Bundesstelle für
Flugunfalluntersuchung

German Federal Bureau of
Aircraft Accident Investigation

Study

Concerning

Airproxes and Collisions of Aircraft in German Air Space 2010 - 2015

This investigation was conducted in accordance with the 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 the Federal German Law relating to the investigation of accidents and incidents associated with the operation of civil aircraft (*Flugunfall-Untersuchungs-Gesetz - FlUUG*) of 26 August 1998.

The sole objective of the investigation is to prevent future accidents and incidents. The investigation does not seek to ascertain blame or apportion legal liability for any claims that may arise.

This document is a translation of the German Investigation Report. Although every effort was made for the translation to be accurate, in the event of any discrepancies the original German document is the authentic version.

Published by:

Bundesstelle für
Flugunfalluntersuchung

Hermann-Blenk-Str. 16
38108 Braunschweig

Phone +49 531 35 48 - 0
Fax +49 531 35 48 – 246

Email: box@bfu-web.de
Internet: www.bfu-web.de

Content Page

Abbreviations

ACAS	Airborne Collision Avoidance System
ADS-B	Automatic Dependent Surveillance - Broadcast
AMSL	Above Mean Sea Level
AOPA	Aircraft Owners and Pilots Association
ATC	Air Traffic Control
ATSB	Australian Transport Safety Bureau
BAZL	Bundesamt für Zivilluftfahrt
BEA	Bureau d'Enquêtes et d'Analyses
BEKLAS	Erkennbarkeit von Segelflugzeugen und kleinen motorisierten Luftfahrzeugen
BFU	Bundesstelle für Flugunfalluntersuchung (German Federal Bureau of Aircraft Accident Investigation)
BMVI	Bundesministerium für Verkehr und digitale Infrastruktur (Federal Ministry for Transport and Digital Infrastructure)
CAA	Civil Aviation Authority
CAS	Commercial Air Service
CAT	Commercial Air Transport
CS	Certification Specifications
DAeC	Deutscher Aero Club e.V.
DFS	Deutsche Flugsicherung (German air traffic service provider)
DULV	Deutscher Ultraleichtflugverband e.V.
EASA	European Aviation Safety Agency
ECCAIRS	European Co-ordination Centre for Accident and Incident Reporting Systems
EGAST	European General Aviation Safety Team

EHS	Enhanced Surveillance
FAA	Federal Aviation Administration
FAF	Final Approach Fix
FlUUG	Flugunfall-Untersuchungs-Gesetz (Federal German Law relating to the investigation of accidents and incidents associated with the operation of civil aircraft)
FSAV	Verordnung über die Flugsicherungsausrüstung
FUS	Flugunfalluntersuchungstelle (now: BFU)
GA	General Aviation
GND	Ground
GPS	Global Positioning System
ICAO	International Civil Aviation Organization
IFR	Instrument Flight Rules
ISM-Band	Industrial, Scientific and Medical - (frequency) Band
LBA	Luftfahrt-Bundesamt (German civil aviation authority)
MO-ATS	Manual of Operations Air Traffic Services
NfL	Nachrichten für Luftfahrer (Notices for airmen)
RA	Resolution Advisory
RAFIS	Radar enhanced Flight Information Service
RMZ	Radio Mandatory Zone
SERA	Standardised European Rules of the Air
SRD-Band	Short Range Devices - (frequency) Band
SSR	Secondary Surveillance Radar
STCA	Short Term Conflict Alert
TA	Traffic Advisory

TAS	True Airspeed
TCAS	Traffic Alert and Collision Avoidance System
TMZ	Transponder Mandatory Zone
TSB	Transportation Safety Board of Canada
UAV	Unmanned Aerial Vehicle
UL	Ultraleichtflugzeug (Ultralight Aircraft)
VFR	Visual Flight Rules

Synopsis

This study takes into consideration airproxes and collisions of aircraft which occurred in German airspace between 2010 and 2015. Of a total of 490 reported occurrences, 15 were accidents, 31 serious incidents and 8 incidents. A total of 19 persons were fatally and 2 severely injured; 15 suffered minor injuries.

Due to timely traffic warnings by air traffic control, or on-board collision avoidance systems, and adherence to the See and Avoid principle, the BFU classified most of these occurrences as ”not worthy to be further investigated”.

Most of the serious incidents occurred in airspaces where air traffic in accordance with Instrument Flight Rules (IFR) and Visual Flight Rules (VFR) mix. In the current airspace structure this occurs mostly in Airspace E.

The accidents occurred either in VFR cruise flight or during VFR aerodrome traffic.

During the accidents and serious incidents the See and Avoid principle had failed.

As part of this study several international investigations, publications, and their respective recommendations concerning airproxes and collisions were analysed.

It was determined that the consequent use of the already available technical means would considerably minimise the collision risk in airspaces where controlled IFR traffic and uncontrolled VFR traffic occur at the same time. The airspace structure could also safely separate “Known” and “Unknown” traffic.

With the respective compatible anti-collision equipment of all air traffic participants, the collision risk in VFR cruise flight and in the VFR aerodrome traffic could be reduced.

The German Federal Bureau of Aircraft Accident Investigation will issue two safety recommendations as a result of this study. The safety recommendations refer to conflict traffic recognition for air traffic control units and on-board anti-collision systems.

1. Initial Situation

1.1 Objective

For years, the German Federal Bureau of Aircraft Accident Investigation (BFU) has been receiving reports of airproxes of aircraft in German airspace. These reports range from observations of third parties, to reports of crew members involved or of air traffic control services, to reportable airprox occurrences.

In addition to the airproxes, collisions occur involving aircraft in cruise flight and aerodrome traffic, most of them resulting in severe injuries.

Due to these facts, the BFU has decided to compile a study based on 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. The study is a survey of the general framework and reports, as well as a summary of the conclusions of similar studies and determinations of safety deficits as a result of safety investigations of serious incidents and accidents:

- Survey of the general framework
    - Airspace structure in Germany
    - Users of the airspaces and traffic volume
    - IFR and VFR flight rules and the See and Avoid principle
    - Aviation regulations regarding collision avoidance
    - Technical tools for collision avoidance
    - Flight safety information issued by BFU and LBA
- Reports received by the BFU between 2010 and 2015
- Results and recommendations of similar studies and publications
- Analysis
- Recommendations

1.2 Survey of the General Framework

The danger of an unintended airprox or collision of aircraft was already recognised at the beginning of air travel and the concentration of several aircraft inside a limited area - at the latest since the first recorded collision on 3 October 1910 at Milano Circuito Aereo Internazionale.

The overview below shows the different means, e.g. a variety of actions, regulations, procedures, air space structures, and technical tools, which were implemented with the aim to counteract the collision risk.

Risks and subsequent actions for collision avoidance Source: UK AIRPROX Board

1.2.1 Airspaces

International Regulations

The International Civil Aviation Organisation (ICAO) has issued guidelines and recommendations in ICAO Annex 2 Rules of the Air and ICAO Annex 11 Air Traffic Services in regard to air space structure, air traffic control, visual and instrument flight rules, and procedures for collision avoidance, among other things.

The differentiation of the airspaces is mainly based on the extent of control (controlled / uncontrolled airspace), and operational recommendations for the use of the respective airspace, such as maximum speed, minimum visibility (in-flight and ground), ground in sight, and minimum distance to clouds.

Air traffic control units are responsible for the control of the airspaces. They can, but do not have to, be supported by radar.

APPENDIX 4. ATS AIRSPACE CLASSES — SERVICES PROVIDED AND FLIGHT REQUIREMENTS

(Chapter 2, 2.6 refers)

Class	*Type of flight*	*Separation provided*	*Service provided*	*Speed limitation**	*Radio communication requirement*	*Subject to an ATC clearance*
A	IFR only	All aircraft	Air traffic control service	Not applicable	Continuous two-way	Yes
B	IFR	All aircraft	Air traffic control service	Not applicable	Continuous two-way	Yes
	VFR	All aircraft	Air traffic control service	Not applicable	Continuous two-way	Yes
C	IFR	IFR from IFR IFR from VFR	Air traffic control service	Not applicable	Continuous two-way	Yes
	VFR	VFR from IFR	1) Air traffic control service for separation from IFR; 2) VFR/VFR traffic information (and traffic avoidance advice on request)	250 kt IAS below 3 050 m (10 000 ft) AMSL	Continuous two-way	Yes
D	IFR	IFR from IFR	Air traffic control service, traffic information about VFR flights (and traffic avoidance advice on request)	250 kt IAS below 3 050 m (10 000 ft) AMSL	Continuous two-way	Yes
	VFR	Nil	IFR/VFR and VFR/VFR traffic information (and traffic avoidance advice on request)	250 kt IAS below 3 050 m (10 000 ft) AMSL	Continuous two-way	Yes
E	IFR	IFR from IFR	Air traffic control service and, as far as practical, traffic information about VFR flights	250 kt IAS below 3 050 m (10 000 ft) AMSL	Continuous two-way	Yes
	VFR	Nil	Traffic information as far as practical	250 kt IAS below 3 050 m (10 000 ft) AMSL	No	No
F	IFR	IFR from IFR as far as practical	Air traffic advisory service; flight information service	250 kt IAS below 3 050 m (10 000 ft) AMSL	Continuous two-way	No
	VFR	Nil	Flight information service	250 kt IAS below 3 050 m (10 000 ft) AMSL	No	No
G	IFR	Nil	Flight information service	250 kt IAS below 3 050 m (10 000 ft) AMSL	Continuous two-way	No
	VFR	Nil	Flight information service	250 kt IAS below 3 050 m (10 000 ft) AMSL	No	No

* When the height of the transition altitude is lower than 3 050 m (10 000 ft) AMSL, FL 100 should be used in lieu of 10 000 ft.

ICAO airspace classifications — Source: Excerpt ICAO Annex 11

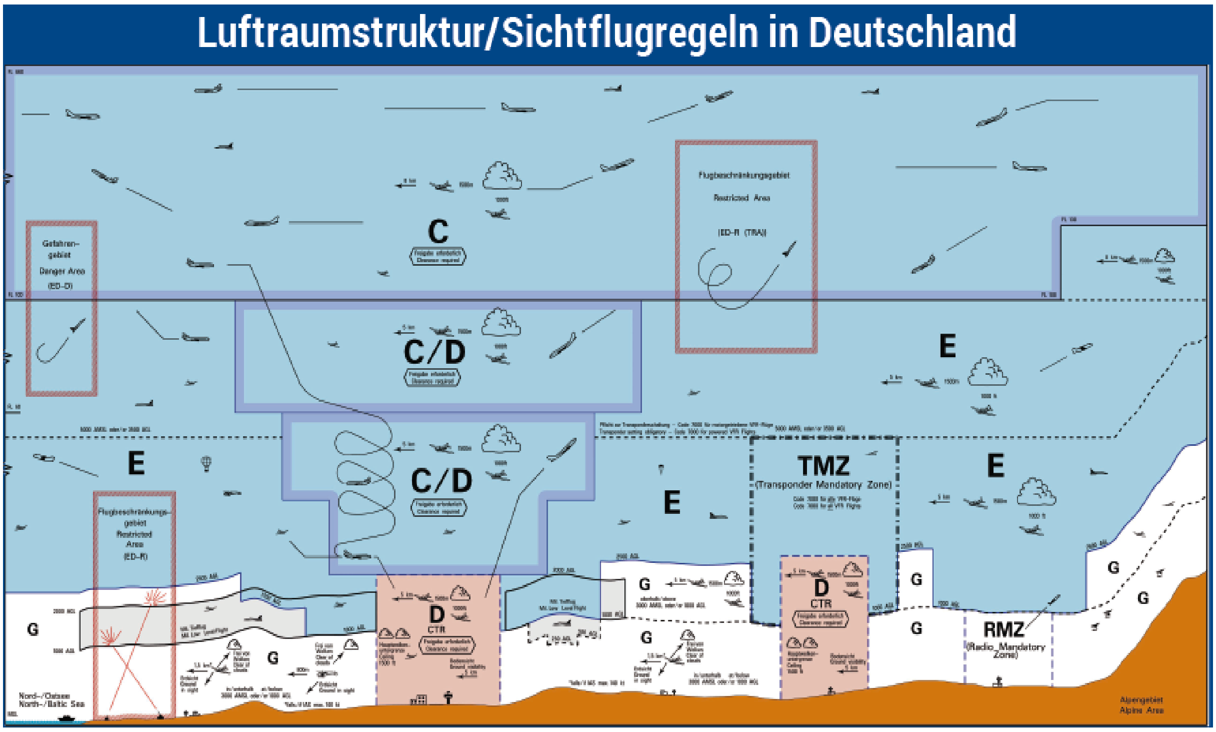
European Regulations

The Commission Implementing Regulation (EU) No 923/2012 of 26 September 2012 laying down the common rules of the air and operational provisions regarding services and procedures in air navigation established in Section 6 of its annex and in Appendix 4 Standardised European Rules of the Air (SERA). The implementing regulation came into effect on 5 December 2014 and became then mandatory for Germany also.

German Regulations

The Ministry of Transport and Digital Infrastructure (BMVI) establishes the airspace structure in Germany. The Deutsche Flugsicherung GmbH (air traffic service provider) was instructed by the BMVI to carry out the duties in regard to the airspace structure and prepare the respective airspace changes in agreement with the BMVI.

Starting in 1997 the Ministry prepared an airspace criteria catalogue which is checked and amended annually. Taking into account the interests of the different user groups (commercial aviation, military aviation, general aviation, and flight clubs, operators of airports, regional airports, airfields, special airfields, and glider airfields), the airspace criteria catalogue established criteria for the implementation, amendment, and cancellation of airspaces, especially in the vicinity of airports with IFR traffic.



Airspace structure in Germany Source: DFS

In the opinion of the BMVI the number of take-offs and landings in accordance with Instrument Flight Rules (IFR) at an airport is a decisive criterion for the protection of the approaching and departing IFR traffic by special airspace measures. It is also the opinion of the BMVI that safe IFR - VFR mixed traffic in Airspace Class E cannot exclusively be ensured by the See and Avoid principle, especially with increasing traffic volume.

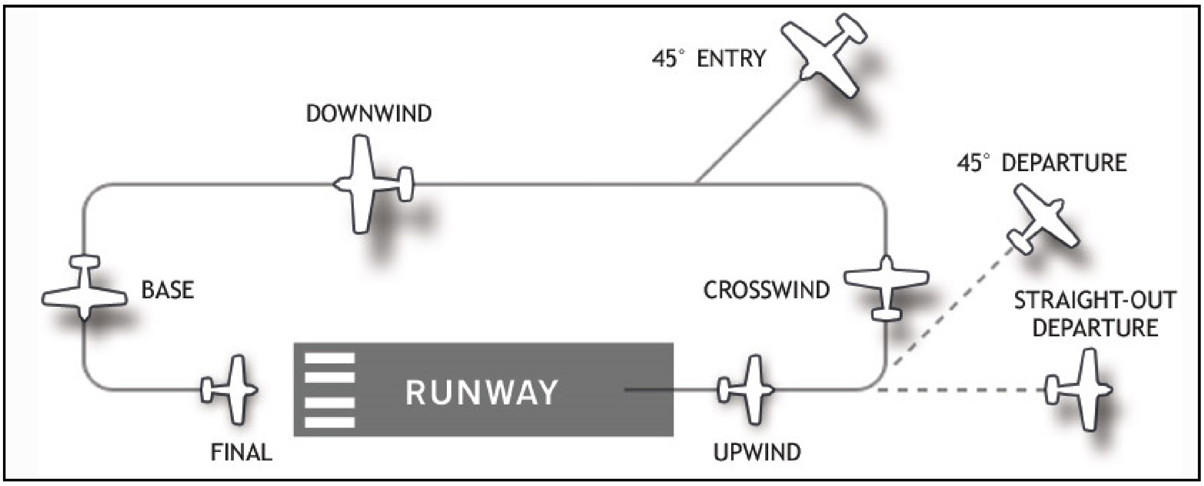
Based on the number of annual IFR take-offs and landings, all airports with IFR traffic were classified into six categories, and for some special airspace measures were stipulated.

Category	Number of IFR take-offs / landings per year	Airspace measure
1	< 10,000	No measure, beyond D(CTR) Airspace E or RMZ
2	Approximately 10,000 - 30,000	TMZ, RMZ or RMZ/TMZ
3	Approximately 30,000 - 50,000	Airspace D (not CTR) up to FL 60 and, if appropriate, TMZ and / or RMZ between FL 60 and FL 100
4	Approximately 50,000 - 100,000	Airspace C up to FL 60 and, Airspace D (not CTR) or TMZ and / or RMZ between FL 60 and FL 100
5	Approximately 100,000 - 150,000	Airspace C up to FL 60 and, Airspace D (not CTR) between FL 60 and FL 100
6	> 150,000	Airspace C up to FL 100

Criteria of the classification of airspace measures Source: BMVI

VFR Aerodrome Traffic

The traffic pattern is a standardised approach and departure procedure for flights in accordance with Visual Flight Rules (VFR). They serve, for example, as initiation of a safe landing approach, but also as protection of noise sensitive areas surrounding airports. In Germany, special approach charts are available depicting the flight path and altitude for the traffic pattern. At airports with a mixture of glider, ultralight, and powered aircraft traffic several traffic patterns are common. Internationally normally the ICAO standard traffic pattern applies.



Overview standard traffic pattern Source: FAA

The pilot may deviate from the traffic pattern if the safe conduct of the flight (e.g. conflicting traffic, weather conditions, airplane performance, etc.) makes it necessary.

Only uncontrolled airports have stipulated and published traffic patterns.

At uncontrolled airports, the pilot should report his/her position once during each traffic pattern leg so as to keep approaching or departing or any other kind of air traffic in the traffic pattern informed (refer to e.g. Flugunfallinformation V 129 „Richtige Positionsangaben", FUS, 1995).

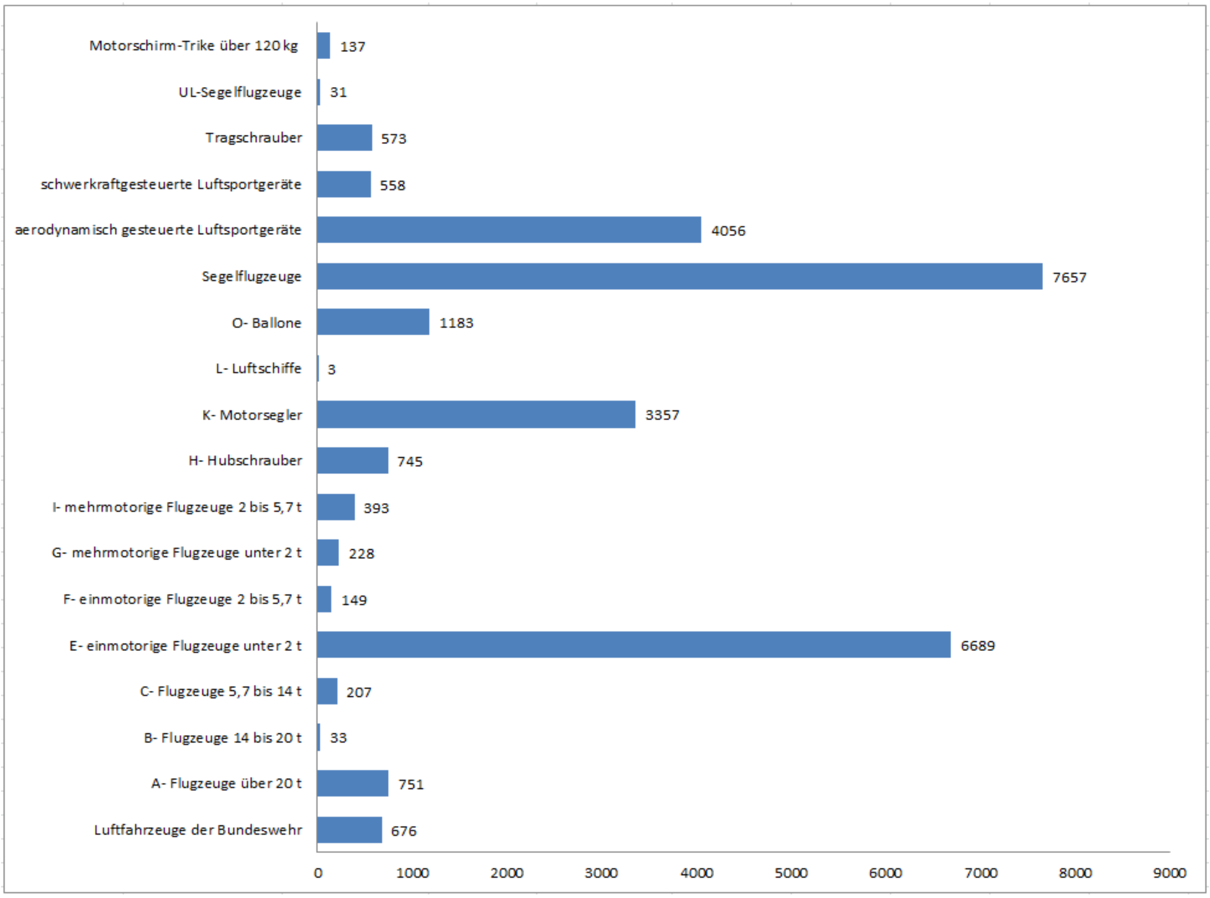
1.2.2 Airspace Users

German airspace is used by a number of different users. Here strongly deviating interests, flight performance parameters, and financial possibilities of owners and pilots, meet.

These are: commercial air transport of passengers and goods with large transport aircraft (Commercial Air Transport, CAT), commercial flight operations and so-called non-public company flights with business jets (Business Aviation), commercial flight operations with airplanes and helicopters for a number of operations (e.g. police, Search and Rescue (SAR), passenger transport, aerial work, aerial banner towing, flight training), military aviation and General Aviation (GA). Furthermore, there are weather balloons, flying models, and civil and military unmanned aerial vehicle (UAV).

Especially in General Aviation there is a great spectrum of use and aircraft. It ranges from IFR traffic with multi-engined aircraft, to VFR traffic with powered aircraft, gliders and aerial sports equipment of every description, to parachuting and model flying operation.

According to the Luftfahrt-Bundesamt (German civil aviation authority, LBA), the Deutsche Aero Club e.V. (German Aero Club, DAeC), the Deutsche Ultraleichtflugverbande e.V. (German Microlight Association, DULV) and the German Armed Forces, in 2014 a total of 21,395 civil aircraft, 4,087 aerodynamically controlled light sports aircraft, 695 gravity controlled light sports aircraft, 548 gyrocopters, and 676 military aircraft were registered in Germany.



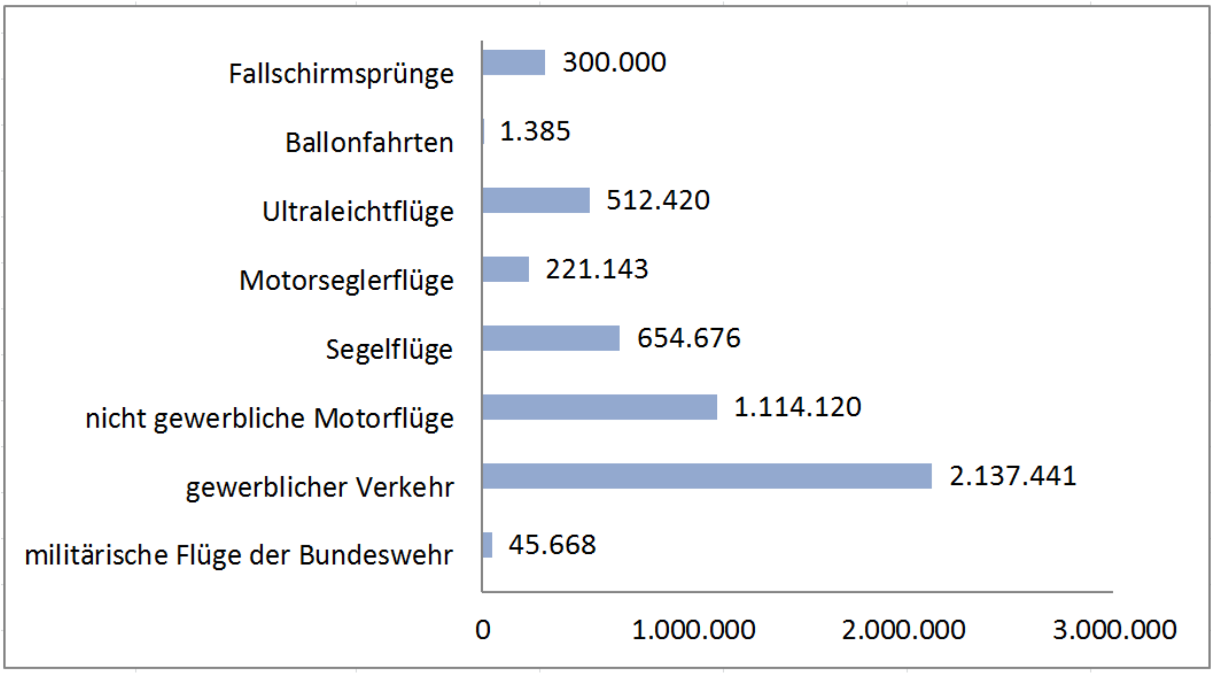
Registered aircraft and aerial sports equipment in 2014 Graph: BFU

1.2.3. Traffic Volume

In general, air traffic can be deviated in flights in accordance with visual flight rules and instrument flight rules and in commercial air transport and non-commercial (private) flight operations.

According to the Bundesamt für Statistik (Federal Office for Statistics), the German Armed Forces and the Deutsche Fallschirmsportverband e.V. (German Sky Diving Organisation, DFV) in 2014 approximately 4.6 million flights were conducted and approximately 300,000 sky divers dropped in Germany.

In addition there are currently countless unmanned civil and military flying objects (weather balloons, flying models, and Unmanned Aerial Vehicles (UAVs)).



Air traffic volume and sky diving in 2014 Graph: BFU

1.2.4 Visual and Instrument Flight Rules and „See and Avoid“ Principle

Small aircraft and aerial sports equipment (General Aviation) mostly use Visual Flight Rules (VFR) in low altitudes in the uncontrolled Airspace G and the controlled Airspaces D and E. During low level flight military aircraft are also flying in accordance with VFR. Commercial flights with large transport aircraft and business aviation are generally conducted in accordance with Instrument Flight Rules (IFR).

Visual Flight Rules

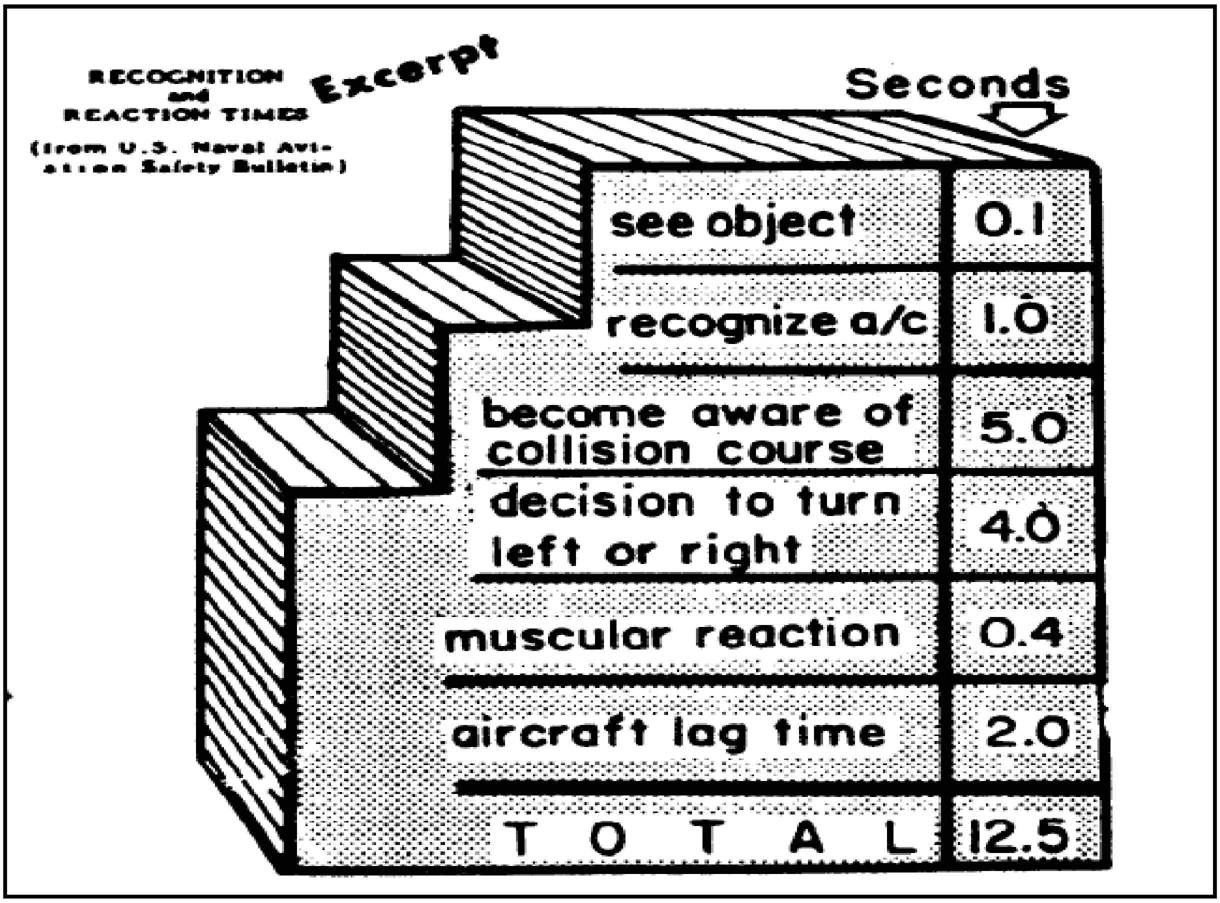
Visual Flight Rules (VFR) are a set of regulations for VFR flights. Typically, VFR flights are not separated from other air traffic by any air traffic control unit. The “See and Avoid” principle applies. Therefore, observing the airspace is one of the most important tasks of the pilot. This is especially true for flight operations in the vicinity of an airport and in a traffic pattern with increased traffic volume.

The FAA Regulation 14 CFR Part 91.113 (b) defines “See and Avoid” as follows:
“When weather conditions permit, regardless of whether an operation is conducted under instrument flight rules or visual flight rules, vigilance shall be maintained by each person operating an aircraft so as to see and avoid other aircraft. When a rule of this section gives another aircraft the right-of-way, the pilot shall give way to that aircraft and may not pass over, under, or ahead of it unless well clear."

"See and Avoid" requires the application of: Effective visual scanning, the ability to gather information from radio transmissions from ground stations and other aircraft, Situational Awareness, and the development of good airmanship.”

See and Avoid is subject to a number of limitations such as light intensity, contrast, view constriction from the cockpit due to design, approximate angle and speed, personal visual performance and reaction time.

As example, the reaction time from the moment of recognition of an approaching object to the avoidance reaction is depicted in the graph below:



Reaction time from the moment of recognition to the avoidance manoeuvre Source: US Navy

Instrument Flight Rules

In Germany, flights in accordance with Instrument Flight Rules (IFR) are on principle only intended to occur in controlled airspaces (classes C, D, E). Stipulated approach and departure procedures apply for take-offs and landings. Radio Mandatory Zones (RMZ) were established for individual IFR approaches and departures at some airports without air traffic control, surrounded by uncontrolled Airspace G. Since 11 December 2014 these RMZs replace the former German Airspace F.

Mixed Air Traffic

In controlled airspaces, especially in the Airspaces E and D, VFR and IFR air traffic mix. It has to be considered that air traffic controllers separate IFR traffic but, as a general rule, not IFR and VFR traffic. In general, the air traffic controller has no information as to the flight path of the VFR traffic in Airspace E, since it does not have to be reported to air traffic control. Collision avoidance and sufficient separation to other aircraft flying in accordance with VFR is the responsibility of the pilot flying in accordance with IFR and of the VFR pilot.

The DFS pointed out in the information for IFR pilots published in 2016: *IFR flights do not have a general right of way in Airspace E. The right of way rules in accordance with Luft (VO) apply. The right of way of gliders, hang gliders, parachutes, balloons, and aerotows has to be adhered to. This not only applies when the flight is radar controlled but also if the IFR flight adheres to an IFR procedure, e.g. SID or STAR. In order to avoid a so-called airprox one has to deviate from SID or STAR and contact ATC.*

1.2.5 Aeronautical Regulations for Collision Avoidance

A number of aeronautical regulations contain provisions, actions, and rules for collision avoidance in air traffic. Some relevant excerpts are listed below.

Luftverkehrs-Ordnung (Air Traffic Order)

Based on the ICAO recommendations and guidelines, until the end of 2014 the Luftverkehrs-Ordnung (LuftVO) provided rules for pilots and the operation of aircraft of any kind in Germany. The LuftVO supplemented the Luftverkehrsgesetz (Federal Aviation Act).

The LuftVO applied to all aircraft participating in air traffic, including model aircraft and UAVs. In addition to the general rules for IFR and VFR flights a number of provisions were made which included avoidance of airproxes and collisions.

- *Para 12 Avoidance of collisions*
- *Para 13 Right of way*
- *Para 14 Cloud flying with gliders and aerial sports equipment*
- *Para 17 Lights to be displayed by aircraft*
- *Para 22 Flight operations at an airport and its vicinity*
- *Para 26b Position reports*
- *Para 28 Flights in accordance with Visual Flight Rules (VFR) in airspaces with the classification B to G*
- *Para 32 VFR flights above the cloud cover*
- *Appendix 3 (to paras 33 and 37) semi-circular flight rules*

- *Appendix 4 (to para 10 subpara 2 LuftVO) airspace classification and air traffic services*

Commission Implementing Regulation No 923/2012

Due to the European harmonisation of the aeronautical provisions the Commission Implementing Regulation (EU) No 923/2012 applies now. It supplemented and changed parts of the LuftVO becoming effective on 6 November 2015. The following rules were issued in regard to collision avoidance:

SERA.3201 General

Nothing in this Regulation shall relieve the pilot-in-command of an aircraft from the responsibility of taking such action, including collision avoidance manoeuvres based on resolution advisories provided by ACAS equipment, as will best avert collision.

- *SERA.3205 Proximity*
- *SERA.3210 Right of way*
- *SERA.3215 Lights to be displayed by aircraft*
- *SERA.3225 Operation on and in the vicinity of an aerodrome*
- *SERA.5005 Visual flight rules*
- *SERA.6001 Classification of airspaces*
- *SERA.6005 Requirements for communications and SSR transponder*
- *Radio Mandatory Zone (RMZ)*
- *Transponder Mandatory Zone (TMZ)*
- SERA.7001 General — Objectives of the air traffic services
- *The objectives of the air traffic services shall be to: (a) prevent collisions between aircraft; [...]*
- SERA.8005 Operation of air traffic control service

  (b) Clearances issued by air traffic control units shall provide separation:
  (1) between all flights in Airspace Classes A and B;
  (2) between IFR flights in Airspace Classes C, D and E;
  (3) between IFR flights and VFR flights in Airspace Class C;
  (4) between IFR flights and special VFR flights;
  (5) between special VFR flights unless otherwise prescribed by the competent

authority; except that, when requested by the pilot of an aircraft and agreed by the pilot of the other aircraft and if so prescribed by the competent authority for the cases listed under b) above in Airspace Classes D and E, a flight may be cleared subject to maintaining own separation in respect of a specific portion of the flight below 3 050 m (10 000 ft) during climb or descent, during day in visual meteorological conditions.

- *SERA.8010 Separation minima*
- *SERA.8025 Position reports*
- *SERA.9005 Scope of flight information service*

  (b) Flight information service provided to flights shall include, in addition to that outlined in (a), the provision of information concerning: […] 2. collision hazards, to aircraft operating in Airspace Classes C, D, E, F and G; [...]
- *Appendix 3 Table of cruising levels*

Verordnung über die Flugsicherungsausrüstung der Luftfahrzeuge (FSAV) (Regulation Concerning Avionics Equipment of Aircraft)

Para 3 Avionics equipment for IFR flights

[...] 4. A secondary radar response unit (Transponder) equipped with 4,096 response codes for interrogation mode A, and with automatic altitude transfer for interrogation mode C. As of 31 March 2004 at the latest for all new aircraft and of 31 March 2005 for all aircraft is Mode S technology in accordance with international standards (at least Level 2 with SI Code and Elementary Surveillance (ELS) is required. As of 31 March 2007 Enhanced Surveillance (EHS) is additionally required for all aircraft with a maximum take-off mass of more than 5,700 Kilogram or a True airspeed (TAS) of more than 250 Kt.

7. As far as it is a turbine-powered airplane with more than 30 seats or a maximum take-off mass of more than 15,000 Kilogram, an Airborne Collision Avoidance System (ACAS II) in accordance with international standards (at least TCAS II with software change 7). As of 1 January 2005 this also applies to turbine-powered airplanes with more than 19 seats or a maximum take-off mass of more than 5,700 Kilogram.

Para 4 Avionics equipment for VFR flights

[...] (5) For the following VFR flights the aircraft have to be equipped with a secondary radar response unit (Transponder):

1. Flights in Airspace Classes C and D (not control zone),

2. Flights in airspaces with required transponder set-up (Transponder Mandatory Zones -TMZ),

3. Flights at night in controlled airspace,

4. Flights with powered aircraft, except in the operating mode gliding, above 5,000 ft NN or above 3,500 ft above ground, whereupon the higher value is decisive.

Commission Implementing Regulation (EU) No 1207/2011 and Commission Implementing Regulation (EU) No 1028/2014 of the Commission dated 26 September 2014 Changing Commission Implementing Regulation (EU) No 1207/2011

Laying down requirements for the performance and the interoperability of surveillance for the single European sky.

Article 1 Subject matter: This Regulation lays down requirements on the systems contributing to the provision of surveillance data, their constituents and associated procedures in order to ensure the harmonisation of performance, the interoperability and the efficiency of these systems within the European air traffic management network (EATMN) and for the purpose of civil-military coordination.

Manual of Operations Air Traffic Services (MO-ATS), Excerpts:

212 Objectives of the Air Navigation Services

212.1 The objectives of the air traffic services are to:

.11 prevent collisions between aircraft;

213 RESPONSIBILITIES

.11 Air traffic control service shall be provided:

.111 to all IFR flights in Airspace Classes A, B, C, D and E;

.112 to all VFR flights in Airspace Classes B, C and D;

.113 to all special VFR flights;

.114 to all aerodrome traffic at controlled aerodromes.

213.3 Only one ATC unit shall be responsible for the control of all aircraft operating within a defined airspace (area of responsibility / control sector). However, control of one or several aircraft may be delegated to another ATC unit provided that coordination between all air traffic control units concerned is assured.

328 WAKE TURBULENCE SEPARATION

328.4 In cases where ATC does not influence the piloting of an aircraft (e.g. VFR flights), information on possible hazards from other aircraft shall – as far as possible - be provided:

.41 by stating the type of aircraft, the position and - if relevant - the level, e.g. when the succeeding aircraft is in the traffic circuit and preplanned as number 2 to land

or

.42 by using the phrase CAUTION WAKE TURBULENCE, e.g. when an aircraft departs behind an aircraft of a higher weight category.

428 ACAS/TCAS PROCEDURES

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

428.3 Procedures

.31 The controller should be aware of the fact, that in the event of an ACAS/TCAS-resolution advisories (RA) to alter the flight path pilots shall respond immediately and manoeuvre as indicated unless doing so would jeopardize the safety of the aircraft.

.32 When a pilot reports a manoeuvre induced by an ACAS/TCAS-resolution advisory (RA), the controller:

.321 shall not attempt to modify the flight path of an aircraft responding to an resolution advisory;

.322 shall not issue any clearance or instruction to the aircraft involved until the pilot reports returning to the terms of the assigned ATC clearance or instruction;

.323 shall acknowledge by using the phrase ROGER;

and

.324 should provide traffic information if deemed necessary.

430 SEPARATION

431 GENERAL PROCEDURES

431.2 Clearances issued by air traffic control units shall provide separation:

a) between all flights in Airspace Classes A and B;

b) between IFR flights in Airspace Classes C, D and E;

c) between IFR flights and VFR flights in Airspace Class C;

d) between IFR flights and special VFR flights;

e) between special VFR flights

473 VFR FLIGHTS WITHIN AIRSPACE CLASS C BELOW FL 100 AND WITHIN AIRSPACE CLASS D (not control zone)

473.4 VFR flights within Airspace Class C shall receive:

.41 traffic information concerning VFR flights

and

.42 avoidance advice on request.

473.5 VFR flights in Airspace Class D (not control zone) shall receive:

.51 traffic information concerning IFR flights

and

.52 traffic information concerning VFR flights.

513 RADAR FLIGHT INFORMATION SERVICE

513.1 Radar-assisted flight information service (RAFIS) for military flights under visual flight rules. […]

513.3 Apart from the functions of the general flight information service, RAFIS shall have the following additional functions: […]

.32 traffic information shall be issued when the danger of a collision might occur;

.33 traffic avoidance advice shall be issued if the pilot does not have the reported traffic in sight;

541 TRAFFIC INFORMATION BASED ON RADAR INFORMATION

541.1 Within the scope of the flight information service, traffic information should be issued whenever possible. […]

Note 1: This also applies to airspace where unknown flights are not to be expected, as a rule.

541.2 Traffic information based on radar information shall be issued in an exact and descriptive manner. Such information should contain:

.21 a short description of the target concerned;

.22 azimuth from the target in terms of the 12-hour clock;

.23 distance from the target;

.24 general direction in which the target is proceeding;

.25 other information known or recognisable.

541.3 Avoiding action may be suggested to a pilot. In this connection, the right-of-way rules shall be observed.

Unmanned Aerial Vehicle (UAV)

The BMVI and the DFS have published provisions for operation of UAVs in German airspace which include prevention against airproxes and collisions with manned aircraft:

- NfL I 281 / 13
- NfL 1-437-15
- Kurzinformation des BMVI über die Nutzung von unbemannten Luftfahrtsystemen, 2014 (Brief information of the BMVI regarding the use of unmanned aircraft systems)

- Information der DFS zu Flugmodellen und Drohnen, 2015 (Information of the DFS regarding flying models and UVAs)

Currently EASA is preparing pan-European aeronautical requirements for the operation of UVAs ('Prototype' Commission Regulation on Unmanned Aircraft Operations, as at 22 August 2016). EASA founded a 'Drone Collision'-Task Force. On 4 October 2016 it published a Final Report assessing the possible risk of a collision between UVA and aircraft and possible effects on the airworthiness of aircraft.

1.2.6 Technical Tools for Collision Avoidance

Radar and Transponder

At present German air traffic control is based on secondary radar information and transponder signals. For collision avoidance the DFS centres are equipped with ground conflict warning systems (Short Term Conflict Alert, STCA). Based on the tracks generated from secondary radar data impending or existing conflict situations of two aircraft are determined. Warnings generated by the STCA are displayed visually and acoustically at the controllers' workstations.

Presently, primary radar equipment is rarely used in civil air traffic control. Flight target detection therefore needs transmission of a transponder signal.

Operation, Excerpt BEKLA Study, 2004:

The primary radar ("non cooperative") transmits radar beams and analyses the beams reflected by objects. Therefore (almost) all objects in the observation range are depicted. However, initially stationary objects such as mountains and houses are depicted as well. In order to suppress them the moving objects are filtered with the use of the doppler shift when the reflected signals arrive and only these objects are then depicted on the controllers' radar screens.

The second variant is the secondary radar (Secondary Surveillance Radar, SSR, "cooperative"). It is working in combination with the primary radar but actively transmits interrogations on a special interrogation frequency (1030 Mhz) into the observation volume. A transponder on board an aircraft can receive these interrogations. The transponder answers on a second frequency (1090 Mhz).

There are different transponder modes: Mode S is characterised by the fact that each transponder receives a world-wide unique 24-bit address. Therefore about 17 million *different addresses are possible. Another major benefit of the Modes S Technology is that the transponder address, the airplane's altitude and other data can be transmitted.*

Several manufacturers have developed transponders with ADS-B transmission, which are suitable for battery-powered gliders due to their low weight and power requirements.

Airborne Collision Avoidance System (ACAS)

Since 2005, turbine-powered airplanes with more than 19 seats or with a maximum permissible take-off mass of more than 5,700 Kilogram have to be equipped with an Airborne Collision Avoidance System (ACAS).

Operation, Excerpt BEKLA Study, 2004:

The basic principle of ACAS is that the system tracks neighbouring airplanes equipped with secondary radar transponders. It is therefore also a so-called cooperative system. The transponders are interrogated approximately every second and the runtime between interrogation and answer results in the slant range and the content of the answer in the barometric altitude of the interrogated airplane. The system estimates the development of the situation and advises the pilot accordingly with a Traffic Advisory (TA) or a Resolution Advisory (RA).

Traffic Alert and Collision Avoidance System (TCAS)

The US System TCAS is currently the only Airborne Collision Avoidance System on the market.

There are a number of TCAS revisions:

TCAS I: This tool issues traffic information which is supposed to help the pilot with the visual detection of the traffic. Its range is approximately 6 NM.

TCAS II: Contrary to TCAS I, this system does not only issue traffic information but also vertical avoidance recommendation. If both aircraft are equipped with TCAS, the avoidance recommendation is coordinated through the unique Mode S transponder address.

TCAS III: In addition, horizontal avoidance recommendations are issued. A Mode S transponder is also required.

Research conducted by the Lincoln Laboratory during traffic alert and collision avoidance system (TCAS) flight testing showed that a pilot alerted to the presence of *other aircraft visually acquired the other aircraft in 57 of 66 cases; the median range of visual acquisition was 1.4 nautical miles (nm). In cases where the pilot was not alerted to the presence of the other aircraft, visual acquisition of the other aircraft was achieved in only 36 of 64 encounters; in the successful encounters, the median acquisition range dropped to 0.99 nm. These studies showed that verbal guidance as to where to look increased the acquisition probability for the pilots and found that a pilot who had been alerted to the presence of another aircraft was eight times more likely to see the aircraft than was a pilot who had not been alerted.*

Automatic Dependent Surveillance - Broadcast (ADS-B)

Automatic Dependent Surveillance - Broadcast (ADS-B) is a cooperative system. Each aircraft involved transmits digital GPS based data every half second on 1,090 MHz. This data can be received by respective ground stations (e.g. ATC) but also by other aircraft involved. With respective display units in the cockpit, traffic information and avoidance manoeuvre recommendations, similar to TCAS, can be generated, among other things.

FreeFlight Systems: *With ADS-B, the Air Traffic Control (ATC) system becomes a giant wireless network where aircraft are the "clients" and ground stations are wireless access points. Each aircraft equipped with the required WAAS GPS and an ADS-B datalink radio that automatically shares its precise position with ATC and other aircraft, and "sees" nearby traffic via the network. The network also can share weather and other data with aircraft equipped with an optional ADS-B receiver.*

In several countries (e.g. America, Australia, Canada, Europe) the next generation of traffic information and control is based on ADS-B technology.

FLARM

Since 2004 FLARM collision avoidance systems have been on the market. Originally, they were developed for gliders. But nowadays, they are also used in other areas of the general aviation. According to the manufacturer more than 25,000 FLARM units are currently in use world-wide.

FLARM is based on the cooperative exchange of digital data via radio, similar to ADS-B. FLARM units determine their own position and generate a prediction as to the future flight path. This is broadcast via a digital encrypted radio channel. The frequency used is part of the public domain of the SRD and ISM band. FLARM units close to each other receive the data and compare their flight paths regarding dangerous airproxes. In case of mid-air collision risk, in both airplanes a warning is generated. In addition, FLARM can warn of obstacles. Newer FLARM units, which are based on PowerFLARM technology, contain optional ADS-B and transponder receiver (SSR) Mode C/S.

FLARM is not compatible with TCAS, i.e. aircraft equipped with FLARM transmission are not indicated on collision avoidance systems used in commercial aviation.

Traffic Indication and Warning Systems

Several avionics manufacturers offer traffic information and warning systems specifically for general aviation. These units are mostly able to receive transponder signals, ADS-B messages and FLARM information, as well as analyse and then indicate them on a display in the cockpit. They do not issue an avoidance recommendation such as e.g. TCAS II does.

Colour Markings

The term colour markings indicates markings, which are applied to aircraft either permanently (e.g. paint) or temporarily (e.g. adhesive film). Usually these are areas contrasting with the colour of the aircraft to heighten contrast.

Striking colour pattern on a powered glider Photo: A. Schleicher Flugzeugbau

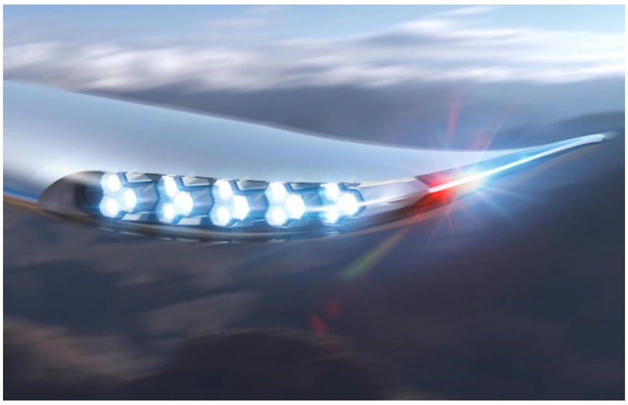
According to NfL-II 26/83 and NfL-II 64/88, *instead of all-round anti-collision lights, colour markings can be applied to the upper and bottom side of the wing tips, the fuselage nose and on both sides of the upper end of the vertical tail of airplanes whose maximum mass does not exceed 600 kg, or which do not have an aircraft electrical system, or a power system sufficient to operate a warning system in uninterrupted service, or to powered gliders and gliders. [...] A colour pattern is to be chosen which allows for optimal visibility under consideration of the colour of the* *aircraft. [...] Gliders with a white to light yellow colour and which are only used between sun rise and sun set, the colour marking is optional. […]*

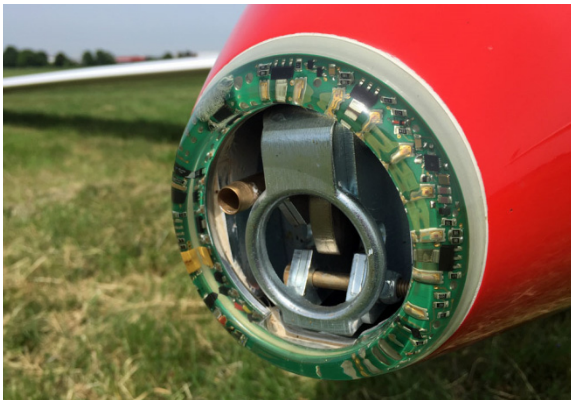
In August 2000, Cranfield University, Centre for Aeronautics, England, conducted an investigation of the effect of colour adhesive film on aircraft surfaces. But proof of any significant effects could not be determined. In 2002 tests with reflective foil initially on wings, then on aileron and rudder of powered gliders were conducted. Reflective foil on fixed aircraft parts (wings) showed no significant changes, as was the case with the earlier tests. When the reflective foil was put on moveable parts of the aircraft (like control surfaces) the powered glider could be recognised much earlier.

Anti-Collision Lighting System

Certification Specification (CS) 23 for powered aircraft determines the requirements for anti-collision lighting in CS 23.1401 Anti-collision light system.

Certification Specification CS 22 for gliders and powered gliders stipulates in CS 22.1385 External lights: *If external lights are to be installed they must be approved.* There is no general requirement to install anti-collision warning lights. According to NfL-II 26/83 and NfL-II 64/88 gliders and powered gliders do not need anti-collision warning lights for flights between sun rise and sun set. Nonetheless, some manufacturers equip their gliders with energy-efficient LED anti-collision lights.





LED technology on aircraft Source: Cirrus, DG Flugzeugbau

1.2.7 Flight Safety Information of FUS and BFU

Due to the decade-old problem FUS, and after 1998, the BFU have issued various Flight Safety Information publications:

1983	V 18	Zusammenstöße bei Sichtflügen (Mid-air collision during VFR flights)
1986	V 54	Zusammenstoß Segelflugzeug – Hängegleiter (Mid-air collision glider - hang glider)
1995	V 129	Richtige Positionsangaben (Correct position information)
1995	V 136	Zusammenstöße von Segelflugzeugen (Mid-air collision of gliders)
1995	V 138	Verantwortlichkeiten bei VFR-Flügen in Kontrollzonen (Responsibilities during VFR flights in control zones)
2000	V 158	Vermeidung von Zusammenstößen bei Flügen nach Sichtflugregeln (Avoidance of mid-air collisions during VFR flights)
2006	V 167	IFR/VFR - konfliktfreies Miteinander im Luftraum E (IFR/VFR - conflict-free cooperation in Airspace E)
2011	V 176	IFR/VFR-Flugverkehr im Luftraum E, verständnisvolles Miteinander (IFR/VFR air traffic in Airspace E, appreciative cooperation)

1.2.8 Flight Safety Information of the LBA

The LBA has issued the following Flight Safety Information publications:

1976	fsm 4/76	Einschalten des Landescheinwerfers, Minderung von Zusammenstoß- und Vogelschlaggefahr (Use of landing lights, reduction of collision risk and bird strikes)
1994	fsm 1/94	„Sehen und Vermeiden“, das Erkennen von Zusammenstoßgefahren im Sichtflug (See and Avoid, the recognition of collision risks during VFR flights)

1.3 Reporting and Investigation of Occurrences.

ICAO Annex 13, Regulation (EU) No 996/2010, the Law Relating to the Investigation into Accidents and Incidents Associated with the Operation of Civil Aircraft (FlUUG), and the Air Traffic Order (Luftverkehrs-Ordnung, LuftVO) make stipulations regarding the assignment of the German Federal Bureau of Aircraft Accident Investigation (BFU) to investigate accidents, serious incidents and incidents.

1.3.1 Requirements for Reports and Classification of Incidents

Paragraph 7 LuftVO (formerly paragraph 5 LuftVO) stipulates that pilots in command, crew members, or the operator of an aircraft have to inform the German Federal Bureau of Aircraft Accident Investigation immediately about accidents and serious incidents, e.g. near misses and airproxes (refer to Appendix FIUUG or Regulation (EU) No 996/2010: List of examples of serious incidents: *a near collision requiring an avoidance manoeuvre to avoid a collision or an unsafe situation or when an avoidance action would have been appropriate […]*).

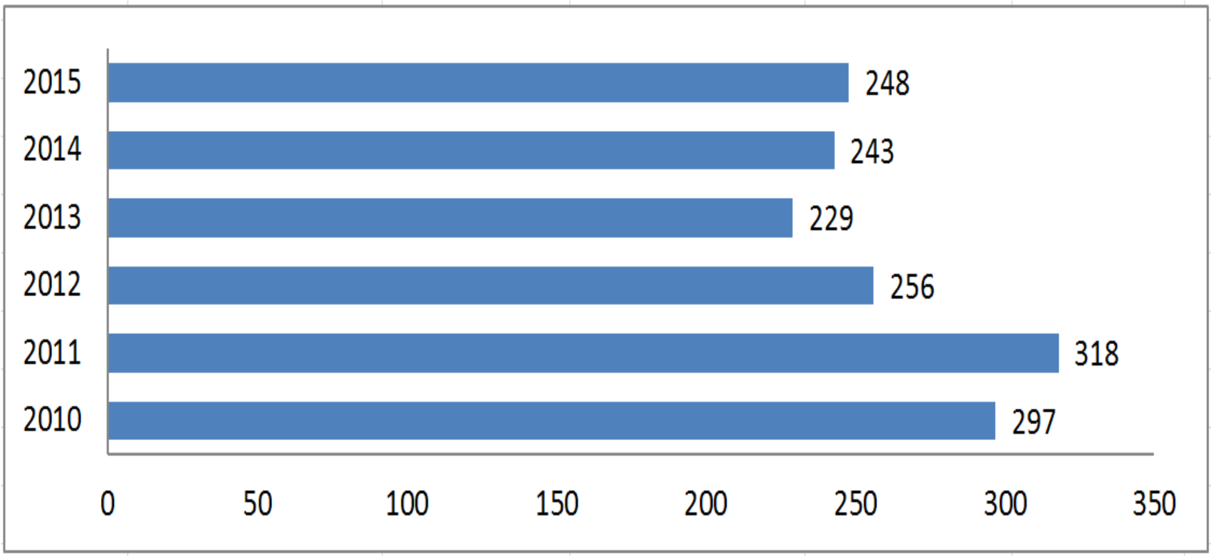
Definitions in accordance with Manual of Operations Air Traffic Services (MO-ATS):

Infringement of separation: Converging of aircraft in space and time which constitutes a violation of a given set of separation minima.

Aircraft Proximity: A situation in which, in the opinion of a pilot or air traffic services personnel, the distance between aircraft as well as their relative positions and speed have been such that the safety of the aircraft involved may have been compromised.[...]

Air traffic control service providers separate aircraft by means of radar, vertical, or conventional separation procedures. The MO-ATS lists the respective stipulated minima.

The Federal Supervisory Authority for Air Navigation Services (BAF) stated that between 2010 and 2015 a total of 1,591 separation infringements were registered:



Number of separation infringements reported to the BAF Graph: BFU

Separation infringements and airproxes always pose a potential safety risk, but are not always considered to be a serious incident or accident as defined by the Law Relating to the Investigation into Accidents and Incidents Associated with the Operation of Civil Aircraft (FlUUG) or Regulation (EU) No 996/2010. The definition of an accident is very clear. There is, however, a certain margin of discretion for the classification of a serious incident.

A serious incident according to the FlUUG is an occurrence with the operation of an aircraft involving circumstances indicating that an accident nearly occurred. There is an appendix to the law containing some examples of serious incidents to help with the application of the definition. Among others, near misses and airproxes are listed.

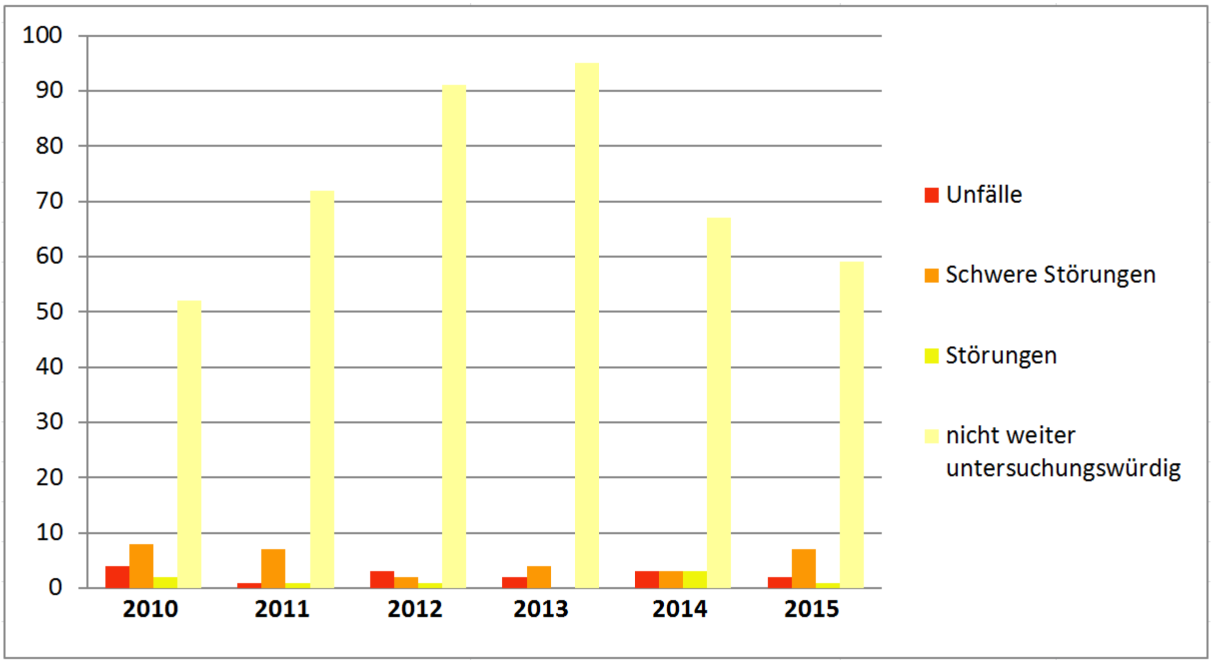
Based on this aeronautical background, ATC occurrences are investigated by the BFU if they meet the definition for either an accident or a serious incident. Investigations by the ATC provider as part of their quality assurance, and by supervision authorities (e.g. the BAF), or through other bodies (e.g. APEG), remain unaffected.

1.3.2 Reported Aiproxes and Collisions between 2010 and 2015

Between 2010 and 2015 the BFU received a total of 490 reports regarding airproxes, near misses, mid-air collisions, separation infringements, TCAS events, and collisions.

According to the classification of the BFU there were: 15 accidents, 31 serious incidents, 8 incidents, and 436 occurrences classified as “not worthy to be investigated further”.

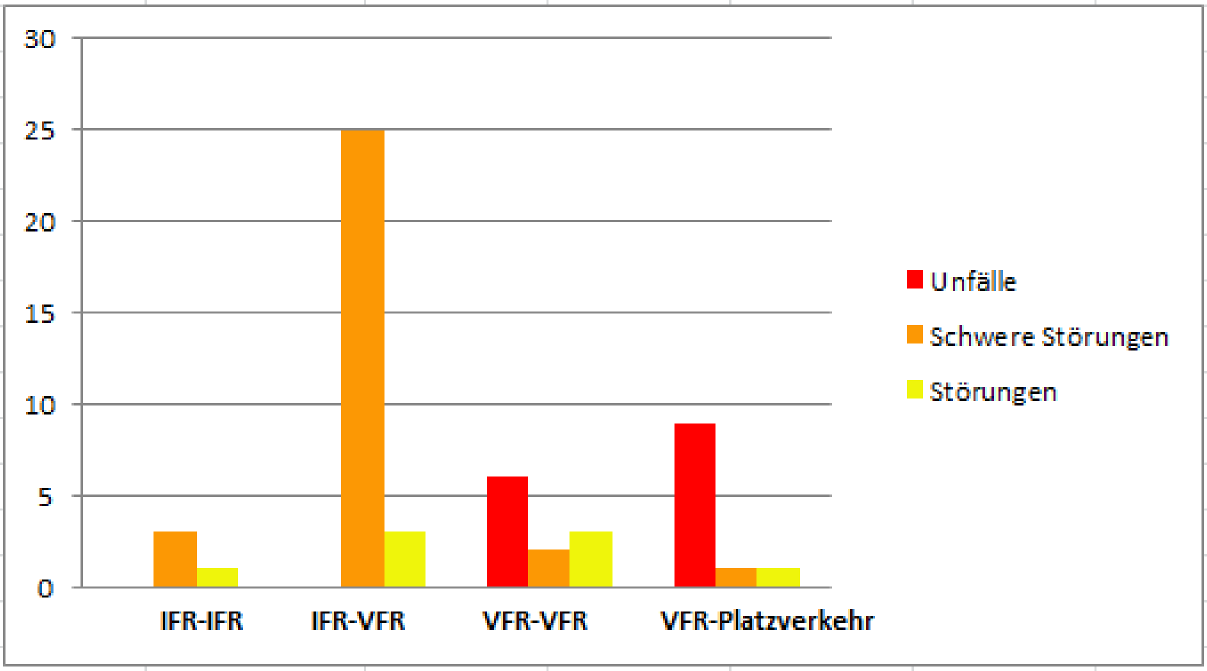
In the accidents a total of 19 persons were fatally injured, 2 persons were severely injured and 15 suffered minor injuries.



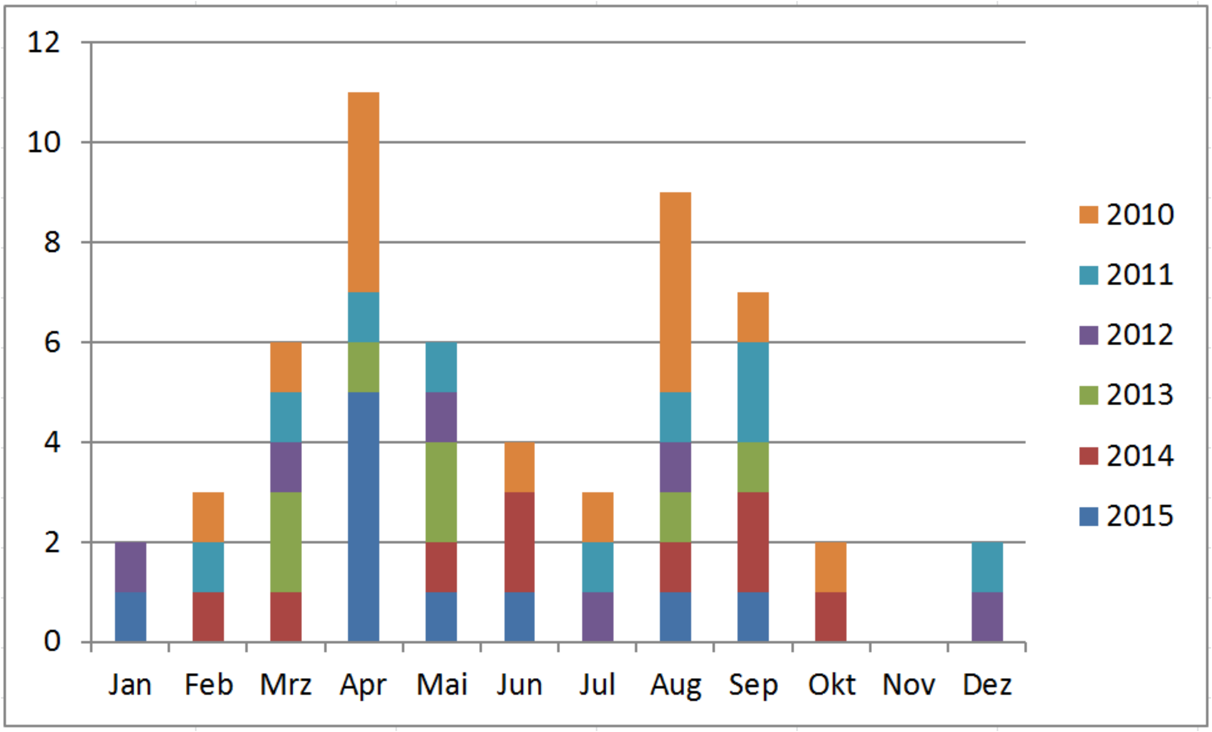
Distribution of the reported occurrences Graph: BFU

The reported occurrences could be divided into airproxes and collisions of aircraft which were in a VFR traffic pattern or operated in one of the following operating modes: IFR-IFR, IFR-VFR, VFR-VFR.

In 2015 the BFU received seven reports regarding airproxes involving an aircraft and an UAV.



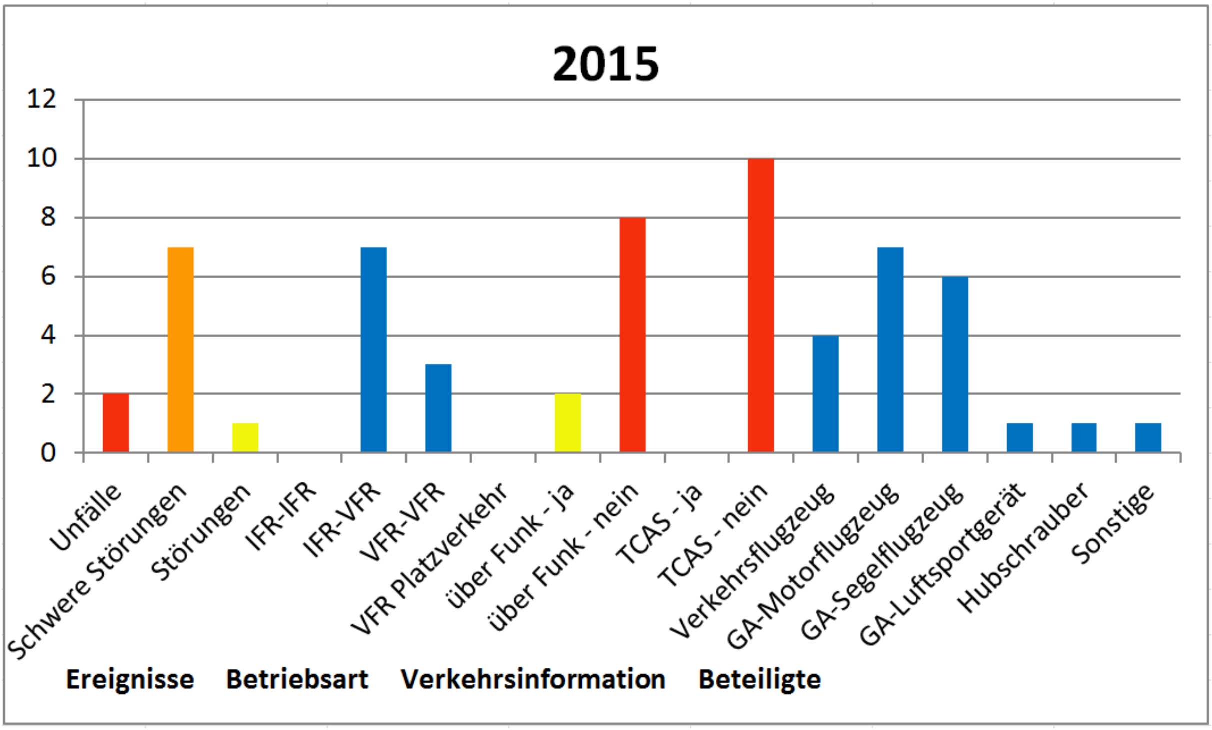
Occurrences between 2010 - 2015 sorted by operating mode Graph: BFU



Occurrences between 2010 - 2015 sorted by month Graph: BFU

1.3.2.1 Summary of the occurrences between 2010 and 2015

The accidents, serious incidents, and incidents of 2010 to 2015 are described by means of the summaries entered into the European Coordination Centre for Accident and Incident Reporting System (ECCAIRS) database.



Accidents (2):

- Near Sandstedt a collision occurred involving a Cessna 172 R and a Piper PA 28. The Cessna crashed. The Piper was able to perform an emergency landing.
- During aerotow near Kaiserslautern a collision occurred involving a Socata MS 963 and a glider Rolladen Schneider LS 4.

Serious Incidents (7):

- During approach to Stuttgart Airport an airprox occurred involving an Airbus A319 and a glider. The Airbus crew stated that the closest distance to the glider was 0.5 Nautical Miles (NM).

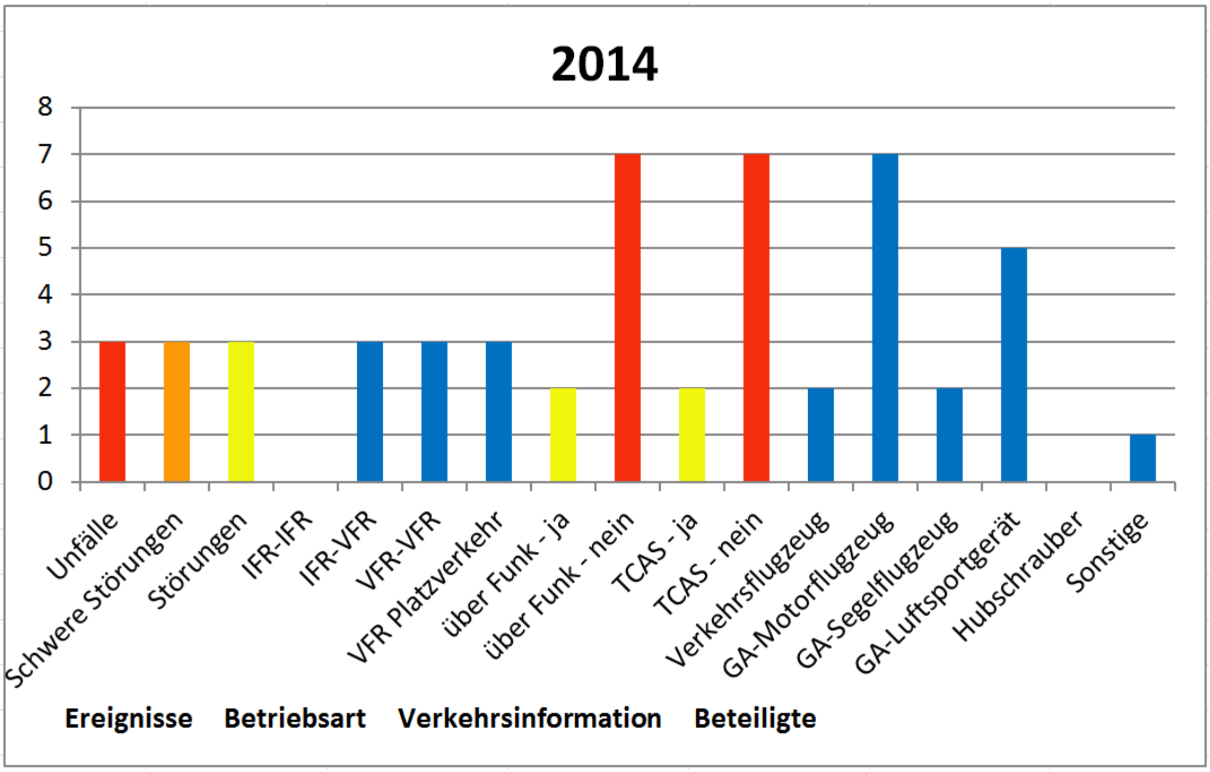
- During an IFR training flight near Bergheim in Airspace E an airprox occurred involving a Cessna 172 RG and an unknown glider. The Cessna crew stated the closest distance had been approximately 40 - 60 Meter.
- A Boeing B737-800 was on a scheduled flight from Antalya, Turkey, to Nuremberg, Germany. During descent to Nuremberg Airport an airprox occurred in Airspace E involving an unidentified glider. The Boeing crew stated that the distance was approximately 100 to 150 m horizontally and 150 to 200 ft vertically.
- In the departure area of runway 14 at Westerland Airport (Airspace E) an airprox occurred involving a Piper PA 46 and a Piper PA 34. The PA 46 was flying in accordance with VFR and the PA 34 in accordance with IFR. The closest distance was 0.246 NM horizontally and 100 ft vertically.
- During approach to Paderborn Airport (Airspace E) an airprox occurred in 5,000 ft AMSL involving a Falcon 2000 and an unknown glider. The Falcon 2000 crew estimated the lateral distance was approximately 500 m in the same altitude.
- During the approach to Memmingen Airport an airprox occurred involving an Airbus A320 and a glider. The Airbus had been flying in accordance with IFR. The A320 crew initiated an avoidance manoeuvre. According to the radar data the closest lateral distance was 0.247 NM.
- In Airspace C two airproxes occurred one right after the other involving a Piper PA28 and an ultralight Ikarus C42. During the first airprox, the closest distance between the two aircraft was 0,153 NM horizontally and 300 ft vertically. During the second, the closest distance was 0.414 NM at the same altitude.

Incidents (1):

- During an ambulance flight near Löchgau an unidentified model aircraft passed the Eurocopter EC135 helicopter very close.

Occurrences classified as “not worthy to be investigated further”:

- There were 59 reports concerning other airproxes.



Accidents (3):

- During the landing approach to Münster-Telgte a D4 Fascination collided with the towline of an approaching TL 96 Sting. The D4 Fascination entered an uncontrolled flight attitude, crashed to the ground, and caught fire.
- In the approach sector of Koblenz-Winningen Airport a mid-air collision occurred involving a glider Schleicher Ka8B and a ultralight Z 602 XL. The recovery system of the ultralight was triggered and both aircraft became wedged together and floated to the ground.
- During aerial target demonstrations near Olsberg-Elpe a collision occurred involving a civil Learjet 35 A and a Eurofighter. The Learjet crashed and the severely damaged Eurofighter landed at the military air base Nörvenich.

Serious Incidents (3):

- An airprox occurred in the control zone of Ingolstadt-Manching Military Airbase involving a Socata TB20 and a Scheibe SF 25C. The Socata flew in accordance with IFR and the Scheibe with VFR. According to the radar recordings, the closest lateral distance was approximately 0.09 NM. According to witnesses the closest vertical distance was approximately 10 ft.

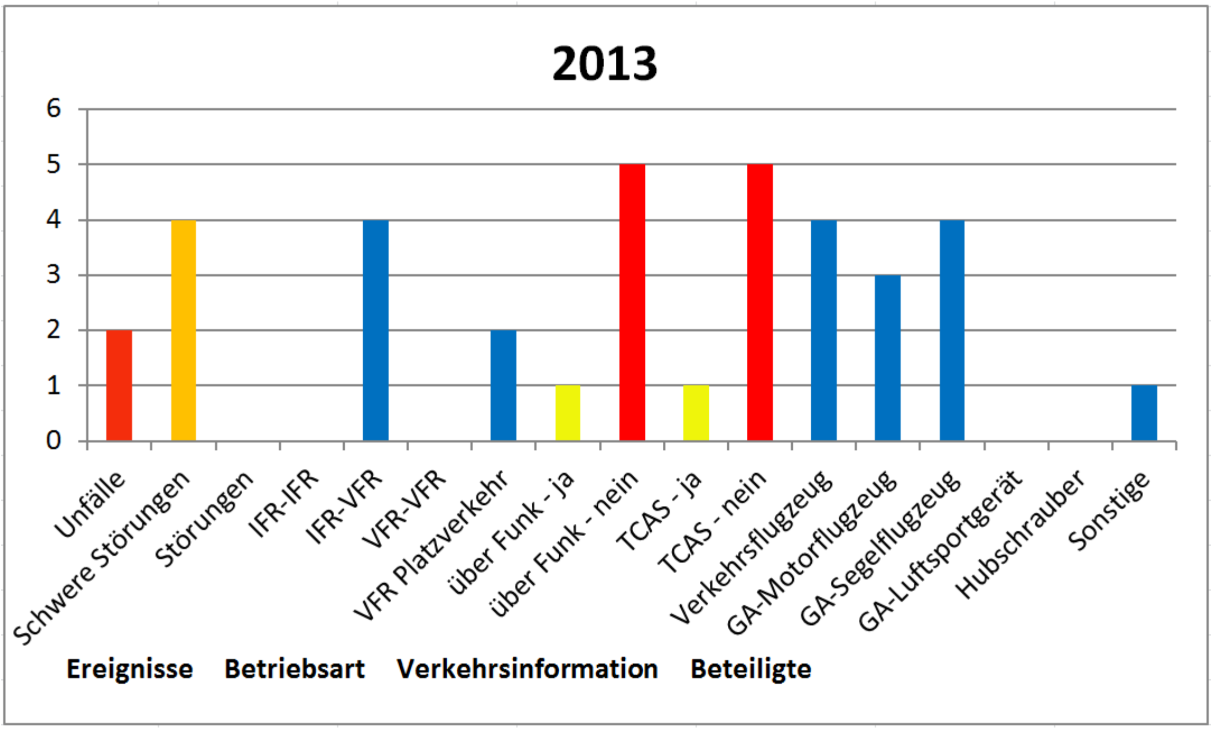
- The pilot of an Autogyro Cavalon gyrocopter stated that a descending Piper PA 28R had overflown his gyrocopter, as he had been in the downwind leg of runway 16 of Speyer Airport. He said the Piper had been about 15 m above him. Approximately 50 m ahead of him the Piper had already been below his altitude. The Piper flight crew stated they had not noticed overflying the gyrocopter. Both aircraft later landed safely on runway 16.
- An airprox occurred in the control zone of Nuremberg Airport (D(CTR)) involving an AVRO RJ100 and a FK9. The AVRO was flying in accordance with IFR and the FK9 with VFR. The closest distance was approximately 0.07 NM horizontally and about 200 ft vertically.

Incidents (3):

- A powered aircraft Mooney M20J crossed the flight path of a glider G103 Twin Astir winch launching at Schwarzheide-Schipkau Airfield. The glider pilot stated the closest distance had been approximately 20 - 30 m. The powered aircraft had approached very fast and unexpectedly from the south. According to the radar recording and the statement of the pilot the airport had been overflown in approximately 1,700 ft AMSL; airport elevation had been about 270 ft AMSL. During the overflight the glider pilot and the Flugleiter of the airport noticed the powered airplane which continued on its way without any noticeable reaction of the pilot. The pilot of the powered aircraft stated he had not noticed the glider. The wife of the pilot was in the right-hand seat of the powered airplane. She had advised him about a glider taking off while they were flying over, and which she had noticed in her 2 - 3 o'clock position closely below them, before it disappeared from her field of vision below the right wing.
- During climb the pilot of a transport aircraft reduced the rate of climb in accordance with the TCAS RA in order to avoid an airplane flying according to VFR.
- In the traffic pattern of Essen Mühlheim Airport an airprox occurred involving a Cessna 152 R and a Socata TB 20.

Occurrences classified as "not worthy to be investigated further":

- There were 76 reports concerning other airproxes.



Accidents (2):

- At Eschwege-Stauffenbühl Airfield a glider ASK 13 collided with the towrope of another glider, which had just taken off in the opposite direction on a launch winch, and crashed to the ground.
- At Kempten Durach Airfield a collision involving a Cessna F172 and a Diamond DV 20 occurred in the area of the base leg turn of the traffic pattern. The Cessna F172 approached from the downwind leg and entered the base leg with a left-hand turn. The DV 20 entered the traffic pattern in the area of the base leg turn. After the DV 20 had flown an avoidance manoeuvre to the right, the collision with the Cessna F172 occurred. The Cessna crashed to the ground and the Pilot of the DV 20 was able to land his aircraft.

Serious Incidents (4):

- During the approach to runway 24 of Dortmund Airport an airprox involving an Airbus A320 and a glider occurred in Airspace D(HX) in an altitude of 2,500 ft AMSL. The Airbus crew stated that the glider had been at the same height and 100 m to 150 m left of their flight path.
- During the initial approach to Zurich-Kloten Airport an airprox involving an Avro RJ 100 and a paraglider occurred in Airspace C in 6,800 ft. The RJ 100 crew

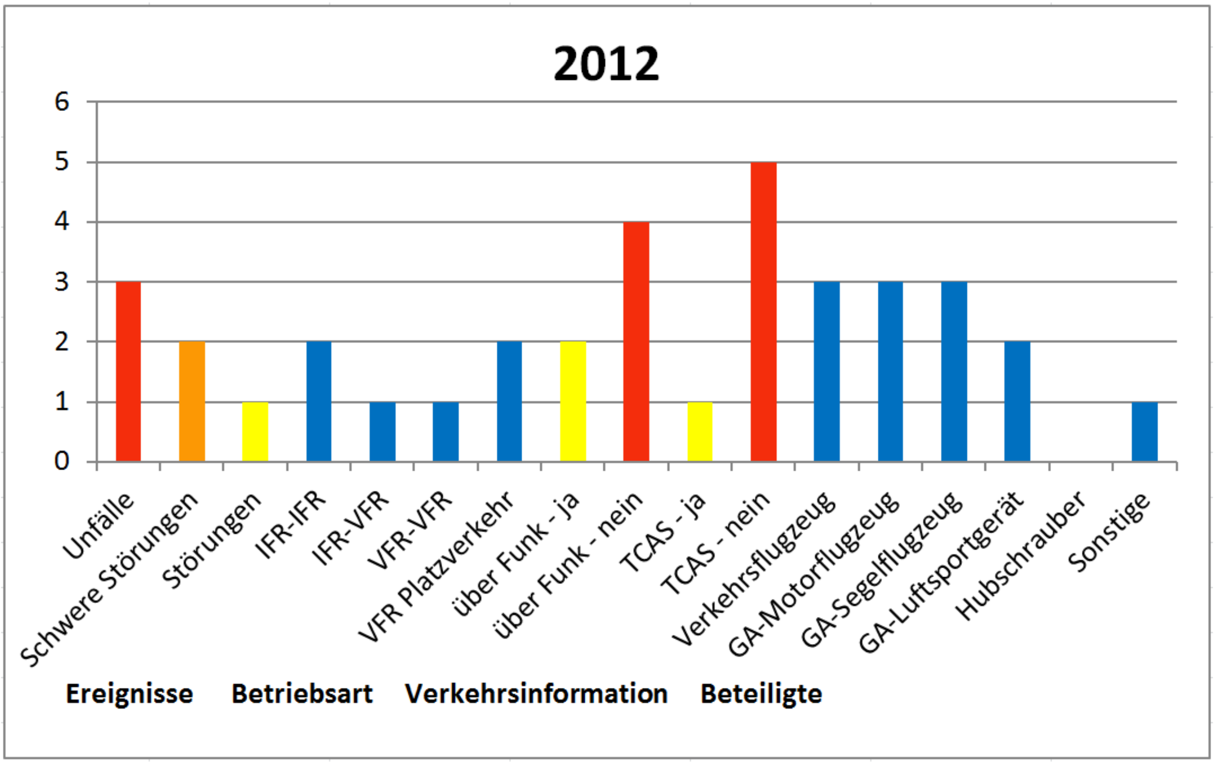
stated that the closest distance had been approximately 50 m to 100 m horizontally and 50 ft to 100 ft vertically.

- In Airspace E approximately 10 NM east of the Regional Airport Frankfurt-Hahn an airprox occurred involving a Boeing B737 flying in accordance with IFR and an unknown glider. According to the radar data the closest lateral distance was 0.1 NM. The Boeing B737 crew stated the altitude difference had been approximately 100 ft.
- Approximately 15 NM west of Mannheim an airprox occurred involivng an Embraer EMB-505 and a Cessna 177 RG. The EMB-505 flew in accordance with IFR and the Cessna with VFR. The closest distance was 0.1 NM horizontally and 300 ft vertically.

Incidents: None

Occurrences classified as “not worthy to be investigated further”:

- There were 101 reports concerning other airproxes.



Accidents (3):

- The Piper PA32 was on a private flight from Stadtlohn to Aschaffenburg. During cruise flight the airplane collided with a Robin DR 400-180 which was on a private flight from Koblenz to Reichelsheim. The aircraft crashed on a field.
- At the beginning of the runway in use of Waldeck Mühlberg Glider Airfield a collision occurred involving a landing glider PZL SZD 51 Junior and a MTOsport gyrocopter on take-off.
- Near Melle-Grönegau Airfield a collision occurred involving a glider Schempp-Hirth Discus bT and an ultralight Tecnam P 92. The glider had been in descent and the ultralight had taken off a short time before. The glider pilot left the aircraft with the emergency parachute. The ultralight landed at the aerodrome of departure.

Serious Incidents (2):

- A Diamond DA 40 was in climb from Neubrandenburg Airport to a flight in accordance with IFR, when an airprox occurred involving a military aircraft

Panavia 200 (Tornado). The Tornado also flew in accordance with IFR. The closest distance was 0.7 NM horizontally and 400 ft vertically.

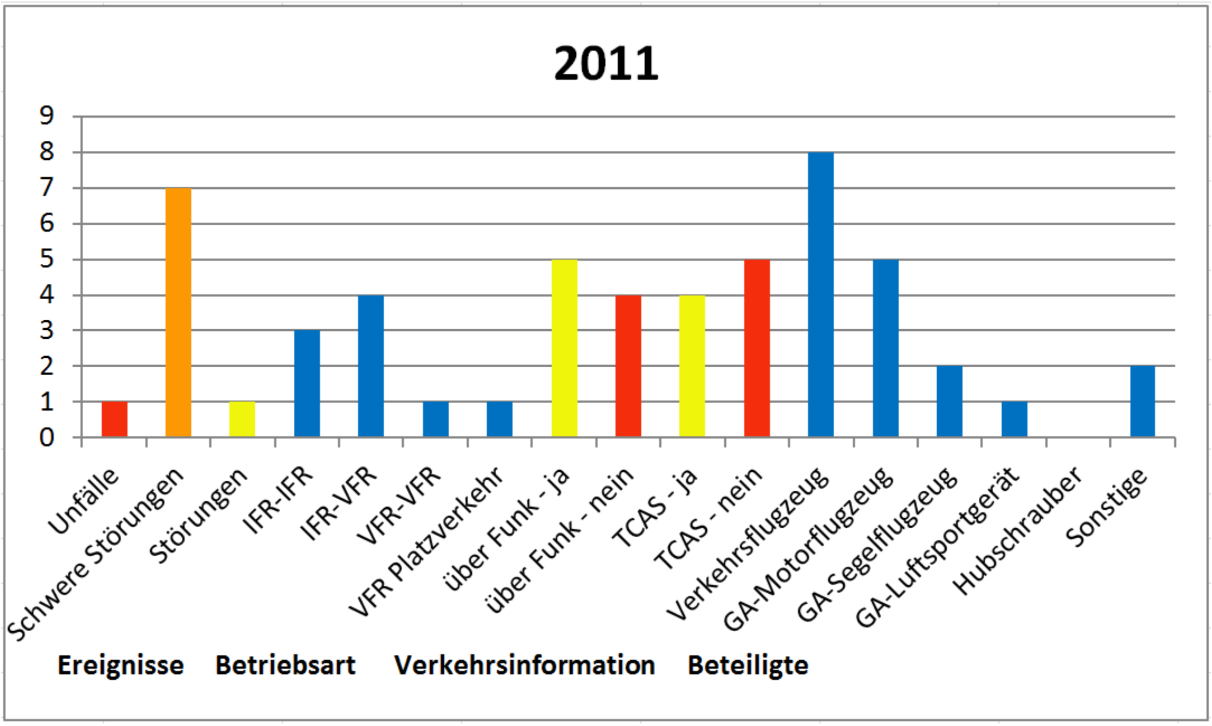
- An airprox occurred involving an Airbus A319 in climb and an ATR 42 in horizontal flight. The closest distance was 1.9 NM horizontally and 200 ft vertically.

Incidents (1):

- An airprox occurred involving an Airbus A340, on approach to runway 14 of Zurich Airport, and a glider. The Airbus had been flying in accordance with instrument flight rules. The A340 crew initiated an avoidance manoeuvre.

Occurrences classified as “not worthy to be investigated further”:

- There were 97 reports concerning other airproxes.



Accidents (1):

- During winch launching at Saarmund Airfield a collision occurred above the airport involving a glider G 102 Astir 77 CS and an ultralight Remos GX.

Serious Incidents (7):

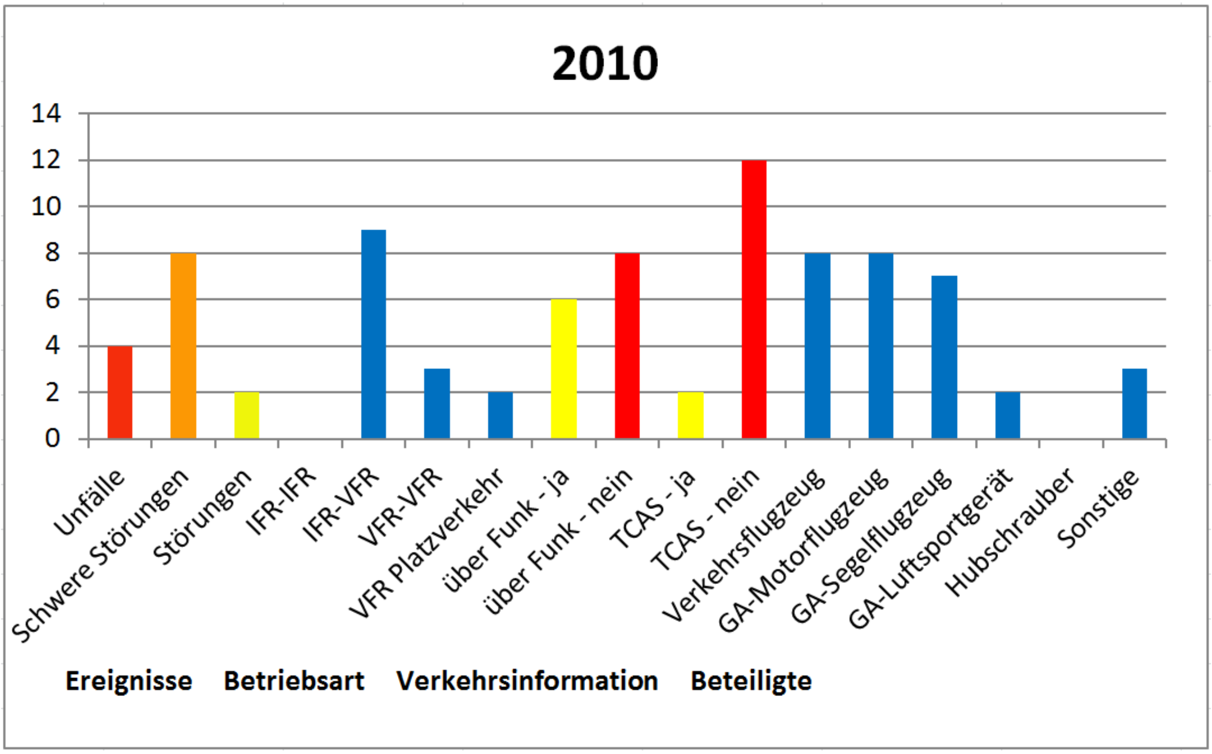
- An Airbus A320-214 taking-off from runway 25C of Frankfurt/Main Airport suffered an airprox with an Airbus A380-800 which had aborted the landing on runway 25L and conducted a missed approach procedure. According to the radar data the closest proximity was 0.97 NM horizontally and approximately 200 ft vertically. The separation minima were 7 NM horizontally and 1,000 ft vertically.
- Near Donzdorf a glider Schempp-Hirth Duo Discus collided with a paraglider Gradient Avax II during thermal soaring in the same area.
- A Cessna 172 flying in accordance with IFR and in holding procedure of Augsburg Airport and a Mooney M20R flying in accordance with VFR passed each other in approximately 0.09 NM in almost the same altitude. The airprox occurred in Airspace E.
- Near Frankfurt/Main the flight crew of a British Aerospace 146-200 reported an airprox with an unidentified cylindrical flying object in the same altitude. They estimated the lateral distance with 50 m to 100 m. The object had had a length of 15 m to 20 m and a diameter of 1 m to 2 m.
- During the descent to the final approach fix for the instrument approach procedure of runway 24 of Dortmund Airport an airprox occurred in Airspace E involving an Airbus A320-200 and a Cessna 525A. The closest distance was 0.2 NM horizontally and 400 ft vertically.
- The Piper PA-46-500 TP was in climb after taking off from Main-Finthen Airfield and on the frequency of Langen Radar. A Cirrus SR-20 was crossing the Piper. It was in radio contact with Langen Information. The two aircraft passed each other in the same altitude and with a distance of 0.06 NM.
- Near Frankfurt/Main an Antonov AN-124 flew in FL330 in westerly direction. An Airbus A380 flew in FL320 in the opposite direction and was followed by a Boeing B747-400 by about 20 NM. One minute after the AN-124 had been passed by the A380, it dropped by 200 ft within 15 seconds, and then climbed again by 700 ft during the subsequent 15 seconds. Then an airprox with the B747-400 occurred. A RA "ADJUST VERTICAL SPEED ADJUST” was generated by the TCAS of the AN-124. All three flights were continued as scheduled.

Incidents (1):

- As a MD-11 was on approach to land on runway 25C of Frankfurt/Main Airport, a Boeing B777 was on take-off run. The MD-11 crew decided to go-around. During the go-around procedure an airprox occurred involving the two airplanes. The closest distance was 1,700 m.

Occurrences classified as “not worthy to be investigated further”:

- There were 81 reports concerning other airproxes.



Accidents (4):

- Near Warngau two airplanes (Extra EA300L und XtremeAir XP-30) conducting formation aerobatic flight collided.
- At Winzeln-Schramberg Airfield a Cessna F152 on approach and a glider DG 300 collided in approximately 100 m. Both aircraft could be landed safely.
- During landing roll at Schweinfurt Airfield a glider ASK 13 collided with another glider (Ka6CR) which had landed before.

- Near Utscheid two gliders (ASK 18 and G 103 Twin Astir) collided during thermal soaring.

Serious Incidents (8):

- During approach via radar vectors to Lubeck-Blankensee an airprox occurred involving an Airbus A320-233 and an aerotow, consisting of a Grob G 109 B and an ASG 27-18E. The Airbus had been flying in accordance with IFR and the aerotow with VFR. The closest distance was 0.02 NM horizontally and 400 ft vertically.
- An airprox occurred involving a Boeing B737-800 on approach to Frankfurt-Hahn Regional Airport and two gliders Schleicher ASW 20L. The closest distance was 0.17 NM horizontally and 509 ft vertically.
- An airprox occurred involving a Boeing B737-800 on approach to Bremen Airport and an unidentified glider. The closest distance was 0.36 NM horizontally. The B737 crew stated that the closest vertical distance had been approximately 200 ft.
- Near Eisenach an airprox occurred involving a Cirrus SR 22 in cruise flight in accordance with IFR and a Mitsubishi MU2 in climb out flying in accordance with VFR. The closest distance was 0.28 NM horizontally and 100 ft vertically.
- During air-to-air refuelling an airprox occurred involving the two aircraft. The Flight Data Recorder (FDR) was read out at the BFU.
- An Airbus A320 was on final approach to runway 08R of Munich Airport, when an airprox occurred with a Cessna 177R flying in accordance with VFR. The closest distance was 0.2 NM horizontally and 400 ft vertically.
- A Boeing B737-500 turned into the final approach to runway 07 of Stuttgart Airport and then an airprox occurred with a Comco Ikarus C42. The closest distance was 1.0 NM horizontally and 300 ft vertically.
- Near Friedrichshafen in Airspace E an airprox occurred involving a Bombadier DHC8 transport aircraft and an unidentified General Aviation aircraft.

Incidents (2):

- The Bombadier DHC8 was in descent to the instrument landing approach to runway 24 of Friedrichsfafen Airport. An airprox occurred involving the

Bombadier and an ultralight Comco Ikarus C42 flying in accordance with VFR. The closest distance was 0.06 NM horizontally and 500 ft vertically.

- Near Lechfeld an airprox occurred in Airspace E involving a Boeing B737-800 and a formation of Torndaos which were refuelling air-to-air. The B737-800 crew followed the TCAS RA and descended by 700 ft. The closest lateral distance was 2.48 NM at the same altitude. The closest horizontal separation was 1.28 NM at an altitude difference of 600 ft. The flight crews had visual contact with each other.

Occurrences classified as “not worthy to be investigated further”:

- There were 66 reports concerning other airproxes.

1.3.2.2 Aircraft Equipment and Traffic Information

The BFU also investigated whether the radar had triggered a short term conflict alert (STCA), or if the airprox had been recognised either by the on-board equipment (transponder, TCAS, FLARM, etc.) or by air traffic control, and whether traffic information or warnings via radio, if applicable, had prevented a collision.

Occurrences IFR - IFR

All IFR operated aircraft involved in the four serious incidents and incidents were equipped with transponders and TCAS, except for one aircraft which only had a transponder. An all cases the air traffic controller had given traffic information.

Occurrences IFR - VFR

In the 25 Serious Incidents and 3 Incidents of aircraft, where one was operated in accordance with IFR and one with VFR, transponders and no TCAS were mostly only on board of one of the aircraft - except when transport aircraft were involved. In 12 cases the controller had given traffic information. In 10 cases gliders without transponder transmission, invisible for ATC and ACAS, were involved. In Airspace E a total of 18 airproxes occurred.

Flugphase	Ort	Flugregeln	Luftraum	Beteiligte Luftfahrzeuge	ATC-Info	TCAS TA/RA
	2015					
Anflug	Stuttgart	IFR-VFR	Luftraum C/E	Verkehrsflugzeug - Segelflugzeug	nein	nein
Ausbildung	Bergheim	IFR-VFR	Luftraum E	Motorflugzeug - Segelflugzeug	nein	nein
Anflug	Nürnberg	IFR-VFR	Luftraum E	Verkehrsflugzeug - Segelflugzeug	nein	nein
Abflug	Westerland	IFR-VFR	Luftraum E	Motorflugzeug - Motorflugzeug	ja	nein
Anflug	Paderborn	IFR-VFR	Luftraum E	Verkehrsflugzeug - Segelflugzeug	nein	nein
Anflug	Memmingen	IFR-VFR	Luftraum E	Verkehrsflugzeug - Segelflugzeug	nein	nein
Reiseflug	Bottrop	IFR-VFR	Luftraum C	Motorflugzeug - Ultraleichtflugzeug	ja	nein
	2014					
Anflug	Manching	IFR-VFR	Luftraum D	Motorflugzeug - Motorsegler	nein	nein
Steigflug	Memmingen	IFR-VFR	Luftraum E	Verkehrsflugzeug - Motorflugzeug	unbekannt	ja
Anflug	Nürnberg	IFR-VFR	Luftraum D	Verkehrsflugzeug - Ultraleichtflugzeug	ja	ja
	2013					
Anflug	Dortmund	IFR-VFR	Luftraum D	Verkehrsflugzeug - Segelflugzeug	nein	nein
Anflug	Zürich	IFR-VFR	Luftraum C	Verkehrsflugzeug - Gleitschirm	nein	nein
Anflug	Frankfurt-Hahn	IFR-VFR	Luftraum E	Verkehrsflugzeug - Segelflugzeug	nein	nein
Reiseflug	Mannheim	IFR-VFR	Luftraum C	Verkehrsflugzeug - Motorflugzeug	ja	nein
	2012					
Anflug	Zürich	IFR-VFR	Luftraum C	Verkehrsflugzeug - Segelflugzeug	nein	nein
	2011					
Anflug	Augsburg	IFR-VFR	Luftraum E	Motorflugzeug - Motorflugzeug	nein	nein
Anflug	Frankfurt Main	IFR-VFR	Luftraum C	Verkehrsflugzeug - unbekannt	nein	nein
Anflug	Dortmund	IFR-VFR	Luftraum E	Verkehrsflugzeug - Motorflugzeug	ja	ja
Abflug	Mainz-Finthen	IFR-VFR	Luftraum E	Motorflugzeug - Motorflugzeug	ja	nein
	2010					
Anflug	Lübeck	IFR-VFR	Luftraum E	Verkehrsflugzeug - Motorflugzeug	ja	ja
Anflug	Friedrichshafen	IFR-VFR	Luftraum E	Verkehrsflugzeug - Ultraleichtflugzeug	ja	ja
Anflug	Frankfurt-Hahn	IFR-VFR	Luftraum E	Verkehrsflugzeug - Segelflugzeug	nein	nein
Anflug	Bremen	IFR-VFR	Luftraum E	Verkehrsflugzeug - Segelflugzeug	ja	nein
Reiseflug	Eisenach	IFR-VFR	Luftraum E	Motorflugzeug - Motorflugzeug	ja	nein
Anflug	München	IFR-VFR	Luftraum C	Verkehrsflugzeug - Motorflugzeug	ja	ja
Anflug	Stuttgart	IFR-VFR	Luftraum C	Verkehrsflugzeug - Ultraleichtflugzeug	ja	ja
Anflug	Friedrichshafen	IFR-VFR	Luftraum E	Verkehrsflugzeug - Motorflugzeug	nein	nein
Reiseflug	Lechfeld	IFR-VFR	Luftraum E	Verkehrsflugzeug - Militärflugzeug	unbekannt	ja

Incidents and serious incidents IFR - VFR between 2010 and 2015 Source: BFU

Occurrences VFR - VFR

The six accidents, two serious incidents, and three incidents where VFR operated aircraft were involved showed that the aircraft were often equipped with transponders but not with collision warning systems. The aircraft were not in contact with an air traffic control unit. Therefore no traffic information via radio or on-board equipment was given.

Occurrences VFR Aerodrome Traffic

The nine accidents, one serious incident, and one incident where VFR operated aircraft were part of the aerodrome traffic showed that the aircraft were often equipped with transponders but not with collision warning systems. There was no suitable traffic information regarding the possible conflicting traffic.

1.4 Previous Actions and Recommendations

Airproxes and collisions of aircraft occur world-wide.

The European Aviation Safety Agency (EASA) stated that between 2006 and 2011 82 collisions occurred in Europe involving aircraft with a maximum take-off mass of less than 2,250 kg.

According to a study by the Bureau d'Enquêtes et d'Analyses (BEA) 17 collisions occurred in France between 1989 and 1999.

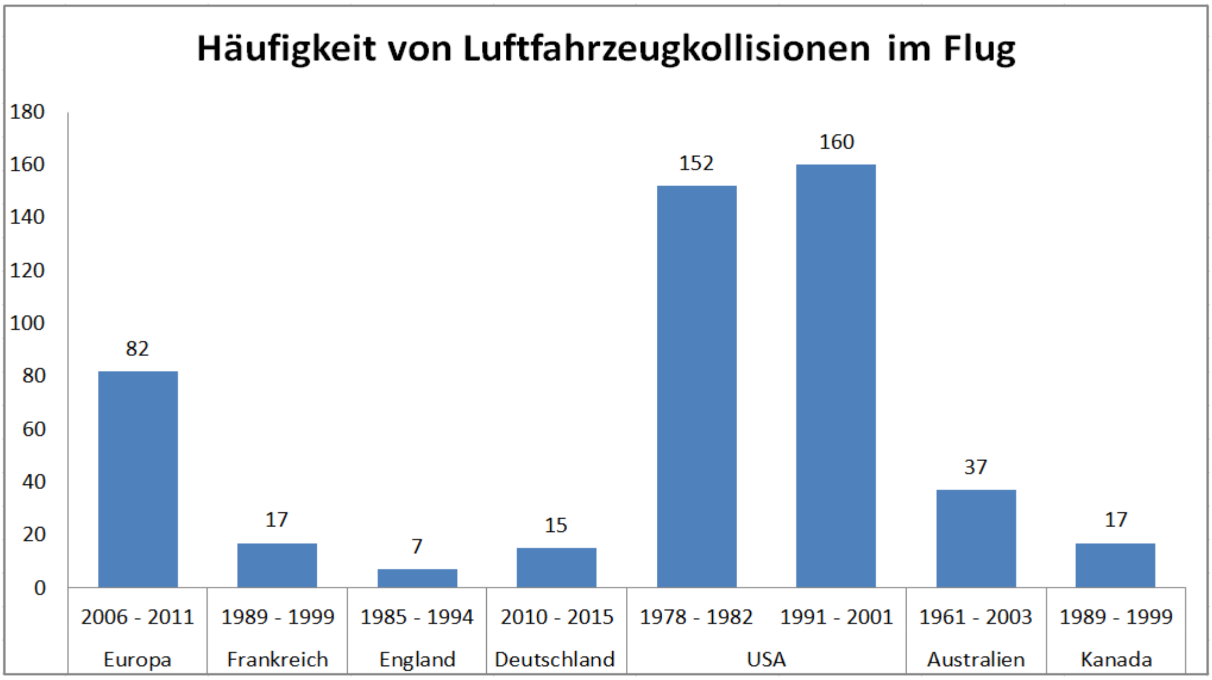
The British Civil Aviation Authority (CAA) considered all fatal accidents in General Aviation between 1985 and 1994 and determined that 7 aircraft collisions had occurred.

The Federal Aviation Administration (FAA) stated that between 1978 and 1982 152 collisions and between 1991 and 2000 an average of 16 collisions had occurred per year in the USA.

A study by the Australian Transport Safety Bureau (ATSB) came to the conclusion that between 1961 and 2003 37 General Aviation aircraft collisions had occurred in Australia.

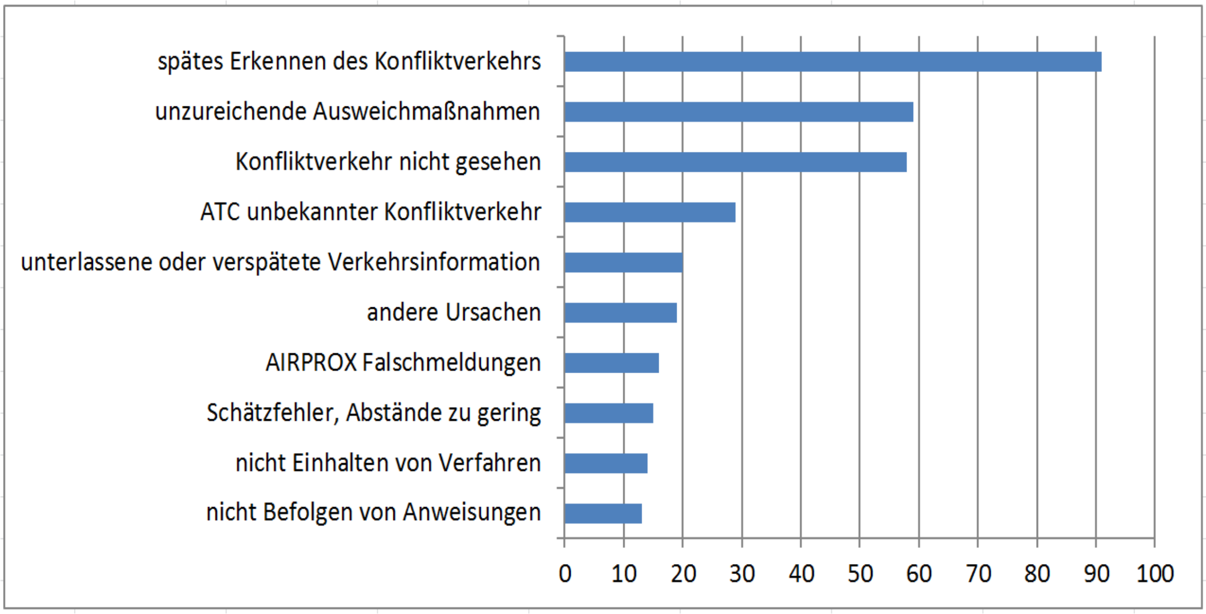
The Transportation Safety Board of Canada stated that between 1989 and 1999 17 collisions had occurred.

The larger part of these collisions had occurred at daylight during good visual meteorological conditions and also as part of aerodrome traffic operations.



Summary of world-wide in-flight collisions Graph: BFU

The British Airprox Board summarised the causes for airproxes in its annual report 2014 as follows:



Causes for in-flight airproxes Graph: AIRPROX Board / BFU

In addition to the corresponding accident investigations, several studies and information publications regarding visual flight, mixed traffic, and collision avoidance have been conducted and published, respectively. These documents included action recommendations for pilots and recommendations for aircraft equipment in regard to collision avoidance.

1.4.1 Studies and Publications to "See and Avoid"

- Pilots' Role In Collision Avoidance — FAA — 1983 / 2016
- Limitations of the See-and-Avoid Principle — ATSB — 1991
- Collision Avoidance Must Go Beyond "See and Avoid" to "Search and Detect" — Flight Safety Foundation — 1997
- Characteristics of U.S. Midairs — FAA — 2001
- MID-AIR Collisions, Safety Study — BEA — 2002
- TAGA - Traffic Awareness for General Aviation — DFS — 2000 – 2003
- BEKLAS - Erkennbarkeit von Segelflugzeugen und kleinen motorisierten Luftfahrzeugen — BMVBW — 2004
- Review of Midair Collisions Involving General Aviation Aircraft in Australia between 1961 and 2003 — ATSB — 2004
- The Detection and Recognition of Light Aircraft in the Current and Future ATM Environment — EUROCONTROL — 2005
- Collision Avoidance, Strategies and Tactics — AOPA — 2009
- Collision Avoidance, Methods to Reduce the Risk — EGAST — 2010
- Scoping Improvements to 'See And Avoid' for General Aviation (SISA) — EASA — 2011
- Vermeidung von Zusammenstößen — AOPA — 2012
- Collision Avoidance — CAA — 2013
- Die Grenzen des Wahrnehmungsvermögens – Effektivität von "see and avoid" zur Verhinderung von Zusammenstößen — BAZL — 2015
- VFR Pilot Info, Luftraum E — DFS — 2015
- Traffic Warnings – So, Who's Really Out There? — CAA — 2015

•	Collision Avoidance for Light Aircraft	EUROCONTROL	2015
•	IFR Pilot Info 01/2016, Luftraum E	DFS	2016
•	VFR Pilot Info 02/2016, Luftraum E	DFS	2016
•	VFR Pilot Info 'Luftraumstruktur' 2016	DFS	2016

1.4.2 Recommendations of the Studies and Publications

The results of the investigations, the studies, and information publications for pilots are very similar. Excerpts:

ATSB

Recommendation R20040015

The CAA should take into account the limitations of see-and-avoid when planning and managing airspace and should ensure that unalerted see-and-avoid is never the sole means of separation for aircraft providing scheduled services.

Recommendation R20040016

In light of the serious limitations of the see-and-avoid concept, the CAA should continue to closely monitor the implementation of TCAS in the US and should consider the system for Australia.

Recommendation R20040020

Pilots should recognise that they cannot rely entirely on vision to avoid collisions. Consequently, they should attempt to obtain all available traffic information, whether from Air Traffic Services or a listening watch, to enable them to conduct a directed traffic search.

EGAST Operational Techniques

Chapter headings with corresponding explanations: *Check Yourself, Plan Ahead, Clean Windows, Night Flying, Adhere to Procedures, Avoid Crowded Airspace, Compensate for Blind Spots, Equip to be Seen (Lights, Transponder, Colour), Talk and Listen, Traffic Detection Systems, Make use of all information, Use all available Eyes*

AOPA Tactics

Plan your flight, Equip yourself (Radio, Transponder), Educate your passengers, Communicate, Use sunglasses, Observe proper procedures, Improve your visibility, Scan traffic, Use aircraft lights

BAZL Recommendations for Visual Airspace Observation

Limit the amount of time in the cockpit where you keep your head down.

Ask your fellow traveller for help with the visual observation of the airspace.

Avoid being distracted by on-board gadgets (e.g. mobile phones, tablets, GPS hand sets, etc.).

Do not install additional equipment on the cockpit window so that the field of vision is not restricted.

Apply suitable methods for the visual observation of the airspace; e.g. EGAST..

Move your head so that the field of vision becomes larger and the airspace which is e.g. hidden by spectacle frames or cockpit struts becomes visible.

Train your eyes for spacial and clear vision (near and distance adaption).

Adherence to stipulated minima, distance to clouds, minimum flight altitude, and speeds.

Permanent standby, to adjust the flight path or fly an avoidance manoeuvre because of the sudden appearance of an aircraft coming out of the clouds, or a narrow valley, or a crest, etc.

Engage the transponder even below 7,000 ft AMSL (Code 7000) so that ATC can recognise you, because ATC traffic information to IFR flights increases the chance to recognise an aircraft on collision course by eight times.

When overflying local airports listen in to the radio communications of other traffic and repeatedly report e.g. position, altitude, and intention on the airport frequency.

Use standard phraseology during radio communications so that others can understand you better.

Turn the lights on so that others can see you better.

Use on-board equipment to reduce air proximities (ACAS, TAS, transponder, FLARM, FLOICE, etc.).

EASA Research Recommendations

To develop a technical standard for collision warning systems in the field of general aviation.

To develop common procedures and requirements for operation of one or more system solutions in uncontrolled airspace. A safety leaflet could support the harmonization of system solutions and procedures.

Safety monitoring will remain as difficult as today, but a large equipage with avoidance systems, this may support surveys of situations EASA and National Aviation Authorities could then more easily analyse in more detail commonalities of hazards and causal factors related to See and Avoid, develop specific Safety Performance Indicators (SPIs), and then also monitor how these SPIs evolve in Europe.

Training material shall be developed that cover not only the safety benefits for the users but also the limitations and human factor issues such as the potential over-reliance on the equipment.

Eurocontrol

This collision risk between IFR CAT and VFR GA aircraft could also be reduced by creating a 'Known' traffic environment in the vicinity of aerodromes. This could be accomplished using the following options:

a) Mandate carriage and operation of SSR transponders for all flights within all classes of CAS. This would ensure interoperability with current and future ATC surveillance systems and ACAS within CAS around aerodromes. […]

b) Implement mandatory SSR transponder carriage zones for all flights in the uncontrolled airspace around airports. This could be implemented permanently across the board, selectively in the areas of highest risk, or temporarily using the FUA concept. The dimensions of these zones would be dependent on the activity and flight profiles of the IFR CAT operating at the particular aerodromes. […]

c) Mandate the carriage and operation of SSR transponders on all aircraft in all airspace classes. Baseline interoperability between all categories of aircraft would then be assured irrespective of airspace class or flight profile.

d) With sub-paragraphs (b) and (c) above, safety and situational awareness could be further enhanced by the availability of TIS data for VFR aircraft not equipped with

TCAS. Furthermore, use of the Mode S 1090 Extended Squitter functionality would facilitate the future implementation of ADS-B. When combined with multilateration techniques, these facilities could be particularly useful at lower altitudes and in other areas where surveillance radar coverage is not ideal.

e) Guarantee the provision Air Traffic Services to VFR aircraft and encourage the use of these services in high risk airspace.

The collision risk between two VFR GA aircraft in uncontrolled airspace could be reduced as follows:

a) Improve the effectiveness of 'See and Avoid' techniques and the visibility of aircraft.

b) Improve the situational awareness through better promulgation, notification and information flow about activity to permit 'routes to avoid' to be planned. The availability of TIS for GA and, in the future, ADS-B for all flights could also be extremely beneficial but widespread SSR carriage would be needed on all GA aircraft for this to be an effective solution for this scenario.

c) Encourage voluntary equipage with technology developments such as FLARM for use between GA aircraft.

DFS, Clues for VFR Flights in Airspace E

Use Flight Information Service (FIS).

In the vicinity of airports, pay attention to IFR traffic especially in the area of extended runway centre lines. Aircraft on final approach and landing aircraft have the right of way.

Do not insist on you having the right of way! The field of vision from the cockpit of a transport aircraft cannot be compared to the one from a smaller airplane. For you it is easier to recognise a transport aircraft than the other way around.

Initiate a timely and wide avoidance manoeuvre; wake turbulences of a transport aircraft are invisible but very dangerous.

Fly with engaged transponder even below A5,000 ft (3,500 ft GND). Thus you are recognisable on the controller's screen and he can give traffic information to the pilot of the transport aircraft. In addition, the on-board TCAS of the transport aircraft can generate avoidance manoeuvres.

2. Analysis

2.1 Airspace Structure and Air Traffic Control Procedures

The airspace structure in Germany is based on the international recommendations and requirements of ICAO, the European Union, and national regulations.

The procedures of German air traffic control services are based on international requirements. The equipment of the radar installations in regard to collision avoidance (Short Term Conflict Alert, STCA) corresponds with current standards.

The airspace system, consisting of controlled and uncontrolled airspaces, with control zones, radio mandatory zones and transponder mandatory zones, tries to do justice to the principle of Para 1 of the Luftverkehrsgesetz (LuftVO, Federal Aviation Act) *„Die Benutzung des Luftraums durch Luftfahrzeuge ist frei […] (Use of the airspace by aircraft is free)"* and many groups of interest.

In airspaces C, D, and E below FL100 flights in accordance with instrument flight rules and flights in accordance with visual flight rules take place. In Airspace C IFR traffic does not have to adhere to any speed limits. In airspaces D and E speeds up to 250 kt IAS may be used by IFR and VFR traffic (military traffic may fly even faster under certain circumstances). It is not uncommon that IFR traffic flies in and out of, or climbs or descends through clouds. At the same time VFR flights, some without transponder transmission use larger cloud gaps during climb or descent or fly in cruise flight closely below or on top of clouds, which corresponds with aeronautical regulations.

The current airspace actions of the BMVI allow IFR traffic in general to operate, up to FL100, in a so-called known environment during departure and approach of an airport with high numbers of IFR take-offs and landings. This applies for air traffic control as well as on-board collision warning systems.

During take-offs and landings of less frequented airports, which are often conducted by low-cost carriers, or as non-public company flights with business jets, or as charter flights, IFR traffic has to cross Airspace E during climb or descent or even remains in Airspace E. Then IFR - VFR mixed traffic occurs, where each flight crew, each pilot is responsible for separation and collision avoidance according to the See and Avoid principle. Airprox investigations have shown that flight crew of controlled IFR traffic are not aware of or familiar with this fact. In addition, significant limitations of the field of vision exist in a lot of transport aircraft, which make airspace observation more difficult or impossible from some perspectives.

The BMVI course of action to determine airspace actions at airports with IFR traffic solely by the number of take-offs and landings reduces the possibility of a collision between IFR and VFR traffic, but the potential risk with possibly severe consequences remains, especially at low-frequency airports. Even at airports with airspace actions for the protection of the IFR traffic, e. g. with a TMZ, serious incidents have occurred repeatedly because the IFR traffic was, for example, cleared early for the approach descent below 5,000 ft AMSL or for the approach procedure still outside of the TMZ. In this context the air traffic control unit should issue clearances with a commensurate steep departure or approach profile so that it occurs by 5,000 ft AMSL or lower, within the airspace action.

If radio contact is established, the air traffic control unit should give traffic information if collision risk is recognised. Because up to 5,000 ft AMSL and for gliders up to FL100 neither equipment nor use of a transponder is mandatory, a significant portion of aircraft in Airspace E are unknown for air traffic control and therefore traffic information is not possible.

In Germany, Airspace E is the basic element of the airspace structure, up to FL100 and FL130, respectively. This airspace can be used by any VFR pilot without clearance or radio contact with an air traffic control unit, as long as the minima flight visibility and the distances to the clouds are adhered to. The BFU is of the opinion that it is misleading to call an airspace controlled, where known and unkown air traffic meet without air traffic control having any influence. This produces a false and nowadays not justified feeling of safety, even if this description meets international provisions.

2.2 Airproxes and Collisions

For years the BFU has received reports about separation infringements, airproxes, near misses, and collisions. The BFU noticed that whenever transport aircraft and General Aviation aircraft were involved, generally the crew of the transport aircraft reported the airprox. The reason may be that the other pilot involved considered the collision risk as not so high, because, for example, he has had the larger transport aircraft in sight much earlier, or it may be owed to the reporting culture of the General Aviation community.

By publishing investigation reports and flight safety information the FUS / BFU has addressed the problems, the existing dangers, possible actions, and recommendations. The LBA has also published commensurate flight safety information.

The occurrences and the number of reports, serious incidents, and accidents are comparable with the numbers quoted in studies of other European countries, the USA, Canada, and Australia. The recommendations in these publications can be applied to Germany.

The serious incidents and accidents of the years 2010 to 2015 allow the classification in accordance with operating modes: IFR-IFR, IFR-VFR, VFR-VFR, and VFR aerodrome traffic.

IFR-IFR

The analysis of the occurrences showed that collisions did not occur due to aircraft equipment requirements with transponders and, if appropriate, also with TCAS, the stipulated supervision, and traffic control by air traffic control. In spite of more than 12 million IFR flights in Germany in the last six years, the BFU only registered three serious incidents and one incident. The BFU classified the major part of the reports as “not worthy to be investigated further”, because either ATC or on-board TCAS had issued either timely traffic warnings or avoidance manoeuvres. However, the large number of aiproxes, TCAS, and separation infringement reports, and one accident such as the collision on 1 July 2002 near Überlingen show, that the collision risk exists and has to be proactively counteracted.

IFR-VFR

The investigations showed that in mixed air traffic airproxes occurred during climb and descent through Airspace E and approach and departure through Airspace D involving an IFR transport aircraft and a VFR General Aviation aircraft. In these cases only a small number of the VFR aircraft transmitted transponder signals, which corresponds to aviation regulation, and only a limited number of them in Airspace E was in radio contact with air traffic control services. Therefore in 15 out of 28 airproxes issuance of traffic information by air traffic control or warning and avoidance recommendation from on-board equipment was not possible. The pilots were responsible for separation and collision avoidance. Both pilots, the one in the IFR transport aircraft and the one in the General Aviation aircraft, had to solely trust the See and Avoid principle. Especially gliders without transponder can hardly be seen because of their slim silhouette and usually white varnish with poor contrast despite good weather conditions and daylight. This problem increases because gliders remain unknown for air traffic control, radar, and TCAS even above 5,000 ft AMSL, because they can be operated without transponder.

Investigations in connection with the implementation of TCAS have shown, that a warned pilot, either by traffic information via radio or collision warning system, most likely recognises another aircraft both earlier and from farther away, than a pilot who can only depend on visual observation of the airspace.

From a technical standpoint, neglect to transmit transponder signals is nowadays no longer necessary. Several manufacturers have light, small, and energy-saving transponders on offer. Transponder Mandatory Zones (TMZ) proof already that such equipment is possible and beneficial for improvement of the safety of everyone using the airspace.

The BFU is of the opinion that with such equipment maximum benefit could be achieved for the entire Airspace E.

VFR-VFR and VFR Aerodrome Traffic

The investigated occurrences showed that neither collision warning systems had been on board, nor had traffic information via radio been given. Therefore, timely warning about the impending airprox or collision was not possible. In these cases, the principle See and Avoid reached its limits due to very different reasons.

The occurrences in VFR aerodrome traffic occurred in the uncontrolled Airspace G, outside the responsibility of ATC. The possible safety benefit of precise position information via radio to the aerodrome operations manager or other pilots in aerodrome traffic, concentrated monitoring of radio communications, turning on all aircraft lighting, and the adherence of traffic pattern procedures were not made use of to the full extent.

The resulting risks and concrete dangers were described in various publications along with recommendations to decrease the collision risk.

2.3 See and Avoid Principle

The project “Erkennbarkeit von Segelflugzeugen und kleinen motorisierten Luftfahrzeugen“ (BEKLAS, 2004 (recognizability of gliders and small powered aircraft)) on behalf of the Bundesministeriums für Verkehr, Bau- und

Wohnungswesen (Federal Ministry of Transport and Urban Affairs) had thoroughly examined the problem of recognition of gliders and small powered aircraft. The project's final report states: *"Air traffic is based on the basic principle See and Avoid. Although it originated from the early days of air traffic the concept is still valid today. As the name implies, it is essential to see other traffic and to be seen by other traffic to avoid collisions. Key element therefore is the capability of a pilot to notice other airplanes, estimate course and speed, and deduce the right action for the situation."*

Quote Cirrus, DG Flugzeugbau *Observation of the airspace, adherence to code of conduct, and warning markings are essential but cannot prevent collisions: Due to geometry, collisions occur exactly then when objects are moving in constant bearing. The other object does not move it is only slowly getting larger. The human eye is not constructed to recognise such slow changes.*

Due to their construction and size it is not possible to detect gliders early. BEKLAS, 2004: *"Gliders can best be seen, when the rudder with the fuselage, or, with commensurate bank angles, the wing depth reflects the sun light and impresses by their size. However, during stationary circling flight this is almost never the case. Due to a circle time of approximately 20-30 seconds there are only less than five seconds per perspective. If the mean fuselage width is 62.4 cm, the distance is more than 3.2 km, and the point vision sharpness is 1.5, the fuselage cannot be recognised, only the wing depth (The mean wing depth at the root is 92 cm for nine different synthetic single-seater.). If distance is increasing to more than 4.7 km the wing depth also disappears. Then only the flashing of the wing in the sun can be observed as above-threshold impulse (Similar to a cobweb which can only be recognised by the reflection otherwise remains invisible.). These reflections are not present in shadow or below a cloud."* Assuming a speed of 250 kt IAS, the crew of a transport aircraft has about 37 seconds to prevent a collision. But since a glider presents such an optimum only for a brief period the time span can be considerably shorter.

The BFU is of the opinion that the principle See and Avoid remains a basic code of conduct. It is, however, no longer up to date as sole collision avoidance tool in Airspace E if the current growth prognosis for commercial air traffic (passenger transport and business aviation) is taken into consideration.

Regarding the increasing number of UVAs the principle See and Avoid has to be viewed as insufficient. Especially for police and rescue helicopters flying at low altitude, and partially for approaching and departing air traffic collisions with UAVs pose e new threat (besides bird strikes).

2.4 Technical Options to Prevent Collisions

Modern technology offers a number of different technical solutions for conflict traffic recognition. These enable timely ground and on-board traffic warning.

By means of primary radar air traffic control services could detect reflecting air traffic. Due to numerous limitations and miss-reflections only the secondary radar, the tracking of aircraft with transponder signal transmission, is used. Therefore in Airspace E up to 5,000 ft AMSL a number of airspace users and gliders above 5,000 ft AMSL remain unknown. It is therefore often not possible to give traffic information regarding conflicting traffic or avoidance recommendations. The STCA equipment of radar stations is useless in these cases.

In view of future air traffic regulations (e.g. Commission Regulation (EU) 1207/2011) which currently concern in Europe mostly flights in accordance with instrument flight rules, more and more ADS-B information for air traffic control are used. As long as not all users of the respective airspaces transmit an ADS-B signal, the use of ADS-B ground stations by air traffic control services is still fragmentary as far as collision avoidance is concerned.

Undoubtedly, in commercial air traffic collision warning systems (TCAS) are a useful part of flight safety equipment, in addition to air traffic control and the See and Avoid principle. This equipment can only warn about impending dangers and issue avoidance recommendations if these can be detected (known traffic). With the current technology this means that possible conflict traffic should transmit either a transponder or ADS-B signal.

Several avionics manufacturers have developed collision warning systems for General Aviation aircraft. These collision warning systems could indicate other air traffic transmitting a transponder, ADS-B, or FLARM signal, and therefore support See and Avoid. Presently the installed number of such systems is still small. There is no aeronautical obligation to equip General Aviation VFR operation aircraft with collision warning systems in addition to a transponder.

FLARM collision avoidance systems in gliders were developed due to numerous collisions during circling in thermal and hillside gliding. Many glider owners have equipped their gliders with FLARM systems without corresponding aeronautical requirements. Glider pilots are now warned about other gliders equipped with FLARM and, if Power FLARM technology is used, about other traffic, transmitting transponder or ADS-B signals. But they remain invisible to collision warning systems (TCAS) of commercial air traffic due to incompatibility.

Present-day transponders, inclusive ADS-B transmission for future traffic control regulations, are available for almost all types of aircraft. Several manufacturers have systems on offer with little weight, low power consumption, and battery option. The BFU is of the opinion, that compared with the collision risk with a transport aircraft, neglecting to equip an aircraft with a transponder is no longer justified.

Modern lamp technology makes it possible to increase the recognition of anti-collision, position, flashing, and landing lights. With the service life of aircraft it will take years, if not decades, to replace the light bulbs of the current external lighting on a large scale.

2.5 Conclusions and Recommendations of other Publications

The numerous investigations, studies, articles, and flight safety information publications describe the same problem: *„[…] mid-air collisions can occur in all phases of flight and at all altitudes. However, nearly all mid-air collisions occur in daylight and in excellent visual meteorological conditions, mostly at lower altitudes where most VFR flying is carried out. Because of the concentration of aircraft close to aerodromes, most collisions occurred near aerodromes when one or both aircraft were descending or climbing, and often within the circuit pattern."*

The publications describe almost with the same wording the same causes for airproxes and collisions of VFR aircraft:

- The performance limitations of the human eye
- Not seeing the conflicting traffic (pilot and air traffic control)
- Late recognition of the conflicting traffic
- Insufficient and late avoidance manoeuvre
- Late or inaccurate traffic information
- Misinterpretations of the pilots involved

- Non-adherence to regulations and procedures

The recommendations for airproxes and collision avoidance are very similar in context or are even almost identical. It is basically recommended to support the See and Avoid principle by technical measures. Other important basic rules are anticipatory actions and using all available information (traffic information via radio).

All require in regard to the risk of a transport aircraft (IFR operation) colliding with a General Aviation aircraft (VFR operation):

[…] This collision risk between IFR Commercial Air Transport (CAT) and VFR General Aviation (GA) aircraft could also be reduced by creating a 'Known' traffic environment in the vicinity of aerodromes.

[…] Ensure that unalerted see-and-avoid is never the sole means of separation for aircraft providing scheduled services

[…] Mandate carriage and operation of SSR transponders for all flights within all classes of Commercial Air Service (CAS).

[…] Improve the situational awareness through better promulgation, notification and information flow about activity to permit 'routes to avoid' to be planned. The availability of TIS for GA and, in the future, ADS-B for all flights could also be extremely beneficial but widespread SSR carriage would be needed on all GA aircraft for this to be an effective solution for this scenario.

[...] Use on-board equipment to reduce air proximities (ACAS, TAS, transponder, FLARM, FLOICE, etc.).

Current transponders and ADS-B technology would be suitable to support the See and Avoid principle.

3. Conclusions

This study takes into consideration airproxes and collisions of aircraft which occurred in German airspace between 2010 and 2015. Of a total of 490 reported occurrences, 15 were accidents, 31 serious incidents and 8 incidents. A total of 19 persons were fatally and 2 severely injured; 15 suffered minor injuries.

Due to timely traffic warnings by air traffic control, or on-board collision avoidance systems, and adherence to the See and Avoid principle, the BFU classified most of these occurrences as ”not worthy to be further investigated”.

Most of the serious incidents occurred in airspaces, where air traffic in accordance with Instrument Flight Rules (IFR) and Visual Flight Rules (VFR) mix. In the current airspace structure this occurs mostly in Airspace E.

The accidents occurred either in VFR cruise flight or during VFR aerodrome traffic.

During the accidents and serious incidents the See and Avoid principle had failed.

Technical tools such as Anti Collision Lights (ACL), high-contrast varnish, partially existing transponders, ADS-B, FLARM, or radio contact with air traffic control were not sufficient, because at least one of the aircraft involved was technically not visible (unknown) for the other aircraft or air traffic control and could not visually be recognised by the crew.

The consequent use of the already available technical means (transponder transmission or ADS-B signals) would minimise the collision risk considerably in airspaces where controlled IFR traffic and uncontrolled VFR traffic occur at the same time. A known traffic environment could be created nation-wide for ATC and on-board collision warning systems, if gliding operations above 5,000 ft AMSL or 3,500 ft GND were no longer exempted from transponder transmission. Below 5,000 ft AMSL or 3,500 ft GND voluntary transponder transmission would improve safety. In addition, current airspace actions could safely separate known and unkown traffic below 5,000 ft AMSL or 3,500 ft GND. The BFU is of the opinion that commercial flights in accordance with Instrument Flight Rules with aircraft of more than 5.7 t take-off mass or more than 19 seats should only be operated from airports with integrated airspace actions from the ground up to 5,000 ft AMSL or 3,500 ft GND.

With the respective compatible anti-collision equipment of the entire air traffic, the collision risk in VFR cruise flight, in the VFR aerodrome traffic, and in “unknown” airspace classes (currently Airspaces E and G) could be reduced.

The numerous publications concerning this issue come to the same conclusions and recommendations.

At this time, the BFU cannot estimate the potential dangers posed by the operation of UAVs.

4. Safety Recommendations

Safety Recommendation No 02/2017

The Federal Ministry of Transport and Digital Infrastructure (BMVI) should cancel the existing exception that allows neglect of transponder transmission for the operating mode gliding above 5,000 ft AMSL or 3,500 ft GND according to the Verordnung über die Flugsicherungsausrüstung der Luftfahrzeuge (FSAV) (Regulation Concerning Avionics Equipment of Aircraft).

Safety Recommendation No 03/2017

The Federal Ministry of Transport and Digital Infrastructure (BMVI) should ensure that commercial flights in accordance with Instrument Flight Rules with aircraft of more than 5.7 t take-off mass or more than 19 seats only occur in airspaces where air traffic control is able, at any time, to issue traffic information and avoidance recommendations regarding all other aircraft operating in the same airspace, and on-board or ground-based collision warning systems (ACAS and STCA) can warn about impending collisions.

Investigator in charge:	Axel Rokohl
Assistance:	Christian Blanke
	Jens Eisenreich

Braunschweig den 17 January 2017