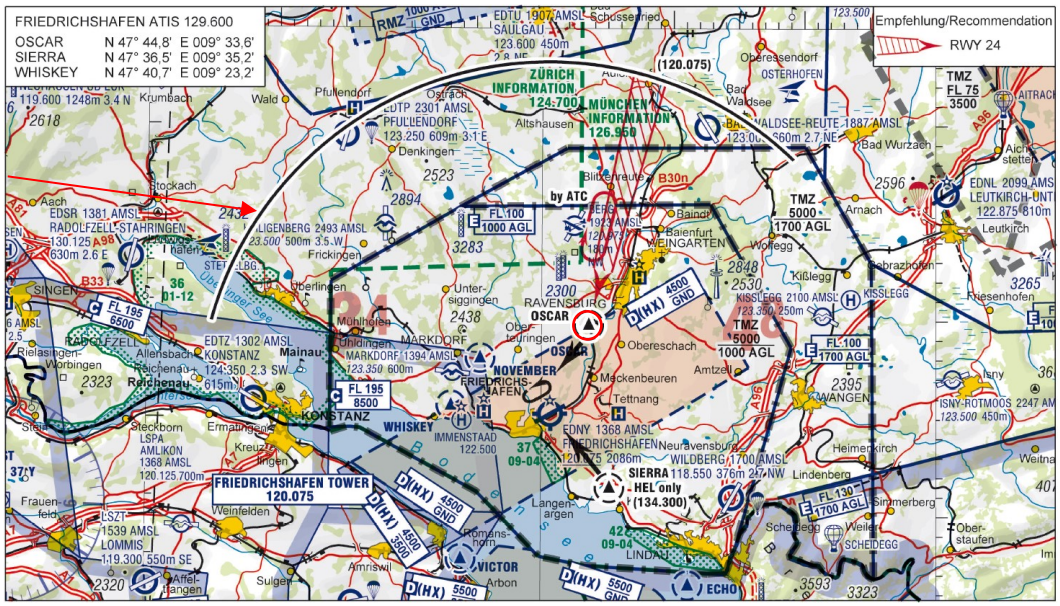

Figure 7: VFR chart pursuant to the publication AIP SUP VFR 07/16 of 14 April 2016, valid from 18 April to 24 April 2016, with the circular arc plotted at 18 NM around EDNY (red arrow) and the VFR arrival corridor to the compulsory reporting point OSCAR (red circle highlighted by the STSB)

1.8 Flight recorders

1.8.1 VLM 22TX

1.8.1.1 Flight data recorder

The flight data recorder (FDR) had in the meantime been overwritten and was no longer available to the investigation. Only the recording of the quick access recorder (QAR) was available. This device records essential parameters accessible to the airline in order to monitor flight opration and for maintenance porposes.

1.8.1.2 Cockpit voice recorder

The cockpit voice recorder (CVR) had in the meantime been overwritten and was no longer available to the investigation.

Immediately after the landing in Friedrichshafen, the commander wanted to safeguard the CVR for a possible investigation. An accountable person for the technical division of the flight operations did not allow it, stating that a replacement device could not have have been organised in due time and that, as a consequence, OO-VLF would not have been available for scheduled service on the afternoon of 21 April 2016. Furthermore, this person was also of the opinion that the CVR had not recorded the radiotelephony communications anyway. As a consequence, the recordings of the conversations between the flight crew members as well as the sounds emitted by the TCAS on the flight deck were not available, resulting in the loss of a detailed evidence base.

In compliance with the requirements of the minimum equipment list (MEL), the operation of OO-VLF would have been possible for up to 8 subsequent flights and for up to 72 hours without limitations, thus enabling the safeguarding of the CVR recordings. Furthermore, the FDR must be available in this period of time.

1.8.2 OK-ELL

Not installed nor required.

1.8.3 Downlink Mode S

During the serious incident no downlink messages related to a resolution advisory (RA) were recorded.

1.9 Tests and research

1.9.1 TCAS analysis

On the basis of the available recordings from the multi radar tracking (MRT) done every 4 seconds, the TCAS installed on board VLM 22TX was tested for proper functioning during the dangerous convergence, according to its technical specifications.

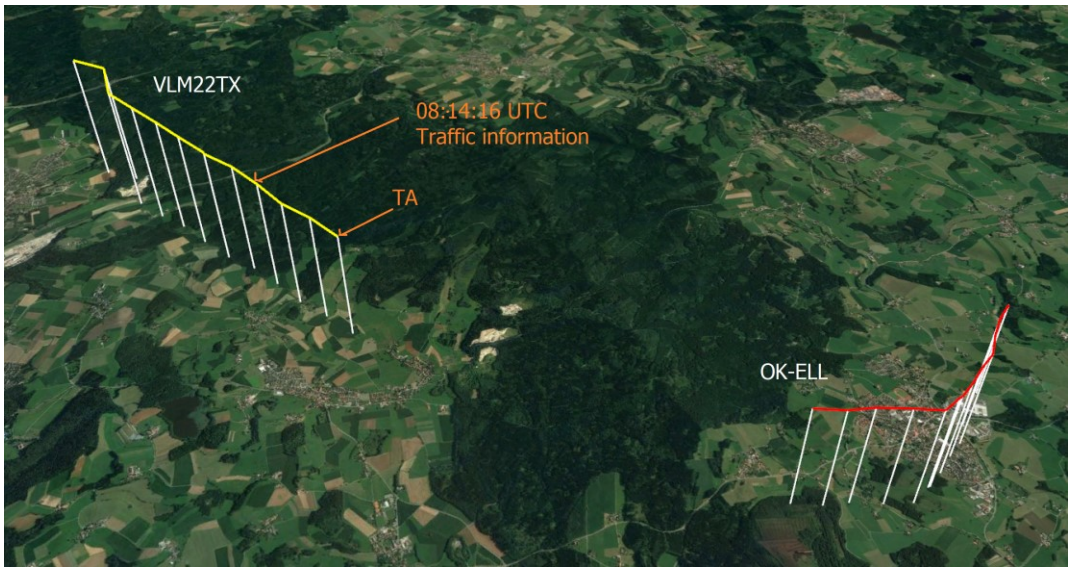

Figure 8: Convergence of the two aircraft based on the recordings of the MRT every 4 seconds and activation of a traffic advisory (TA) at approximately 08:14:27 UTC (orange), featured in Google-Earth

The following conclusions can be drawn from the analysis of the radar recordings during the convergence between the two aircraft:

- Both aircraft, flying at an almost constant airspeed, were maintaining approximately the same and constant altitude. The resulting time-to-go (TAU) until the closest point of approach (CPA) could be predicted with the necessary precision by the TCAS on board VLM 22TX.
- At these altitudes of about 4000 ft AMSL, the height over ground of 1500 ft was never undershot. In this range of altitudes, the sensitiy level (SL) for the time-to-go (TAU) until the activation of a traffic advisory (TA) was 25 s, respectively 15 s for a resolution advisory (RA).
- During the convergence of the two aircraft flying at the same altitude, the prediction time to the vertical CPA ($t_{pred,Z}$) was less than 15 seconds.
- The prediction time (t_{pred}) to the CPA in the horizontal dimension decreased constantly during the convergence (cf. figure 9) and temporarily fell below the TAU for a TA (orange horizontal line), respectively for a RA (red horizontal line).
- Consequently, in terms of prediction time to CPA, the conditions on board VLM 22TX were satisfied for the activation of a TA between 08:14:27 UTC and 08:14:55 UTC, respectively for a RA between 08:14:41 UTC and 08:14:54 UTC.
- During the convergence, the estimated horizontal miss distance (HMD) decreased continuously, however never fell below the threshold value (DMOD[8]) of 0.2 NM for the activation of a RA (cf. figure 10).

[8] DMOD: Distance modification: In certain circumstances (E.g. two aircraft flying in parallel) a hazard identification solely based on the closure rate would not be adequate, as already a small change of direction of the other aircraft would suddenly result in a high closure rate and therefore would not leave any margin for the timely activation of an alarm. This problem was solved with the concept of DMOD, whose altitude dependent SL values are only related to the physical separation between the two aircraft and activate an alarm regardless of the time to collision or the closure rate.

- The CPA occurred at 08:14:54 UTC, as both aircraft were already on divergent trajectories. The separation was 0.5 NM horizontally and 100 ft vertically.

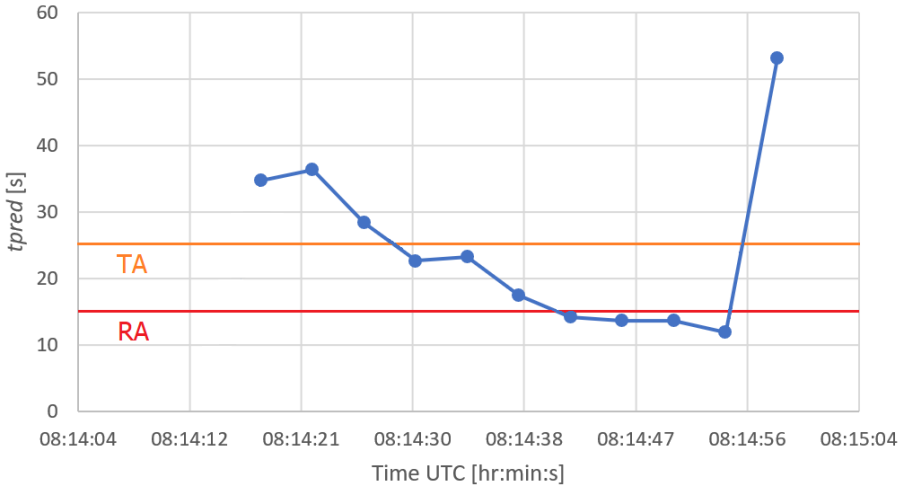

Figure 9: Prediction time (t_{pred}) to the CPA in the horizontal dimension during the convergence between the two aircraft with the two threshold values (TAU) for a traffic advisory (TA) (orange horizontal line), respectively for a resolution advisory (RA) (red horizontal line)

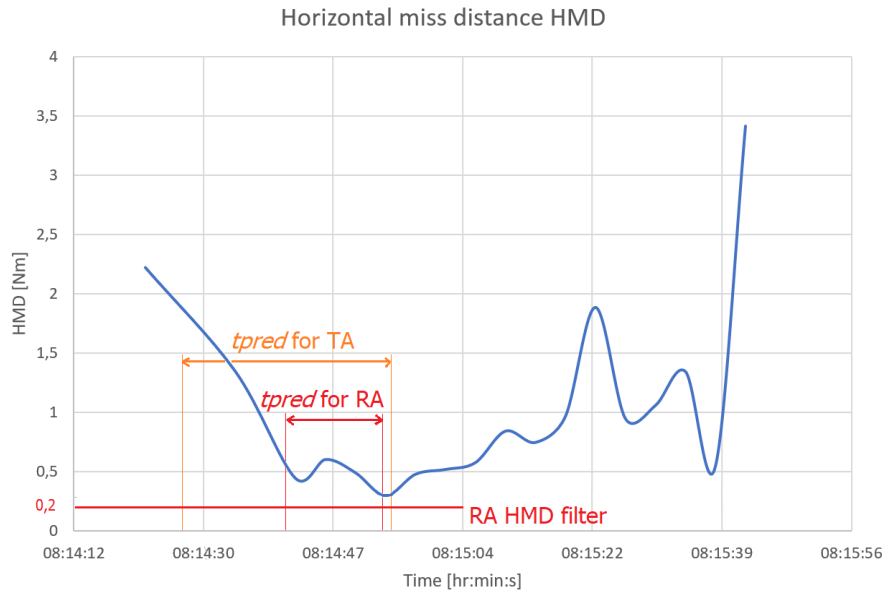

Figure 10: Horizontal miss distance (HMD) during the convergence between the two aircraft with the threshold value for a resolution advisory (RA) (red horizontal line) of 0.2 NM as well as the period of time during which the conditions were satisfied for the activation of a TA (t_{pred} for TA), respectively for a RA (t_{pred} for RA).

1.10 Organisational and management information

1.10.1 Skyguide

1.10.1.1 Skyguide's Service Delegation

Skyguide holds a service delegation, not to be confused with an airspace delegation, for the airspace in the vicinity of Friedrichshafen Airport.

With a service delegation, the responsibility for the standard arrival route (STAR), the standard instrument departure (SID) for Friedrichshafen Airport, the allocation

of the airspace classifications around its CTR as well as the publication of the procedures during the aviation exhibition „AERO Friedrichshafen“ remains with the German authority.

1.10.1.2 General principle of sector ARFA

One air traffic controller usually ensures the management of arriving and departing IFR traffic at both the airports of St. Gallen-Altenrhein and Friedrichshafen, including the traffic in transit and the special flights within the sector ARFA.

Most of the work consists of the coordination of the IFR traffic with the aerodrome control units of Friedrichshafen and St. Gallen-Altenrhein and the surrounding sectors, as well as Zurich Approach/Departure, Langen/Stuttgart, München Lech/Füssen and the Swiss military operations centre.

The potential for conflict resides in the interdependence of the arrival and departure routes at both airports. This requires a separation based on time, which must take the different airspeeds and rates of climb of the aircraft involved into consideration.

1.10.1.3 Sector ARFA during the event „AERO Friedrichshafen“

The ATCOs are trained on a yearly basis by Skyguide in preparation for this event. They first train for one day in a simulator in a two-man OPS constellation in conditions of dense and high volume traffic. The basis of the simulator exercises is based on the experience acquired during the AERO of the preceeding year and takes the yearly increase in aircraft movements into consideration.

Both workstations of the radar executive controller and of the radar coordinator controller have the same technical equipement.

A service order (SO) O 2016-015E was published by Skyguide for its internal processes on 6 April 2016 and covered the guidelines and directives for the practical implementation.

In the document, additional work shifts were planned during the „AERO Friedrichshafen“ in order to take into account the high demands and traffic density.

The list of duties of the radar coordinator controller are also described in the SO as follows:

„3.5.2.1 ARFA Radar Coordinator duties

RC ARFA shall carry out the following tasks:

- *monitor the traffic situation (safety assistant);*
- *monitor the ARFA frequency;*
- *prepare flight strips; and*
- *assist RE ARFA whenever needed, for example:*
  - *monitor airspace E for possible unknown VFR traffic;*
  - *coordination with Friedrichshafen* [EDNY] *TWR*[9]*, St. Gallen-Altenrhein* [LSZR] *TWR, Zurich APP/DEP, Munich ACC and Langen ACC (e.g. TWR check);o radar coordination with other sectors; or*
  - *carry out, receive and forward revisions, expedite CLR* [*Clearance*]*, diversions, OIR* [*Operational Incident Report*] *and approval requests.”*

9 TWR: *tower*

According to his list of duties, the radar executive controller remains the sole person responsible for air traffic service within the whole sector ARFA. His duties are described in the ATMM II *Lower*, Section 1, § 1.1 *Tasks ARFA ATCO*:

"Within his AoR [*Area of Responsibility*]*, the ARFA ATCO* [*Air Traffic Control Officer*] *is responsible for:*

- *Providing Air Traffic Service to all aircraft under his responsibility;*
- *Issuing route clearance if appropriate;*
- *Recording clearances issued to a flight by means of paper control strips and electronic entries (SKYVISU[10] / CALM[11]);*
- *Obtaining the necessary releases form adjacent units;*
- *Conducting the necessary coordination with adjacent units, ACC sectors, Zurich APP, EDNY/LSZR TWR and FIC[12]/Delta[13] including revisions, expedite clearances and approval requests;*
- *Recording the coordination in SKYVISU and on the paper control strips;*
- *Verifying the correct transmission of estimates and revisions by FDPZ[14] and, if necessary, perform these tasks manually;*
- *Providing approval or delay, if deemed necessary, for special requests which impact AoR ARFA (e.g. firing, photo flight), to the requesting party;*
- *Coordinating requests that affect AoR TWR LSZR/EDNY with the respective TWR, prior providing the approval or delay, if deemed necessary, to the requesting party;*
- *Using best judgement to support an aircraft in a state of emergency;*
- *If ARFA Coordinator is unmanned, ARFA RE takes over ARFA Coordinator tasks."*

1.10.1.4 Daily work routine

To be able to carry out his mission, the radar executive controller must continuously adapt the range of the radar image according to the various tasks. For example, a general overview with a wide coverage is chosen for punctual coordination conversations or for the management of the upcoming arriving and departing traffic. A smaller area is used by the ATCO for the radar guidance of an aircraft onto an ILS or to place precise inputs on the radar.

In practice the radar executive controller activates the speed vector function when controlling IFR traffic, giving him an additional visual aid concerning the timing and direction of "his" traffic. Major changes to the heading are particulary well detected when the speed vector is displayed.

VFR traffic is authorized to fly within the airspace E without a clearance and/or radio contact, and is therefore not in contact with the sector ARFA. The transponder mandatory zones (TMZ) EDNY A and B around Friedrichshafen Airport only require VFR traffic to use of a transponder. The tags of the VFR traffic are shown in pale yellow on the radar image and only with the symbol "V", its speed and altitude. In good weather conditions as well as during the aviation exhibition

[10] SKYVISU: Visual presentation of the airspace on the radar screen

[11] CALM: Computer Assisted Approach and Landing Management

[12] FIC: Flight Information Centre

[13] Sector of the Area Control Center (ACC) Zurich

[14] FDPZ: Flight Data Processing Zurich for the update of an active flight plan

"AERO Friedrichshafen", a concentration of several VFR aircraft in a limited area is inevitable and the simplified layout of the tags prevents an excessive display of information on the radar image.

The radar coordinator controller is primarily engaged in coordination conversations and is not continuously focusing his attention on his sector.

1.10.1.5 Ground-based warning system

The short term conflict alert system (STCA) generates an alert when the vertical or lateral minimum separations between two aircraft is lower than the parameters defined by the system, irrespective of whether the ATCO is in contact with the pilots involved or not. The period of time until the closest point of approach (CPA) can vary between 5 and 70 seconds, depending on the flight paths and the airspeeds of the two aircraft. Several successive alerts of the STCA at short intervals compel the air traffic controller to determine which conflictual situation must be dealt with as a matter of priority, in order to provide the pilots with the required traffic information.

1.10.2 Austro Control GmbH

1.10.2.1 Aerea of responsability

The air navigation service provider (ANSP) Austro Control GmbH (ACG) is responsible for the aerodrome control in Friedrichshafen.

1.10.2.2 Workstation equipment

The tower workstation is, inter alia, connected to the aeronautical telecommunications network (AFTN), which provides the current flight plans. In addition, the traffic situation is presented on an air situation display for planning purposes (cf. chapter 1.10.3).

1.10.2.3 AERO Friedrichshafen

Both Austro Control air traffic controllers have been interviewed regarding the procedures in force during the „AERO Friedrichshafen“ and their practicality.

Their answers made it clear that the special procedures are desirable to achieve a uniform traffic flow during the aviation exhibition, but that they are not known by all pilots. The procedures are practice oriented, enable a timely first contact with the pilot in approach and allow for recommendations to be made to achieve a homogenous traffic flow.

In low traffic situations the flight paths can be shortened, as a service offered to the customers in order to save flight time.

Moreover, the clearance to proceed to the waypoint ETREM is nothing out of the ordinary for VFR traffic and is known in large part by VFR pilots, even though it is not marked on the visual approach chart. The waypoint is frequently used during the „AERO Friedrichshafen“, rarely at other times of the year.

If absolutely necessary, and depending on available capacities, a traffic information is provided to the pilot, when in conflict with an arriving or departing IFR traffic under the control of sector ARFA.

The radiotelephony recordings of the VFR Pick-up and PL Main reveal at times a heavily congested frequency and a high volume of traffic during the aviation exhibition „AERO Friedrichshafen“. Under these circumstances, the tower check is also occasionally suspended for the entire day (cf. chapter 1.10.3).

1.10.2.4 Internal coordination between the two aerodrome controllers

Approaches via the waypoint OSCAR take place after a transfer to the PL Main air traffic controller. Clearances for a direct approach are only given to the pilots after close coordination between the PL Main and VFR Pick-up air traffic controllers.

The recordings available to the STSB did not reveal any coordination conversation for the aircraft involved.

1.10.3 Coordination between ARFA and the aerodrome control

The instructions for use of the radar by the aerodrome controllers are described in the letter of agreement (LoA) between „Austrocontrol - Friedrichshafen Tower and Skyguide Swiss Air Navigation Services Ltd. – ACC/APP[15] Zurich and ARFA“:

“B.1.6 TWR may use Radar in Aerodrome control for information purposes only. TWR may provide separation by applying procedural control or visual reduction of separation minima in the vicinity of the aerodrome and is responsible for following functions:

- *Support of pilots, especially in case of loss of orientation or emergency;*
- *Separation between IFR departures;*
- *Separation between IFR departures and coordinated IFR arrivals ("tower check");*
- *Separation between special VFR flights;*
- *Separation between special VFR flights and IFR flights;*
- *Immediate action for separating missed approaches from other controlled flights and inform ARFA accordingly;*
- *Immediate action to prevent a possible separation minimum infringement and inform ARFA accordingly.”*

The above mentioned tower check is an umbrella term for a coordination conversation between the air traffic controller at the workstation ARFA and the aerodrome controller, as described below:

“B.2.5 ARFA shall inform TWR by a TWR-check, latest 10NM [final], on:

- *Call Sign;*
- *Intentions, if other than ILS for landing;*
- *Any other relevant information.”*

After consultation with Skyguide, it appears that a practical implementation of the tower check would normally take place on final approach at a distance of 15 to 30 NM from the runway in use.

The cancellation of the tower check in the morning and for the entire day by the aerodrome controller in Friedrichshafen, should also be noted. This course of action is described as a preventive measure against a possible temporary overload at the respective workstations during the aviation exhibition, as the increase in the number of movements usually also requires an increased number of coordination conversations.

1.11 Additional information

1.11.1 Other serious incidents in the region of Friedrichshafen (EDNY)

In the past ten years, one serious incident which took place in the region of Friedrichshafen on 8 August 2010 was investigated by the German aircraft accident

[15] ACC: Area control center, APP: Approach and departure control

investigation bureau *Deutschen Bundesstelle für Flugunfalluntersuchungen* (BFU). On this occasion, a commercial aircraft Bombardier DHC8-314 under IFR and a piston-engined aircraft Ikarus C42 crossed with a lateral distance of 0.06 NM and an altitude difference of 500 ft.

The serious incidents shown in the table below took place in the year 2016.

08.05.2016	**BER600L vs. HB-3152** The TCAS of the commercial aircraft of the operator Air Berlin generated two resolution advisories caused by an unknow aircraft (HB-3152) during an ILS approach to runway 06. The two aircraft crossed at a lateral distance of 1.4 NM and a vertical distance of 100 ft.
07.06.2016	**SUI360 vs. HB-PIX** While they were on an ILS approach to runway 24 the flight crew was alerted by a traffic information about an unknown VFR traffic (HB-PIX). The two aircraft crossed at a lateral distance of 0.8 NM and a vertical distance of 175 ft.
23.06.2016	**THY2ER vs. D-EMDT** The flight crew of the commercial aircraft by the operator Turkish Airlines reported a resolution advisory related to a private aircraft (D-EMDT) which was in radio contact with the flight information service (FIS) during the event. The two aircraft crossed at a lateral distance of 1.4 NM and a vertical distance of 475 ft.
03.07.2016	**SXS4HU vs. D-EDGS** The aerodrome controller in Friedrichshafen informed the air traffic controller at the workstation ARFA about an unknown VFR traffic (D-EDGS), which was south of the ILS and was heading towards the commercial aircraft by the operator SunExpress on final approach which subsequently reported a resolution advisory (RA). The two aircraft crossed at a lateral distance of 0.4 NM and a vertical distance of 200 ft.

1.11.2 Encounters in Class E airspace

The sector ARFA has registered recurrent convergences in airspace E over German territory between controlled IFR traffic and uncontrolled VFR flights since 23 April 2011. In addition, Skyguide keeps a list of events subject to reporting obligation, which has been made available to the STSB:

Year	Total reports	Of which during the AERO Friedrichshafen
2011	206	-
2012	119	0
2013	99	4
2014	81	1
2015	84	8
2016	46	4

Table 1: Number of yearly convergences between IFR and VFR traffic in sector ARFA as well as during the aviation exhibition „AERO Friedrichshafen“ (since 23 April 2011)

1.12 Useful or effective investigation techniques

None

2 Analysis

2.1 Technical aspects

There is no indication of pre-existing technical defects, which could have caused or influenced the serious incident

The analysis of the MRT readings (cf. chapter 1.9.1) show that the conditions for the emission by the traffic alert and collision avoidance system (TCAS) on board VLM 22TX of a traffic advisory (TA) between 08:14:27 UTC and 08:14:55 UTC as well as of a resolution advisory (RA) between 08:14:41 UTC and 08:14:54 UTC were satisfied.

However, the horizontal miss distance (HMD) for a RA of 0.2 NM between the two aircraft was never reached during the convergence (cf. red horizontal line in figure 10), therefore not producing a RA in the present case. The analysis also demonstrates that the TCAS on board VLM 22TX reacted according its specifications and that the height over the ground did not play a role.

2.2 Human and operational aspects

2.2.1 History of the serious incident

Following his first call at 08:03:27 UTC on the Friedrichsafen aerodrome control frequency 120.075 MHz, the pilot of OK-ELL was instructed to fly to the waypoint OSCAR (cf. figure 1) by the VFR Pick-up aerodrome controller. This was in accordance with the operational guidelines in force during the aviation exhibition (cf. chapter 1.7.6.3).

Six minutes later approximately, at 08:09:33 UTC and a second time at 08:09:48 UTC, the pilot of OK-ELL was instructed by the VFR Pick-up aerodrome controller to proceed towards waypoint ETREM, the final approach point FAP of the runway 24 ILS (cf. figure 5). Since he was on long final approach to runway 14 and after having been transferred to the controller at the workstation PL Main, the pilot of OK-ELL called on frequency 134.300 MHz and was once again instructed to turn right towards waypoint OSCAR and to remain outside of the CTR. This change of course in a northerly direction, at an altitude of 4000 ft QNH approximately, resulted in OK-ELL flying towards VLM 22TX which was in a right hand base. Consequently, OK-ELL did not circumnavigate the CTR of Friedrichshafen, as required by the operational guidelines in force during the aviation exhibition (cf. chapter 1.7.6.3), thereby establishing a key condition for the dangerous convergence.

At this time, the flight crew of VLM 22TX was in contact with the radar executive controller of the ARFA sector on another frequency and therefore could not hear the instructions given to the pilot of OK-ELL. The same was true for the radar exective controller RE who, according to his statement, was surprised by the left turn initiated at 08:14:42 UTC by OK-ELL (cf. figure 1), especially since the speed vector unexpectedly and for a short time was pointing towards VLM 22TX. Having observed the fluctuations of altitude and heading of the VFR traffic and the fact that the commercial aircraft was already at the minimum vectoring altitude (MVA) of 4000 ft AMSL, he considered it impossible to give any reliable heading change or descent clearance to VLM 22TX.

These altitude and heading fluctuations can be seen on the radar plot of OK-ELL (cf. figure 1). Besides, the flight crew of VLM 22TX would have been very surprised by an order to climb at this moment in time.

The aggravating situation and the resulting uncertainty of the radar executive controller RE are reflected in the radiotelephony conversations at 08:14:16 UTC and

at 08:14:37 UTC, as he gives the instruction twice, followed by a traffic information to the flight crew of VLM 22TX. The position information, communicated as "*one o'clock*", correlated with the image presented on his radar screen but not with the actual position of the unknown VFR traffic. The fact that the radio button was briefly pressed at 08:14:48 UTC and 08:14:50 UTC, just a few seconds before the moment of the closest point of approach of the two aircraft, shows an intention to communicate a useful instruction.

The radar coordinator controller of sector ARFA was aware of both the STCA alarm at 08:14:06 UTC and the resulting traffic information to VLM 22TX by the radar executive controller RE. The former was, however, otherwise engaged in conversations with the aerodrome controller of St. Gallen-Altenrhein for coordination purposes. This could explain why he was not aware of the incorrect position information about the unknown VFR traffic in the first traffic information at 08:14:16 UTC.

The information concerning the position of the sun (cf. chapter 1.4.3) shows how the flight crew of VLM 22TX encountered strong glare from the sun, while on the base leg, all the while attempting to spot the conflicting traffic on a collision course. It is therefore understandable that the pilots kept track of the situation based on the traffic information and the TCAS display. However, it must be said that due to the low azimuth resolution of the TCAS, the display of the traffic situation is limited, particularly on an IVSI (cf. figure 3). In addition, experience has shown that the convergence of a conflicting traffic in relation to ones own aircraft position is frequently misinterpreted. By way of example, a perpendicular convergence of two aircraft on a horizontal flight is displayed on the TCAS of the respective aircraft as a convergence with an angle of 45 degrees.

As the flight crew was expecting further instruction from the controller, a traffic advisory TA was triggered by the TCAS on board VLM 22TX at approximately 08:14:53 UTC. Subsequently, both pilots expected a resolution advisory RA. The MRT recordings reveal that a RA was not triggered, in accordance with the HMD concept because, after the initiation of the right turn at 08:14:42 UTC, that is before the TA, the threshold value of 0.2 NM for a RA was never reached.

Turning right towards Friedrichshafen Airport seemed obvious to the flight crew, yet, in doing so, they lost the possibility of seeing OK-ELL which was between their eleven to twelve o'clock position (cf. figure 8). In view of the inaccuracies in azimuth and the incorrect interpretation of a conflicting traffic, avoidance manoeuvres based on information displayed by the TCAS entail high risks. In the present case, the underlying safety net withheld the TCAS avoidance order.

Adding to the unfavourable visual conditions for all pilots, both aircraft were approaching each other with a constant angle (constant bearing) between 08:14:10 UTC and 08:14:42 UTC, meaning that the respective position of the other aircraft remained unchanged from the perspective of the pilots, as shown by the black narrow parallel connecting lines in Figure 1. It is, therefore, not surprising that the pilot of OK-ELL saw the large silhouette of the Fokker 50 only late as he initiated a right turn, thereby altering the constant convergence bearing. This indicates that the traffic information given by the PL Main aerodrome controller at 08:14:50 UTC, only four seconds before the closest point of approach, came too late.

2.2.2 Airspace structure of Friedrichshafen Airport

In class E mixed airspace, dangerous convergence of IFR and VFR traffic are likely, because the aircraft in this airspace are not separated from each other (cf. chapter 1.7.4), irrespectively of whether the IFR traffic flies until the CTR limits –

which is the case for the ILS approach to runway 24 – to follow the complete approach procedure from the IFR waypoint MOKOP according the AIP (cf. figure 5), or if under radar vectoring, as was the case in this incident.

Both transponder mandatory zones (TMZ) (cf. figure 4) around Friedrichshafen Airport not only make VFR traffic visible to the air traffic control units equipped with a radar, they also lay the foundation for the safety net of the airborne collision avoidance system (ACAS) relying on the transponder signal.

Even so, that does not guarantee that a VFR traffic will also have radio contact with an air traffic control unit. IFR and VFR traffic fly mostly in the same airspace E without the pilots being aware of the presence of each other. The fact that the pilot of OK-ELL had radio contact with the aerodrome control was not circumstancial, the radio transmissions between the flight crew of VLM 22TX and sector ARFA being conducted on another frequency.

A consequence of this is the increased risk of legal, uncontrolled dangerous convergence, or so-called legal encounters. While dangerous convergence were recorded almost every day in 2011, their number dropped noticeably, down to one event every eight days in 2016 (cf. chapter 1.11.3). Even though the absolute number of dangerous convergences has dropped yearly, the risk of a mid-air collision in airspace E remains, under the aforementioned conditions. It is worth remarking the number of such hazardous encounters which, during the four-day long aviation exhibition „AERO Friedrichshafen“ in the years 2015 and 2016, increased significantly over the average number of events.

The investigation of this dangerous convergence clearly shows that the “see and avoid” principle applied to prevent collisions in dense mixed traffic has reached its limits, despite the existence of a TCAS and the provision of traffic information.

Concentrating the VFR traffic over and across the runway, via the VFR waypoints NOVEMBER and SIERRA for the approach and departure during normal operation, allows for a geographical segregation from the IFR traffic on both runways 06 and 24 (cf. figure 6). Likewise, the VFR traffic in close proximity to the CTR is separated from the IFR traffic by the altitude limit of 3000 ft AMSL during arrival and departure, as the latter intercepts the glide slope of the ILS at 4000 ft AMSL.

According to the visual approach chart published on the occasion of the aviation exhibition, the flights on approach for the concrete runway 24 must proceed over the compulsory reporting point OSCAR, whereby the recommended approach corridor, crosshatched in red, must be followed (cf. figure 7). As a consequence, the VFR traffic is indeed channeled on an arrival route that must, however, cross the approach axis when approaching from the south. The approach altitude of not more than 4000 ft AMSL when flying to the compulsory reporting points constitutes a recommendation and corresponds to the MVA in this sector (cf. figure 1). In view of the lack of a flight altitude limit in the arrival corridor, as well as outside the CTR, an increased concentration of mixed traffic can be expected, especially in the right hand base leg for runway 24 when conduction IFR approaches, representing a systemic safety deficit.

Again, the requirement to contact the aerodrome controller early on (cf. figure 7, radius of 18 NM) is judicious, since the first contact takes place much earlier than usual and improves the scope of influence of the air traffic control, as opposed to the normal daily operation.

Both aerodrome controllers confirmed that a NOTAM procedure applicable during the aviation exhibition can lead to a degree of uncertainty among some pilots, other pilots may not even be aware of the procedure.

2.2.3 Air traffic control

2.2.3.1 ARFA

Skyguide has always planned additional shifts during the aviation exhibition „AERO Friedrichshafen“ and has provides annual training in the simulator, during which the various aspects of increased workload, the inherent risks caused by the changes and the unusual distribution of tasks during the exhibition are were reviewed. All the aforementioned initiatives are sensible. Nevertheless, a deployment during the exhibition requires considerable adjustments on the part of the air traffic controllers compared to their weekly routine work.

The extensive list of duties for the radar coordinator controller call for, among other tasks, the simultaneous handling of the necessary coordination conversations either orally or by telephone, in addition to the monitoring of the ARFA frequency and the traffic situation (cf. chapter 1.10.1.3). However, the tasks stipulated in the list cannot be fully carried on by one person with a heavy workload. This was made clear when the radar coordinator controller did not notice the incorrect position information concerning the unknown VFR traffic during the first traffic information given at 08:14:16 UTC by his collegue, the radar executive controller, to the flight crew of VLM 22TX. The objective of permanently supervising the radar executive controller at his work station, as safety assistant, was not achieved in the present case.

2.2.3.2 Aerodrome control

In principle, traffic information in airspace E is only issued when possible. During periods of intense traffic, convergences between IFR and VFR traffic in the periphery of the CTR occur more often and are part of the day-to-day operations of the aerodrome controller. Traffic information cannot always be provided in due time to those involved, as can be seen in the present case. As a consequence, the safety net for the aerodrome control service ceases to exist, without any other protection or suitable course of action.

In addition, increased traffic and workload load are always associated with aviation exhibitions. The aerodrome control (ADC) was, therefore, attributed to two aerodrome controllers, respectively divided into two distinct frequencies. This distribution of tasks and the discharge of the frequency are appropriate, but imply an increased coordinated effort between the two aerodrome controllers.

The traffic information provided just four seconds before the closest point of approach by the PL Main air traffic controller, shows that the looming conflict was perceived only at a late stage. How and when the two aerodrome controllers involved coordinated the flight path of the private airplane OK-ELL is unknown. The instructions for OK-ELL to proceed first towards OSCAR, then directly towards ETREM and once again towards OSCAR are not indicative of internal coordination.

The last heading instruction for OK-ELL to fly northerly, with no change to its flight altitude, resulted in both aircraft flying towards one another at approximately the same altitude.

Regardless of the high volume of traffic, the pertinence of the instruction to fly directly towards the IFR waypoint ETREM, from the viewpoint of customer service towards the VFR pilot, is questionable, particularly as the point was not indicated on the VFR chart.

2.2.3.3 Coordination between ARFA and the aerodrome control (ADC)

Before an aircraft can change frequency from the ARFA sector of the air traffic control unit Zurich Arrival to the aerodrome control of Friedrichshafen Airport or

inversely, there is an internal coordination that has to incorporate the required specific information (cf. chapter 1.10.3). This tower check only concerns the arriving and departing IFR traffic, since the VFR traffic in airspace E can only receive traffic information when it is in radio contact with a flight information service (FIS) and the situation allows it (cf. chapter 1.7.2).

The cancellation of the tower check had therefore no delaying effect on the approach sequence of the two aircraft involved in the present case and effectively reduced the number of coordination conversations at the aerodrome control service. As a result, the aerodrome control service denied itself an additional opportunity to recognize the conflict early on.

3 Conclusions

3.1 Findings

3.1.1 Technical aspects

- The commercial aircraft was approved for IFR transport.
- The piston, single-engined aircraft was approved for flying under VFR conditions.
- The investigation did not find any indication of pre-existing technical defects, which could have caused or influenced the serious incident.
- The traffic alert and collision avoidance system (TCAS) on board the commercial aircraft reacted according to its specifications and issued a traffic advisory (TA) during the convergence of the two aircraft.

3.1.2 Crew and air traffic control personnel

- The pilots on board both aircraft were in possession of the necessary licences for the flight.
- There are no indications of the pilots suffering health problems at the time of the serious incident.
- The air traffic controllers were in possession of the licenses necessary to exercise their activities.
- There are no indications of the air traffic controllers suffering health problems at the time of the serious incident.

3.1.3 History of the serious incident

- On 21 April 2016 the pilot of the piston, single-engined Piper PA-28RT-201T with three passengers on board, registered OK-ELL, contacted the aerodrome control of Friedrichshafen Airport (EDNY) for the first time at 08:03:27 UTC on the frequency 120.075 MHz for landing.
- He was consequently instructed by the VFR *Pick-up* aerodrome controller to fly directly to the waypoint OSCAR situated north-west of the airport and at the same time to remain outside of the control zone (CTR) of Friedrichshafen Airport.
- Approximately four minutes later, at 08:07:50 UTC, the flight crew of the commercial aircraft Fokker 50, carrying 33 passengers and with the flight plan call sign VLM 22TX, made initial contact with the RE air traffic controller of the sector ARFA. The pilot received both descent and heading instructions for an ILS approach, via a right hand base towards a point situated on the extended centreline at approximately 11 NM from the threshold of runway 24.
- At 08:09:33 UTC, and a second time at 08:09:48 UTC, as OK-ELL was approximately 20 NM east of the airport at an altitude of 4000 ft AMSL, the VFR *Pick-up* aerodrome controller instructed the pilot to proceed to the waypoint ETREM to join the final of runway 24.
- At 08:12:49 UTC, the flight crew of VLM 22TX received clearance to descend to 5000 ft QNH from the RE air traffic controller followed by, approximately half a minute later, the instructions to turn on a heading of 150 degrees for a base leg and to descend to 4000 ft QNH.

- At 08:13:25 UTC the VFR *Pick-up* aerodrome controller transferred OK-ELL to his colleague at station PL *Main* on frequency 134.300 MHz.
- No coordination (tower check) took place between the approach sector ARFA and the aerodrome control concerning the IFR approach of VLM 22TX.
- The pilot of OK-ELL called at 08:13:44 UTC on the frequency 134.300 MHz on a long final to runway 24.
- The PL Main aerodrome controller instructed the pilot of OK-ELL at 08:13:58 UTC, to turn right in direction of the waypoint OSCAR and to remain outside of the CTR.
- At 08:14:06 UTC, the short term conflict alert (STCA) between VLM 22TX and OK-ELL was set off.
- In the period of time between 08:14:10 UTC and 08:14:42 UTC, both aircraft were closing in on each other with a constant angle (constant bearing).
- At 08:14:16 UTC, the RE air traffic controller issued a first traffic information to the flight crew of VLM 22TX about the unknown VFR traffic, followed by a second traffic information at 08:14:37 UTC. Both were in reference to OK-ELL.
- The RC air traffic controller noticed both the STCA alarm and the following transmission of the traffic information to VLM 22TX by the RE air traffic controller and, at 08:14:23 UTC, contacted the aerodrome controller of St. Gallen-Altenrhein for further coordination.
- A traffic advisory (TA) was triggerd on board VLM 22TX at 08:14:27 UTC approximately.
- The flight crew of VLM 22TX was not able to establish visual contact with OK-ELL; the visibility from the flight deck in this phase was affected by the low position of the sun.
- The flight crew was able to identify and follow the traffic flying at the same altitude through the indications of the TCAS on the integrated vertical speed indicator.
- At 08:14:50 UTC the PL Main aerodrome controller issued a traffic information to the pilot of OK-ELL concerning VLM 22TX.
- The flight crew of VLM 22TX expected a resolution advisory (RA) which, following a horizontal avoidance turning manoeuvre, was not triggered.
- During the avoidance manoeuvre both aircraft crossed at an altitude of 4000 ft AMSL. The closest point of approach at 08:14:54 UTC was 0.5 NM horizontally und 100 ft vertically.
- The pilot of OK-ELL was able to visually identify the commercial aircraft due to the avoidance manoeuvre.
- Both aircraft continued their approach and landed uneventfully.

3.1.4 General conditions

- Good visual weather conditions prevailed at the time of the incident.
- The low position of the sun degraded the visibility from the flight deck of the commercial aircraft.

- From 20 to 23 April 2016 the „AERO Friedrichshafen“, an aviation exhibition for general aviation, was being held on its premises as well as at the adjoining Friedrichshafen Airport (EDNY).
- On the occasion of the „AERO Friedrichshafen“ the German air traffic control service Deutsche Flugsicherung (DFS) published, on 31. März 2016 and 14. April 2016 detailed information about overall conditions and recommendations concerning the aviation exhibition.
- Among them was a visual approach chart for VFR traffic according to the publication AIP SUP VFR 07/16 dated 14 April 2016, valid from 18 April 2016 to 24 April 2016.
- The aerodrome control service was to be provided by Austro Control GmbH and the sector ARFA controlled by Skyguide.
- During the „AERO Friedrichshafen“ the aerodrome control was divided into two distinct working positions, the PL Main und VFR Pick-up, each with its own frequency.
- Due to the significant increase in traffic density, the sector ARFA was managed by two air traffic controllers, a radar executive controller (RE) and a radar coordinator controller (RC).

3.2 Causes

The serious incident is attributable to a dangerous convergence of two aircraft flying on a converging course in airspace class E during an aviation exhibition, during which time the commercial aircraft flying under instrument flight rules was in contact with the approach control, while the light aircraft flying under visual flight rules was in radio contact with the aerodrome control.

The dangerous convergence arose from the concurrence of the following factors in chronological order:

- The operational concept consisting of the simultaneous approach of traffic under visual and instrument flight rules during the trade fair entailed systemic risks.
- The pilots of both aircraft were not in radio contact with the same air traffic control unit.
- The traffic guidance within the aerodrome control service concerning the light aircraft approaching under visual flight rules was coordinated inadequately.
- The traffic alert and collision avoidance system on board the commercial aircraft did not generate a resolution advisory due to a lateral avoidance manoeuvre.
- The traffic information provided by the aerodrome control to the pilot of the light aircraft was given too late.
- The pilots of both aircraft only acquired a late visual contact of each other.

The current classification of the airspace, in which the dangerous convergence took place, contributed to the occurrence of the serious incident.

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

4.1 Safety recommendations

According to the provisions of Annex 13 of the International Civil Aviation Organization (ICAO) and Article 17 of Regulation (EU) No. 996/2010 of the European Parliament and of the Council of 20 October 2010 on the investigation and prevention of accidents and incidents in civil aviation and repealing Directive 94/56/EC, all safety recommendations listed in this report are intended for the supervisory authority of the competent state, which must 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 Safety Investigation of Transport Incidents (OSITI):

"Art. 48 Safety recommendations

[1] The STSB shall submit the safety recommendations to the competent federal office and notify the competent department of the recommendations. In the case of urgent safety issues, it shall notify the competent department immediately. It may send comments to the competent department on the implementation reports issued by the federal office.

[2] The federal offices shall report to the STSB and the competent department periodically on the implementation of the recommendations or on the reasons why they have decided not to take measures.

[3] The competent department may apply to the competent federal office to implement recommendations."

The STSB shall publish the answers of the relevant Federal Office or foreign supervisory authorities at www.stsb.admin.ch in order to provide an overview of the current implementation status of the relevant safety recommendation.

4.1.1 Operating concept during the aviation exhibition

4.1.1.1 Safety deficit

On 21 April 2016, the second day of the aviation exhibition „AERO Friedrichshafen", a dangerous convergence took place in airspace E, approximately 10 NM north-east of Friedrichshafen Airport (EDNY) at an altitude of 4000 ft AMSL, between a commercial aircraft under radar guidance for an approach to runway 24 and a light aircraft in radio contact with the aerodrome control, flying under visual flight rules and arriving from the south-east. The closest point of approach was 0.5 NM horizontally und 100 ft vertically.

According to the guidelines of the visual approach chart, published specifically for the trade fair, approaches for the paved runway 24 are carried out via the mandatory reporting waypoint OSCAR, north of the airport, with a recommendation to follow the approach corridor at an altitude no higher than 4000 ft AMSL. As a consequence, the VFR traffic approaching from the south-east must cross the runway axis.

Also, in view of the absence of an altitude limit in the area of the flight corridor as well as outside the CTR of Friedrichshafen, an increased concentration of mixed traffic north-east of the airport is to be expected when IFR approaches via a right-hand base for runway 24 take place simultaneously.

Opting to concentrate the VFR traffic above and across the runway via the VFR waypoints NOVEMBER and SIERRA for the approach and departure, as foreseen during normal operation, allows for a geographical segregation from the IFR traffic on both runways 06 and 24. Likewise, the VFR traffic in close proximity to the CTR is separated from the IFR traffic by the altitude limit of 3000 ft AMSL during arrival and departure, as the latter never intercepts the glide slope of the ILS under 4000 ft AMSL.

The management of the airspace around Friedrichshafen Airport, which is divided into various air navigation service providers (ANSP), organized into jurisdictions, imposed duties, rights and obligations, presents many interfaces. These complicate and/or preclude the rapid implementation of a practical procedure.

The STSB recognizes, therefore, systemic risks in the operating guidelines as well as in the visual approach chart published specifically for the aviation exhibition.

4.1.1.2 Safety recommendation no. 541

The Air Traffic Controlling Office (*Bundesaufsichtsamt für Flugsicherung* – BAF) should in cooperation with the air navigation service provider *Deutsche Flugsicherung* (DFS), Skyguide and Austro Control GmbH examine to what extent the operating concept could be improved upon during the aviation exhibition.

4.2 Safety advices

None

4.3 Measures taken since the serious incident

None

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

Bern, 10 July 2018 Swiss Transportation Safety Investigation Board