

# Collisions under VFR Conditions

Collisions with other aircraft or static obstacles are one of the most frequent reasons of accidents in VFR flying. Consequences of such collisions are always severe. Most of the collisions happen in plain daylight with good visibility. For gliders in Switzerland, if a collision results in only minor injuries, no accident investigation is started anymore. Often, such collisions are not communicated at all by the involved parties.

Each year, there are about 20 collision incidents in General Aviation. In every third collision, at least one involved party is a glider. Every second involved pilot does not survive the collision. Collisions cause about one third of the deaths in gliding and thus, they are the second most important cause of accidents.

Near misses are a lot more frequent than actual collisions. In many cases, the involved parties do not even realize that a near miss has happened. Figures are hard to provide on this.

## The Human Factor Limits of „See and Avoid“

In flight, pilots are constantly diverted by tasks like flying, navigating, optimizing the route, situation reassessment, radio communications, instrument management, eating, drinking etc. Flight computers take a further part of the remaining capacity to scan the vicinity. Other human properties limit our capability to consequently apply the „**See and Avoid**“ principle. Even perfect pilots are impaired by them:

Our **optical perception** is a teamwork of the eye and the brain. The **eye** is an optical sensor with a resolution of  $1/21600^{\text{th}}$  of the full circle. This is about  $1/100^{\text{th}}$  of the size of a thumb on a out-stretched arm, or the diameter of a glider fuselage 2km (1.1 nm) away. Keep in mind that this resolution is available only at the center of our eye, at the periphery, resolution is a lot more coarse. And, that is only achievable for young eyes in good light and perfect atmospheric conditions.

The **brain** generates an **optical impression** based on sensory data, experience and memory. We think that we see focused in a large area when in reality we do not really. Pixel errors of the eye are corrected by the brain, Every person has his/her blind spot – an area with missing pixels. Often, there are other defects as well.

The brain realizes **movements**, i.e. Quick changes of the image, very well. Slow and steady changes, as they occur when aircraft are on a collision course, are recognized a lot less effective.

Our brain can **concentrate on single objects**, but it also masks away other (potentially dangerous) objects.

We rely on **known things and experience**. We have to make a conscious effort to search for the **unknown** as well.

Didn't you ever, after flying „alone“ for some time, discover another glider very close to your position and have then assumed to know about all planes in the vicinity?

The brain is easily **distracted**. A simple diversion can lead to loss of short term memory. This is especially dangerous if I had, for instance, unconsciously recognized a glider close by – and forgot it due to my looking at the instruments.

Stringent, systematic and efficient monitoring of the air space by the pilot is of great importance. It is the basis for collision avoidance in VFR conditions. But even the most advanced pilot is capable of supporting the „**See and Avoid**“ principle under all conditions without limitations.

The probability of collision is enlarged by the fact that we cannot fly in a free three dimensional space. Airports, required or obvious navigation points, air spaces and their boundaries, thermals, thermal lines, slopes and local attractions as well as a GPS-based, very precise flight navigation lead to a very high deviation in air space usage.

## Technical Measures

If we want to fly, but do not want to see collisions as an acceptable risk, we have to find fitting counter measures.

The consequences of a collision can be reduced by technical measures, like chop knives for ropes, emergency locator/transmitters (ELT's), rescue systems,. Etc. The priority however, should be to avoid collisions. It is often good enough if one of the involved parties changes his course to avoid the collision.

Aircraft should be designed to be easily recognizable and noticeable. However, since their form is largely dictated by aerodynamic requirements, available measures are limited. **Color** might help. However, because the background can be almost any surface – ky, galci-ers, pasture, woods, rocks) there is no optimal color scheme. An aircraft should not be of one single color. However, for structural reasons of the materials used to construct gliders, arbitrary coloring schemes are not possible. It is allowed and – from a security point of view – recommendable to mark the tips of all parts using a very intensive color (wing tips, fuselage tip, stabilizer). Cost is neglectable. Additional coloring is not necessarily beneficial – it might result in camouflage rather than attention grabbing by breaking contours.

Strobe lights and reflective stickers grab attention. The latter generate strobe pulses by reflecting sunlight. Electrical strobe lights require proper mounting and thus certification. They might alter the aerodynamic behaviour of the plane, and they need power. Their reflection is limited to a small area, mandating the use of several strobe lights. In addition, in bright daylight, their effectivity is limited at best. Therefore, they are not an option for gliders.

**Passive sensors** evaluate the signal level of transponders of other aircraft and deliver a rough distance. These devices are available commercially for about CHF 1'200.- (€ 800.-). To limit ranging errors to less than 25%, external antennas are required. For those to be effective, they have to be measured and qualified. Because most transponders also signal altitude, altitude separation can be monitored by these devices. There is, however, no bearing information. In addition, these devices can only signal other aircraft carrying a transponder. Thus, there is no autonomy. To get bearing information, you need to have your own transponder.

Even if many other aircraft would carry a transponder, **a radar requesting the transponders to respond is needed** to be able to „intercept“ a transponder transmission. In areas used by gliders, usually located outside of restricted airspace – like the alps and other mountains – this is **not likely to be available**.

Another disadvantage of those systems is their **missing „threat evaluation“**: They warn of any aircraft within your „danger zone“, even if they fly straight away from you. Therefore, these systems are unlikely to provide a security advantage even if transponders would become commonplace in gliders.

A similar approach has been created by Klaus Porod and presented in 2001. He did not use transponder signals, but **RF pulses** which have been issued by the device and allowed other airspace users to locate the sending aircraft using signal strength. The device evaluated the received pulses of other aircraft using several antennas and derived distance and bearing to the sender. The resulting information has been visualized on a circular display of LEDs. The result is comparable to avalanche search beacons („Barryvox“). The project has been canceled due to the small potential increase of safety resulting from its small reach and non-selective signaling.

**Active sensors** search in the environment for obstacles and warn the pilot. It is possible to warn of fixed obstacles (cables), ground and other aircraft. These devices work by actively transmitting and measuring the reflection of that transmission using **ultra sound, laser** or **microwaves**. These devices are autonomous – one of their great advantages. Their disadvantages are the complicated installation, their energy consumption and their price. They are attractive mainly for helicopters. Because of automotive developments (drive and park support systems for cars), system prices are expected to fall considerably shortly.

A suitable flight tactic can reduce the probability of collision with static obstacles considerably. Non-powered aircraft do require the lift available at the slope. Measuring their acceptable risk level is a part of the flight tactic. Static obstacles are catalogued in most countries. It is not a problem to have these data available in a device in the cockpit that visualizes them and sounds a suitable proximity alarm.

**PDA's and moving maps** – coupled with a GPS receiver – are suitable devices for storage, visualization, and proximity calculations. If the objects are completely catalogued and if the database is constantly updated, a small piece of hardware can achieve a considerable increase in safety. Such systems will see widespread use. They work autonomously. Flying close to the slope, having a continuous warning because of the small distance to the slope will, however, be of little use.

## Transponders

In controlled airspace, depending on its class, collisions are mainly avoided by central data gathering and conflict management. **Controllers** get data of variable reliability through **radio, primary and secondary radar (SSR)** about positions, altitudes, current vector and intentions of the airspace users. For VFR pilots, it is important to notice that we are almost always in controlled airspace, but we usually don't need permission to do so (class E). This airspace is shared by IFR and VFR traffic without separation.

**Controllers** are supported by centralized, automated systems, because they have to manage under a lot of stress highly complex, constantly changing situations, but at the same time have to guarantee economic flow management. Their data base is neither very accurate nor up-to-date. Crew-entered transponder codes (**mode A**) allow the controller to assign primary echos and distance information to the aircraft, because the transponder replies with its code to the polling of the radar. In **mode C**, the transponder sends the current barometric altitude of the aircraft. Usually, **modes A/C** are used together.

Transponders with mode A/C are largely mandated, but there are exceptions for hang gliders and gliders. Many airspaces can't be entered without a transponder, or clearances are not given. **TMZ** (transponder mandatory zones) are spreading. It is to be expected that in ten years, in order to use an acceptable part of the airspace, transponders will be needed. There will be no other benefit from having a transponder – they need space, energy, require installation of an external antenna and they are expensive – installation and certification will cost at least CHF 3'000.- (€ 2'000.-).

Transponders can't poll themselves. Systems as discussed under passive sensors can „listen in“ to transponder responses and identify potentially dangerous contacts. This is no big advantage for gliding, though – lacking stationary radars that poll regularly, this system is not reliable to detect dangerous contacts.

To avoid system overload or even breakdowns in areas of heavy air traffic, transponder **mode S (short Squitter)** has been developed. This mode allows for selective polling and requires that both ground station and aircraft use mode S. Each transponder is assigned a fixed, unique identifier. Since 2004, there are mode S transponders usable in General Aviation. They have the same profile regarding space and energy consumption, installation and price as mode A/C transponders. However, they will likely be required by the end of this decade to be able to use controlled airspaces.

The answer of a mode S transponder can include additional information to augment the controller's data set (GPS position, speed vector, intentions). This data link is called **extended Squitter**. However, it is not to be expected that glider-conformant mode S transponders will be enabled for extended Squitter.

Commercial airplanes have their on-board radar which triggers transponders in the vicinity. By installing various antennas, they can calculate the relative position of the other transponders. They can use the mode C altitude signal, as well. A suitable visualization allows to warn pilots of an aircraft equipped like this and to recommend evasive actions. Such systems are named **ACAS** (Airborne Collision Avoidance System) by ICAO (in the US, **TCAS**). They require that the other aircraft has a transponder. In case that both aircraft are ACAS equipped, they exchange information using Mode S transponders so their respective evasive actions do not enlarge the danger. ACAS systems generate a large amount of warnings and false alarms in heavily used areas.

ACAS is not suited for small aircraft, leave alone gliders. Its advantage is that it requires „only“ that other aircraft are equipped with transponders. However, it is not suitable for handling a significant number of gliders flying on typical glider trajectories as found in any well established gliding area.

Prediction works well for large aircraft, because they usually fly straight or on steady trajectories. Small aircraft, and especially all those that require external sources of energy (hang gliders and gliders) change course and altitude quickly and without warning. Thus, position prediction is on very short term, and there may be a large number of airplanes very close together. This use pattern is not suited to ACAS type systems – it is built for well-separated traffic.

Radio transmission is slow, often on a bad connection, only one person can speak at a time and use of local languages prevent clear communication between all radio users. Today's radio technologies are going to be supplemented and later replaced by digital systems (e.g. **VDL** – VHS Data Link). Using these channels, all airspace users can exchange the most important data – for instance, the GPS position, bearing and speed can be measured precisely and communicated instead of being approximated roughly by a ground based system. An example of such a digital transmission system is VDL level 4.

Today, this system is far from global deployment and they will be priced for the commercial airline market.

The automatic blind transmission of locally measured position is called **ADS-B** (Automatic Dependent Surveillance Broadcast). As of now, three incompatible systems are in global deployment – the two above mentioned **Mode S Extended Squitter** and **VDL Level 4**, as well as **UAT**.

### **Today's Situation for General Aviation**

Today, there are no systems available that reduce the risk of collision between general aviation type aircraft significantly, are reasonably priced and easy to install.

Because of the requirements of commercial aviation and airspace management authorities, mode S transponders will have to be carried in controlled airspace to be allowed to use them at all. For General Aviation, transponders offer but one advantage: ACAS equipped airliners will be able to see us in time to avoid collision – if we are allowed to use their airspaces at all. Collisions between General Aviation aircraft will not be avoided by these systems in the foreseeable future.

This situation is highly unsatisfactory. For General Aviation, there is a acute need for a reasonably priced system with a small footprint and little energy consumption, which effectively and efficiently warns the pilot about dangerous traffic in the area and thus optimally supports the pilot in his airspace surveillance.

Since the introduction of the GPS (conceived in the 70's) which delivers position information globally with an error of less than 100m, attempts have been made to broadcast position, bearing and speed of the aircraft using radio transmission. This would allow other aircraft to calculate a danger ratio and warn the pilot. Many studies, dissertations, diploma theses, articles and patents deal with this theme. The massive spreading of GPS devices as well as today's cheap and powerful integration of the electronics needed make such „mini-ACAS“ solutions realizable. We conclude:

**The technology is available.**