Comparative Statistical Analysis of Fatal Spin Accidents for Training Gliders

Murray Stimson and Stu Smith
murray.stimson@gmail.com
Melbourne, Australia

Abstract

Worldwide reports reveal that loss of control (LoC), primarily through spins, accounts for 40-50% of fatal glider crashes. This study aimed to identify if certain two-seat gliders were more prone to fatal crashes involving LoC than others and whether "spin resistance" was correlated with that likelihood. The Aviation Safety Network Wikibase of incident reports was searched for global crashes involving five of the most common two-seat gliders of composite construction. With no globally available risk exposure data, like flights or flight hours, we developed and used Aircraft Service Years from the number of gliders produced and remaining in service. Even using wide uncertainty bounds, the SZD-50 Puchacz glider showed a fatal crash rate several times greater than any other glider in this set. No significant change was observable in the annual rate of fatal crashes over at least three decades. The study calls for a comprehensive global incident database to support safety research and evaluate the effectiveness of safety measures.

Introduction

Across the world of gliding, reports from various countries confirm that crashes involving Loss of control (LoC) remain the largest sub-category (40-50%) of fatal crashes (Appendix A). This makes reducing LoC crashes the highest priority to reduce fatalities in gliding. In fatal crashes LoC most often manifests as a spin (high yaw rate) rather than a stall (little or no yaw) into terrain.

This paper set out to investigate:

1. Are some two-seat gliders safer than others in regard to loss of control?
2. Has the gliding fatality rate per year involving LoC reduced over time?
3. Is the Aviation Safety Wikibase [1] facilitated by the Aviation Safety Network (ASN) a useful resource for gliding safety research?

We made no attempt to identify the factors that resulted in LoC or relevant physical differences between glider types. Regardless of the causes of the LoC, the loss of control was the primary precursor to the resulting fatal impact with terrain. We had insufficient data to analyse whether spin prevention training was adequate, but we did try to identify trends to determine whether the fatal crash rate was reducing. Our literature search did not show any prior attempts to study crash categories or rates on a global basis for gliders of general or specific types.

This article has been reviewed according to the *TS* Fast Track Scheme.

We found no safety rating scheme for gliders such as those available for cars and trucks. The Australian ANCAP and Euro NCAP have been widely used for automobile purchasing decisions, but focus largely on protection in the event of a crash, giving less weight to crash avoidance. These ratings were derived from extensive tests conducted at the time of market entry for new models, rather than in-service crash performance data. Crashworthiness is very important for gliders, but given the potential for higher impact velocities a higher weighting towards avoidance strategies could be more beneficial than for automobiles.

We did find safety performance of some aeroplanes, cars and trucks has been analysed over decades of real-world use and is reported by some manufacturers. Boeing produced "StatSumm" reports [2] show fatal and hull loss rates per million departures for aircraft types, but EASA and Airbus [3] data are reported only by category of aircraft, aircraft generation and type of operation. Despite these data summaries, research was sporadic at best into which specific types suffered more crashes and in which crash categories.

A road safety approach prevalent across the automobile industry is that no common small errors by operators should lead to fatal outcomes. This signifies acceptance by car manufacturers and regulators of imperfect operator performance. Excluding causes driven by the operator, only the environment or vehicle can provide a safety buffer against fatalities. In LoC crashes for gliders the environment (weather, terrain, airspace) plays a lesser causal role and high impact energies mean there is limited opportunity for structure-based crash protection. As such the critical vehicle characteristic that may offer greatest safety value is LoC resistance. Glider pilots should avoid the reflexive tendency to blame the pilot involved in a LoC crash.

In pursuing this research we:

1. Calculated and compared the fatal crash rate of different types of two-seat aircraft of mostly composite construction and produced in large numbers, concentrating on those crashes where loss control or spinning was reported or suspected.

2. Identified a potentially valuable new source of aircraft safety data, ASN Wikibase [1], and identified some of the strengths and limitations of that data source for gliding safety research.

3. In the absence of any other reliable globally applicable and statistically valid data, developed a new risk exposure metric based on the number of aircraft in service since the start of production.

The motivations for this paper arose from a crash involving LoC in 2012 at Ararat airfield, near Melbourne, Australia, that resulted in two deaths: a young trainee and an experienced friend, 3 colleague, and instructor. The authors were curious over many years about the wide disparities in the fatal crash rates of two-seat composite gliders involving spinning. This generated questions over spin training policy and aircraft design characteristics related to ease of aircraft departure into spinning modes.

Background

Global Safety Data

Available safety data on gliding operations appears highly variable, across the world and back in time. A small number of countries had long-standing and detailed national incident databases even including government agency investigation reports for gliding crashes. Many others had scant data collection, that may not be available internationally or to the public, or not stretching far enough back in time to capture the full flying history of most glider types. Aggregation of gliding crash data had been missing until the ASN.

The ASN was initiated in 1996 by private volunteers contributing aviation crash reports from around the world to a moderated Wikibase. These reports contained some details about the aircraft, incident location and date, fatalities or injuries as well as a narrative that may or may not explain something of what occurred. News reports from media outlets were combined with official accident investigation reports, where available. The ASN Wikibase was steadily loaded with current and historical cases, so that by 2017 it contained a significant number of gliding crash cases. This represented a new opportunity not previously available for the gliding community. ASN remains private and independent, but for many years has been supported by the Flight Safety Foundation (FSF), a not for profit international organisation based in the USA and dedicated to providing independent and impartial safety information for the global aerospace community. Although the Wikibase is also hosted on the ASN website, the ASN Wikibase is a separate database to the ASN Accident Database.

Unlike the ASN Accident Database for airliners, corporate jets and military transports, FSF or ASN do not accept responsibility for the accuracy or completeness of information provided in the ASN Wikibase. There was possibly no verification of the details relating to any reported incident, so the potential for biased data remains real. For example, if an entry lists only "Spin into terrain" in the narrative section, but there's no supporting evidence, the evidentiary trail is essentially lost and the conclusion can be considered suspect. We also became aware that a few historical crashes from our personal knowledge were not recorded in the database, and for some countries where gliding has been a popular sport there were no or scant recorded incident data.

The typical components of an ASN Wikibase entry are shown below in Fig. 1 using an example from Australia. Although the crash definitely involved a spin in the early phase of a winch launch, it was non-fatal and not involving a two-seat glider. The reference to BASI as the investigating agency refers to the Bureau of Air Safety Investigation, which later became the Australian Transportation Safety Bureau (ATSB). Almost all the details were complete, the narrative appeared factual and the source official, so this was one of the more complete and reliable entries. In the official ATSB investigation report useful data regarding possible LoC risk factors was restricted to the inexperience of the pilot and tendency of that aircraft type to pitch up during winch launch, but even that data was not transferred to the ASN report.

National Safety Databases for Gliding

Some national gliding organisations from around the world have been publishing data and analyses of safety incidents, but most often only as national totals, categorised by type of crash (by primary cause and outcomes for occupants and the glider) and rarely by aircraft type. Because of the amount and quality of available data we reviewed the online safety data from the national gliding authorities of Britain, Germany, the USA and Australia as summarised below.

British Gliding Association

The British Gliding Association (BGA) has been publishing "Accident and Incident Summaries" periodically for many decades, as well as reviews of the crash data from the UK. At the time of writing the BGA website showed the summaries and reviews for the previous several years. The summaries and the reviews were not easily searchable and the focus of the annual reviews depended on the types of crashes experienced that year. Researchers could not extract new useable data without individ-

Date:	**20-OCT-1990**
Time:	15:45
Type:	Glasflügel 201 Libelle
Owner/operator:	
Registration:	VH-GCS
C/n / msn:	462
Fatalities:	Fatalities: 0 / Occupants: 1
Other fatalities:	0
Aircraft damage:	Substantial
Location:	Woodvale, VIC - Australia
Phase:	Initial climb
Nature:	Private
Departure airport:	Woodvale, VIC
Destination airport:	Woodvale, VIC
Investigating agency:	BASI

Narrative:
Shortly after becoming airborne, the nose pitched up very steeply and the glider rolled to the right. The right wing struck the ground, causing the glider to cartwheel into a fence.

Sources:
https://www.atsb.gov.au/publications/investigation_reports/1990/aair/aair199001160/
https://www.atsb.gov.au/media/27508/aair199001160.pdf

Fig. 1: Example record from ASN Wikibase of a crash report.

ually reviewing all the summaries. Even with relatively small numbers of fatal accidents, this task was beyond our resources or the scope of this paper. Data on the glider utilisation was apparently also collected since accident rates have been presented against flying hours or flights, but that underlying utilisation data was not found.

The BGA 2015 annual safety review [4] presented trends from 1976 to 2015 for total fatalities in 7-year periods for four categories of crash (stall/spin, winch, collision and "all other"), but no data was presented for glider types or other risk factors. Fatal crashes involving stall/spins were consistently the fifth largest or second largest of the four categories used, if the winch category was added. Winch launches that resulted in fatal injuries almost always included LoC even from low altitudes, so including winch fatalities was not an unreasonable assumption. The BGA substantially reduced winch fatalities by the successful "Safe Winch Launching" campaign since about 2005 which strongly emphasised three instructions including: early release if a wing drops on ground roll; slow rotation to climb attitude; and landing straight ahead on launch failure. The success of the winch safety program was shown by the substantial reduction of fatalities from winch launches in the most recent period (2008-2015) compared to the three previous periods. Similar or even larger reductions were seen in the data for two other categories of crashes involving collisions and "all other". However, for the most recent 7-year period the fatalities (5) in the stall/spin category, as opposed to the "winch" category, were only marginally below the average (5.4) across the extended period since 1976. Even without factoring in reducing glider usage, these data supported the hypothesis that fatality rates involving LoC showed little or no reduction across many decades. With such small numbers statistical analysis could not be considered reliable.

Deutsche Aero Club

The DAeC website showed an annual report for 2016 containing trends for membership and registered glider numbers, but no data on incidents or fatalities. No safety data was found using normal online search techniques and personal enquiries.

Soaring Society of America

The Soaring Safety Foundation of the SSA has an online searchable incident database that did not return any records for the selected glider types, even from recent years, potentially indicating that it is not functional or not populated fully. The SSA magazine is searchable back to 1937, but only for SSA members, so not readily available for international researchers.

Gliding Federation of Australia

From 2011, the GFA has been collecting incident reports in an online database called Safety Occurrence and Airworthiness Reporting (SOAR), and publishing short "Accident and Incidents" reports in the *Gliding Australia* magazine. The database contained as much data as was available including an assessment of the category of crash, including LoC, but at the time of this research was not searchable for privacy reasons. Two fatal crashes involving the selected two-seat gliders were found in those records, with only one of those categorised as LoC involving a Puchacz at Ararat in 2012, as previously described. On its own, this represents a statistically insufficient sample size, and each of those crashes was reported in the ASN Wikibase.

From 1951 until 2011, the *Gliding Australia* magazine published accident and incident summaries, but no searchable archive was found online.

Resistance to Spin Entry

In 1988, an ASK-21 was flight tested for susceptibility to spin entry by the USAF Air Force Flight Test Center as a result of a fatal crash involving spinning of an ASK-21 of the Air Force Academy. The report [5] by Doyle Janzen and Major Charles Precourt concluded that the ASK-21 was a good aircraft for spin training because spin entry was reliable and predictable, but outside of a narrow range of pitch attitude and bank angle, the aircraft would not enter a spin. This was irrespective of the use of additional tail ballast to compensate for pilot mass. The fatal crash referenced in that report was not found in ASN Wikibase, including under the USAF designation TG-9.

An assessment of the DG-1000S sailplane against US Military Standard criteria for training test pilots by Tim McDonald of the USAF Test Pilot School was reported in 2016 [6]. McDonald concluded that the glider was "resistant" in the aft section of the centre of gravity (c.g.) range and "extremely resistant" to spin entry at all other mass distributions. Both the ASK-21 and DG-1000 series permit the addition of tail ballast to teach spin entry and recovery to pre-solo students.

Martin Simons, in his book "Sailplanes 1965-2000" [7], described the G-103 Twin II gliders as "very difficult to spin". The Twin Astir also can be classified in the spin-resistant category because the redesign to add nose "whiskers" to the Twin III Acro was reported to be necessary to make it spin more easily.

These findings were corroborated by multiple magazine articles from the soaring nations and the authors experience as instructors using the ASK-21, Duo Discus, DG-1000 and DG-500 series whereby specific techniques that would equate to gross mishandling were required to initiate a spin. If the spin entry was not performed correctly or the c.g. was too far forward the gliders either enter a spiral dive or remain laterally stable, a moderate to high sink rate developed and there was noticeable buffet-induced vibration.

In contrast, the SZD-50 Puchacz stands apart from the other selected training gliders in that it is considered as easy to spin. Multiple magazine and online articles [8–10] have referenced the easy spinning nature of the Puchacz and there has been debate over the virtue or otherwise of this intentional design performance feature and the permitted aerobatics manoeuvres, including snap rolls. Both authors have intentionally spun the Puchacz and used the standard recovery procedure.

Under the EASA design certification standard, CS-22 amendment 3, all gliders were required to demonstrate recovery within one further turn once recovery actions commence [11] (CS-22.221), as well as provide adequate stall warning, or continued controllability post stall (CS-22.207). Post-stall controllability implies some undefined level of spin resistance. All five gliders chosen for this paper were certified under CS-22 and therefore have been flight tested and shown to comply with CS-22 on spinning. Further flight testing of the SZD-50 Puchacz in early 1994 on behalf of the BGA and supervised by the UK Defence Research Agency was reported by the UK Aviation Accident Investigation Board (AAIB) [9], after investigating another fatal LoC crash later in 1994. The report stated that: "The trial considered the aircraft to be only marginally compliant in respect of stalls during turns and noted that avoidance of uncontrolled rolling and spinning off a turn was reliant on pilot awareness and skill. The trial also noted that height loss in a spin was significantly greater than on other types and that this was largely due to the steep attitude (70° nose down) of the developed spin".

Future development of the sport is accomplished by improving safety standards through collective attention to systemic causes of fatalities and injuries by manufacturers, regulators, and all operators.

Method

We initially searched ASN Wikibase for glider crashes for a broad set of two-seat gliders, looking to categorise them by the degree of injury and the presence of spinning behaviour. We reviewed more than seven hundred records for crashes from 1960 to 2016, many with scant data. For improved statistical reliability and with limited time we restricted our analysis to unflapped two-seater gliders of composite structure that were built in large numbers (more than 300 produced) and with a long history in service. There were 314 records in ASN Wikibase for this set of gliders. The selected types were:

1. SZD-50 Puchacz
2. Grob G-103 Twin Astir series
3. Schleicher ASK-21
4. Schempp-Hirth Duo Discus
5. DG Flugzeugbau DG500/DG1000 series

We then reviewed each incident report to assign a level of certainty that the event initiated through loss of control. Following categorisation, the number of crashes in each category was summed for both fatal and non-fatal accidents for each glider type.

These totals were divided by a metric of risk exposure not previously encountered in the literature, which we called Aircraft Service Years (ASY). This enabled a comparison across types with significant difference in fleet size and years in service. Further details of this method are provided below.

Certainty of Spinning Behaviour

The chosen categories were: Definite Spin, Probable Spin, Doubtful Spin, Not Spin and Unknown. Events that initiated with another behaviour, such as collisions with other aircraft or break up in-flight were categorised as Not Spin, even if it was certain the glider subsequently spun into terrain. Incidents categorised as Unknown were most often the result of the incident report having no useful safety information about the crash. Types of evidence used to categorise the cases included: official investigation or ASN reports indicating spinning, photographic evidence, or flight path traces. Each of these evidence types is discussed below. A reference to spinning behaviour in the ASN report or official crash investigation reports was taken at face value. The potential for biased reporting in ASN was acknowledged, whereby if any type had a reputation for crashes involving spinning, that would lead to listing as a definite spin more often than actual. In particular, the SZD-50 Puchacz was the subject of articles in different soaring magazines and on web-based forums from the 1990's onward [8–10] highlighting the spinning behaviour of that type by anecdotal evidence. However, with this bias in mind we reviewed sceptically such evidence as was presented to downgrade reports for all types to a lower certainty. The instances where such bias in reporting could have appeared (i.e. no other supporting evidence) were found to be a small fraction ($< 5\%$) of the total crashes reported for the SZD-50.

Photographic evidence of the crashed glider, including fuselage and wing damage was often the most conclusive supporting evidence of spinning behaviour. Characteristic damage for an impact while spinning includes a combination of several features. An absence of witness marks remote from the final resting position suggested an absence of horizontal velocity. Witness marks on surrounding trees or terrain provide similar evidence of trajectory just before impact. Severe damage or a lateral translocation of the forward fuselage often indicated a steep nose down impact angle and possible sideways motion. Damage predominantly to only one of the wings indicated force was applied when one wing possibly contacted the ground first, but not in normal forward flight. And finally, the rear fuselage and empennage generally broke from the rest of the fuselage in many types of crashes, but for spinning behaviour the fin was often found rotated about the longitudinal axis of the fuselage due to sideways motion at impact. Again, no single feature can be taken without reference to all others as supporting or not supporting the presence of spinning behaviour. Flight path traces were found to provide important evidence of spinning behaviour in those more recent cases where the tracks were provided. The evidence might be as obvious as a rapid, almost vertical descent, but this was rare. In some other cases there was more than 50m difference between the height of the last logger record and the impact site. Any one of these characteristics would not necessarily be sufficient to categorise a crash as "definite spin". The label "probable spin" would potentially have been applied.

Aircraft Service Years

We defined Aircraft Service Years (ASY) as the sum of all aircraft remaining in service across the years since construction. Figure 2 shows ASY represented as the area under a curve of the total number of gliders produced minus those removed from the register by crashes where the aircraft was considered a "write-off". Written-off is a term indicating the residual value of a repaired glider would be less than the cost to repair. This does not always mean a crashed glider remains out of service, but as a first approximation represents the declining fleet size over time. Production data was very sparse, apart from historic dates like first flight, so a production profile was estimated. Some manufacturers' websites recorded production milestones, while others gave residual production rates after main production was completed. Data confirming the year initial production ceased was found for most of the types chosen. For glider types with a substantial fleet size and long service history the ASY was seen to be largely insensitive to errors in estimated production rate or the number "written-off".

Of course, the assumption that all gliders counted by ASY were flown in service in any given year was recognised as false. But with large sample sizes (> 300) for glider types of the same general type (glass-fibre, two-seat) the data for all types was potentially skewed equally. Recent data from the GFA on the annual airworthiness inspection returns for Australian gliders shows that nearly half the fleet were not registered as airworthy in any one year. The unregistered aircraft, and therefore not legal to fly, were not isolated to older or vintage gliders. Another potential problem was that some types were exported in large numbers to countries where few, if any crash reports were found in ASN, preferentially reducing their crash rate. A further complication was that as glider annual utilisation declined over the last few decades accident rates from earlier decades would not be reliably comparable with modern values. Nevertheless, in the absence of available global data of flight hours or flights per year for each type, we considered ASY sufficiently valid to make an initial comparison of crash rates for the types selected. In the most common aviation safety publications crash rates have been normalised by either flight hours (per 100,000) or flights (per million for civil air transportation). Whilst annual data for flight hours or flights of gliding activity were available from some countries, the numbers of crashes in each category over periods up to a decade was either zero or in low single figures, making statistical validity untenable. Worse, no such data was found for any type of glider, making comparison impossible until this data is collected and made available.

Results

Fatal Crashes and Crash Rates Involving Spinning

Table 1 shows that two thirds (42) out of the total 64 fatal crashes identified for these five two-seat gliders in ASN Wikibase definitely or probably involved LoC. Table 1 also shows the estimated total production quantity for each type as of 2016.

Table 1 presents the number of fatal crashes rather than the number of fatalities that resulted. The number of fatalities was less than double the number of crashes for two reasons: some flights were solo flights and some crashes were not fatal to both occupants. For example, for the SZD-50 Puchacz fleet the 34 reported fatal crashes resulted in 52 fatalities from 60 occupants. And similarly, for the ASK-21 fleet there were 11 reported fatalities from 14 occupants from all 7 fatal crashes. Since this variability was not dependent on the glider type, all having 2 seats, the number of fatalities was not further analysed.

The ASY associated with each type are shown in Table 2, together with the fatal crash rates for each of the certainty categories. As expected from Fig. 2 above, the Twin Astir series (including the Twin II and Twin III) shows the largest ASY for two reasons: production started a few years (1975) before other types examined (1979+) and the production rate was more than double that of any other type, even though the ASK 21 fleet since has surpassed that for the Twin Astir. Figure 3 represents the rate data from Table 2 in graphical form.

Adding the definite and probable LoC categories for the SZD-50 in Table 2 gives a rate of 3.71 fatal crashes per 1000 ASY, which is 91% of the total fatal crashes for that glider type. In contrast, the proportion of fatal crashes for the other 4 types was in the range of 0-50%. The rate of 3.71 per 1000 ASY for the SZD-50 was over 10 times greater than the next highest rate, 0.33 for the DG-1000/500 series.

Fatal Crash Annual Trend

Figure 4 shows fatal crashes per year categorised as definitely, or probably, involving LoC by type from 1976 through 2016. No discernible trend can be detected towards reducing rates of fatal crashes involving LoC at least for the last three decades. This figure also clearly shows the significant difference over time between the SZD-50 Puchacz and all other two-seat fiberglass gliders in this study.

Particularly noticeable is a period from 1976 through 1988 with no reported fatal crashes involving LoC, when from Figure 2 it can be seen that 3 of the 5 glider types had significant numbers of aircraft already in service. Perhaps the simplest explanation is that the ASN Wikibase has not captured all the fatal crashes that did occur in that period, or later. Any conclusion that there were in fact no such fatal crashes in that period would need strong supporting evidence that later generations became less proficient at avoiding LoC crashes in those types of gliders.

Non-fatal Crash Rate

The data on fatal crashes may have been skewed by the relative crashworthiness of glider types, such that some types did not show up in fatal statistics but experienced similar numbers of reportable crashes involving spins. Or, potentially, the incidents happened at low altitude and velocity such that the impact energies were lower. As a check on these possibilities, we therefore went back to the data collected from ASN and extracted and categorised all non-fatal reported incidents.

Figure 5 shows that for non-fatal crashes, the SZD-50 Puchacz showed a significantly higher rate of crashes involving definite or probable spins than all the other types examined. That glider also showed a much higher number of reports categorised as unknown where there was no additional data about the incidents, including whether there were any fatalities

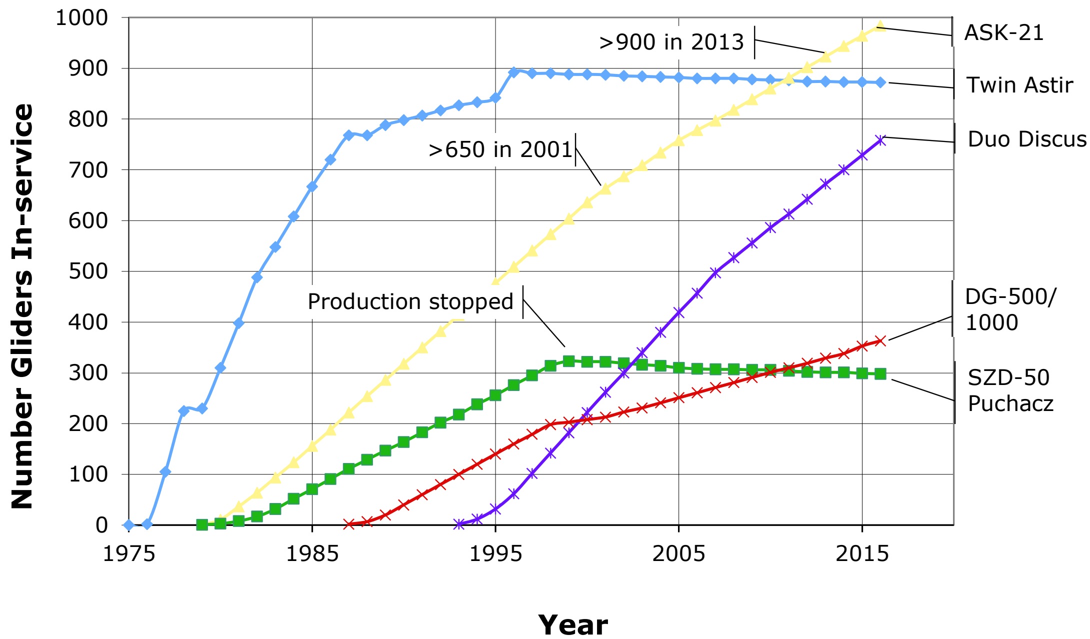


Fig. 2: Aircraft Service Years (ASY) is represented by the area under each curve of estimated production and reported loss rates for selected two-seat gliders until 2016. The corresponding ASY values are listed in Table 2.

Table 1: Fatal crash numbers reported in ASN wikibase versus category of certainty that the crash involved loss of control (spin) for selected two-seat composite gliders.

Type	Total production (2016)	Definite Spin	Probable Spin	Doubtful Spin	Not Spin	Unknown	Total
SZD 50 Puchacz	343	23	8	2	0	1	34
ASK 21	996	0	0	1	5	1	7
G103 Twin Astir	904	6	1	1	4	1	13
Duo Discus	772	1	0	1	1	0	3
DG-500/1000	363	2	1	1	3	0	7
Total	3378	32	10	6	13	3	64

Table 2: **Fatal crash rates per 1000 ASY versus category of certainty that the crash involved loss of control (spin) for selected two-seat composite gliders.**

Type	Aircraft Service Years	Definite Spin	Probable Spin	Doubtful Spin	Not Spin	Unknown	Total
SZD 50 Puchacz	8373	2.75	0.96	0.24	0.00	0.12	4.06
ASK 21	19928	0.00	0.00	0.05	0.25	0.05	0.35
G103 Twin Astir	30055	0.20	0.03	0.03	0.13	0.03	0.43
Duo Discus	9194	0.11	0.00	0.11	0.11	0.00	0.33
DG-500/1000	6093	0.33	0.00	0.33	0.49	0.00	1.15

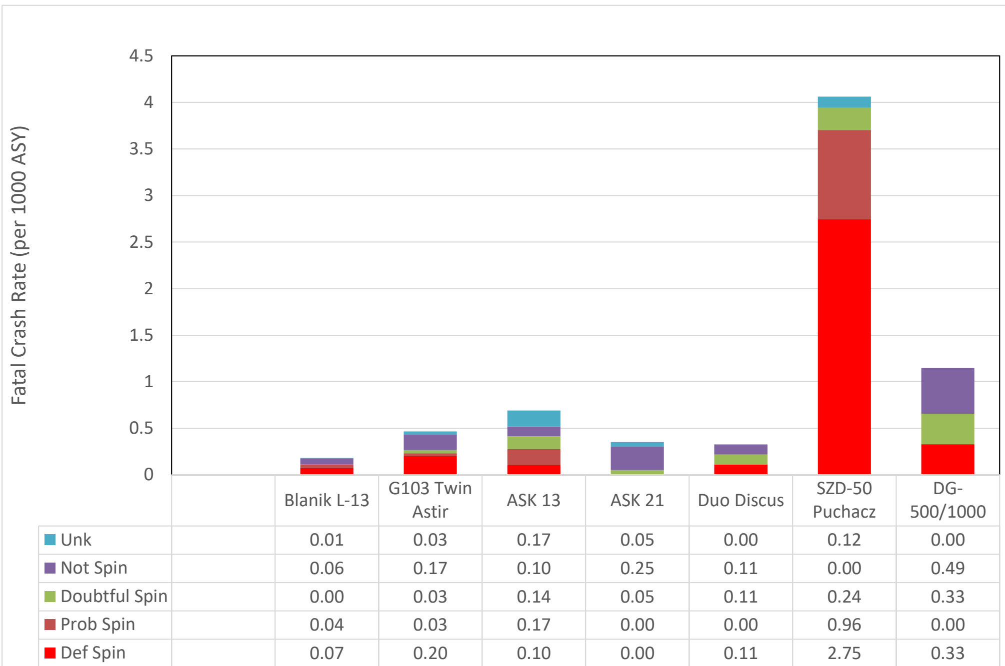


Fig. 3: **Fatal crash rate per 1000 ASY for selected two-seat composite gliders against certainty of Loss of Control (Spin); data from ASN Wikibase to 2016.**

or injuries. Consequently, there was no viable means to assess the likelihood that those incidents involved spinning behaviour. Caveats to be applied to this analysis were that non-fatal incidents were conceivably much less likely than fatal crashes to be reported in ASN Wikibase and all other data sources, and again, the numbers of incidents for each type were statistically small. Reported incidents where the glider was not in flight (trailer crashes, hangar fires, etc.) were not included in the analysis. Anomalies also appeared in the data, such as that 71 out of 113 incident reports involving the G103 series aircraft were from the USA. This seems unlikely to accurately reflect the distribution of G103 across the world, possibly indicating a bias towards under-reporting incidents from some other nations.

Discussion

This paper set out to investigate three questions:

1. **Are some gliders safer than others regarding loss of control?**

(a) Our research has shown a statistically significant difference between the fatal crash rate involving LoC for the SZD-50 glider and the other composite 2 seat training gliders considered. As shown in Fig. 2, for the combined category of definite and probable LoC, the SZD-50 was reported in fatal accidents at a rate of 3.71 crashes per 1000 ASY compared to the next highest (DG-1000/500 series) at 0.33. The fatal crash rate for the SZD-50 was over 10 times higher than any of the other gliders, and there was little reason to separate those other gliders because they had such low numbers of fatal crashes involving LoC.

(b) The possibility of significant bias in the ASN Wikibase incident reports towards over reporting of SZD-50 crashes as involving LoC was investigated and found not to have occurred, or represent less than 5% of the reports. Possible bias from under reporting fatal crashes for the other types in the ASN Wikibase

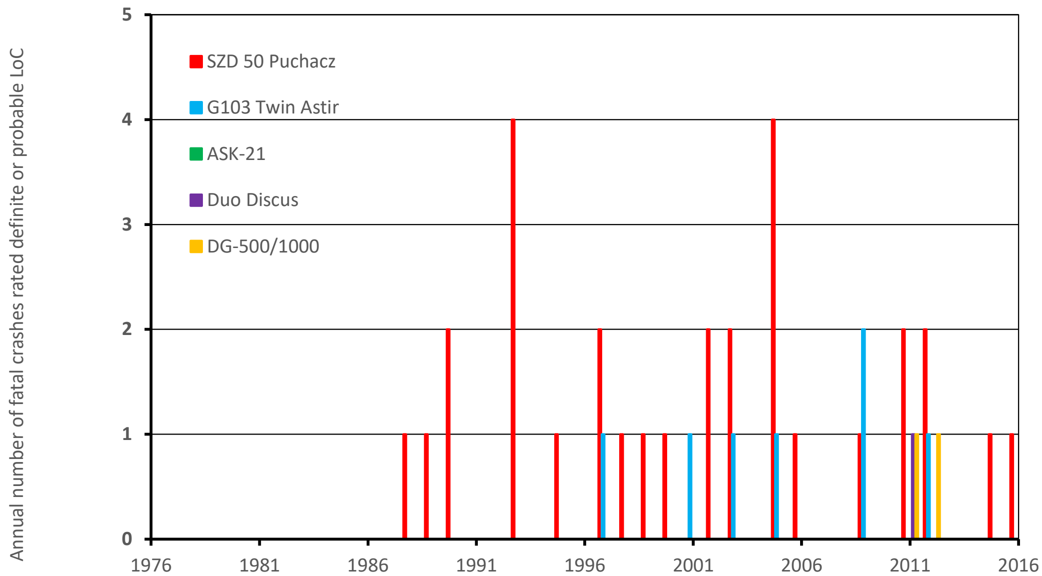
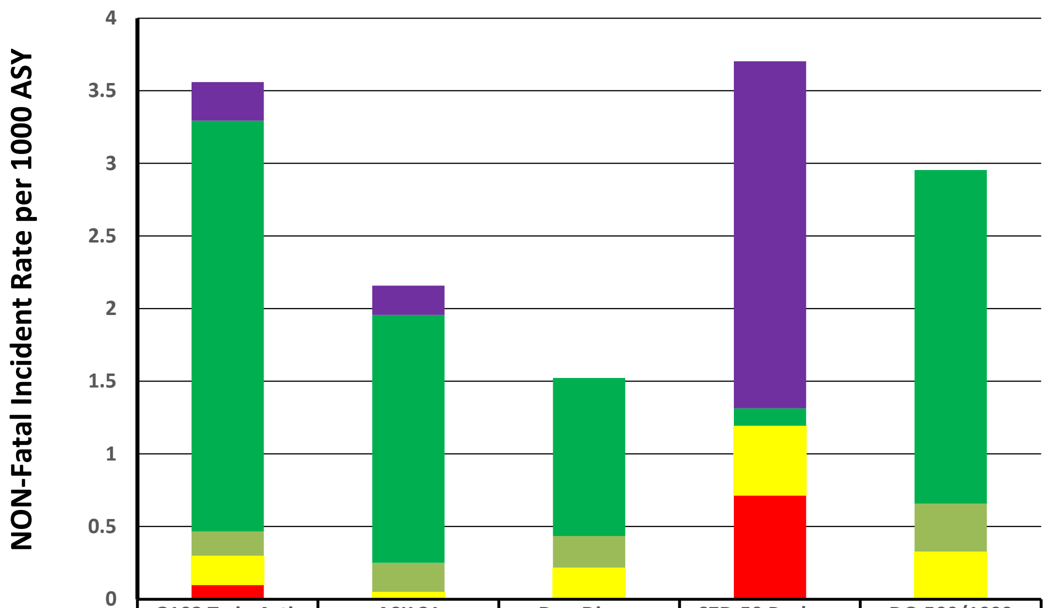


Fig. 4: Global annual numbers of fatal crashes involving spins shows no discernible trend. Two occurrences of 4 crashes in the years 1993 and 2005 for the Puchacz was much worse than any other type examined in this study.



	G103 Twin Astir	ASK 21	Duo Discus	SZD-50 Puchacz	DG-500/1000
Unknown	0.27	0.20	0.00	2.39	0.00
Not Spin	2.83	1.71	1.09	0.12	2.30
Doubtful Spin	0.17	0.20	0.22	0.00	0.33
Probable Spin	0.20	0.05	0.22	0.48	0.33
Definite Spin	0.10	0.00	0.00	0.72	0.00

Fig. 5: The rate per 1000 ASY of non-fatal crash reports was consistent across all types, with only the SZD-50 showing LoC as a significant component of these data.

is possible, but there is no evident reason why this would favour four gliders over one such that the result is invalidated.

(c) A significant design and performance difference between the SZD-50 and the other gliders was the relative ease with which the SZD-50 could be placed into a spin. Anecdotally, this was an intentional design feature to improve aerobatic performance. The other 4 glider types were considered spin resistant, with that conclusion backed up by USAF flight testing for at least one of the other types (DG-1000). Whatever the physical features that produce these differences, safety improvement has resulted for spin resistant types and should be actively pursued for future glider designs.

2. **Has the gliding fatality per year involving LoC reduced over time?**

   (a) For the small set of training gliders considered there was no observable decrease or increase in the annual rate of fatal crashes involving LoC across the 3-decade period from 1986 – 2016, which is dominated by SZD-50 crashes. Apart from the relatively small sample size, further research as to why that has occurred, despite significant safety initiatives such as the BGA effort on winch launch crashes and the implementation of safety systems stressing threat and error management, would require substantial additional data on the relevant risk factors.

3. **Is the Aviation Safety Wikibase facilitated by the Aviation Safety Network (ASN) a useful resource for gliding safety research?**

   (a) With significant qualifications, the ASN Wikibase was able to provide useful data on the in-service crash history of the selected glider types and some of the crash categories. This showed safety benefits of certain design approaches that differ between glider designs, but still all comply with the certification standard. Two qualifications about ASN Wikibase included the need for a large sample size of gliders in the fleets considered and the need for many years of data across the global gliding community. Where no reports of crashes were found for countries known to operate large fleets, such as the large fleet of Blanik L-13 gliders exported to Russia, the ASN Wikibase cannot be reliably used to study safety outcomes.

   (b) However, ASN was not considered useful in studying risk factors that might be relevant for the causes of the crash or the causes of the injuries or deaths that resulted. Even professionally produced accident reports by national aviation or accident investigation agencies did not often contain much or any data that would allow study of systemic risk factors. An example is the lack of specific injury data or causes of death, meaning no data to evaluate improvements in cockpit crashworthiness design that could mitigate injuries. Another limitation was the rudimentary search function on ASN Wikibase that is limited to exact text search characters in several data fields and only outputs pages of about 60-100 records per page.

   (c) We found no other database that was useful for safety research by glider type, nation, or crash category. There was no consistent database with sufficient reports across the world that included possibly relevant factors contributing to the crash occurrence or the resulting injury outcomes.

   (d) As a result of our experience with ASN Wikibase, we make the following recommendations for a future global safety database of gliding crashes:

      i. Develop, as a minimum viable system, a global safety database that includes only incidents resulting in fatal and serious injuries to enable easy compliance and consistency of reporting, rather than including all safety incidents as needed for modern safety management systems.

      ii. At a future stage include a full range of comprehensive safety incident reports, even down the severity scale to procedural non-conformances, that support analysis of all relevant risk factors, which will require enormous resources and international collaboration not yet seen. For example, a comprehensive global database for future research may need to provide data to support analysis of potentially relevant and possibly unquantifiable risk factors for fatalities in LoC crashes, such as:

         - age: health factors like bone or muscle strength, co-morbidities
         - experience, currency, pilot proficiency
         - fitness for flight: health factors, dehydration, mental health, medications
         - type of glider: spin resistant, easily spinnable, cockpit crashworthiness, total mass and energy
         - pilot and club attitudes to safety
         - pilot discipline and focus,
         - pilot awareness of threats and error management,
         - national, club and pilot spin training regime and proficiency (recognition and recovery, number of spins, currency),
         - proximity to terrain,
         - phase of flight (winch, landing),
         - weather

Conclusions

Within acknowledged wide uncertainty bands, the SZD-50 Puchacz was found in this study to have a fatal crash rate many times greater than other two-seat training gliders considered here for crashes that were assessed as definitely, or probably involving Loss of Control. The Puchacz was widely considered to be the only one of the five training gliders to be easily spinnable as compared to spin resistant. The spin resistance of future glider designs therefore should be maximised by all possible means to reduce this most common category of fatal glider crashes. Practitioners and consumers in gliding have previously had no reliable international information on the relative safety history of existing glider types. The ASN Wikibase was found to be a useful global database for specific research questions of this study, as well as the attrition rate for specific types. Much more extensive data would be needed from future incidents to facilitate safety research across all the potential risk factors. With the relatively small number of crashes, especially in any particular category, any database for statistically valid research would need to be global, or at least multi-national. Exposure levels to risks must be considered in determining crash rates by glider type. No flight hours or number of flights data was available across the global gliding community. In the absence of those normally accepted exposure metrics, we defined Aircraft Service Years as a broadly applicable measure of the relative fleet sizes and time in service for a set of two-seat gliders. This proved useful for calculating crash rates. After reviewing data from over three decades up to 2017 for the selected two-seat gliders, no discernible trends were found from the ASN Wikibase dataset in the number or rate of fatal crashes involving loss of control.

Acknowledgements

The authors would like to acknowledge the Flight Safety Foundation and the moderators and contributors to the Aviation Safety Network Wikibase for their diligence and foresight in constructing, populating, and maintaining the ASN Wikibase.

References

[1] Aviation Safety Network (ASN), "Aviation Safety Wikibase," accessed: 2018-05-12. [Online]. Available: https://asn.flightsafety.org/wikibase

[2] Boeing, "Statistical summary of commercial jet airplane accidents, worldwide operations 1959 – 2022," Boeing Commercial Airplane Company, Report, 2023, https://www.boeing.com/content/dam/boeing/boeingdotcom/company/about$_{b}ca/pdf/statsum.pdf$.

[3] Airbus, "A statistical analysis of commercial aviation accidents 1958-2023," Airbus SAS, Report, 2024, https://accidentstats.airbus.com/wp-content/uploads/2024/02/20230873$_A - Statistical - analysis - of - commercial - aviation - accidents - 2024 - version.pdf$.

[4] B. G. Association, "Safety briefing: Accident review 2015," British Gliding Association, Report, 2016, https://members.gliding.co.uk/library/safety/2015-accident-review/.

[5] D. Janzen and M. C. Precourt, "Schleicher ask-21 (tg-9) stall and spin evaluation," US Air Forcre Systems Command, Report AFFTC-TR-89-27, July 1989, https://apps.dtic.mil/sti/citations/ADA213513.

[6] T. McDonald, "And the world turned: spin testing the dg-1000s," US Air Force Material Command, Report 412TW-PA-15656, Jan 2016, https://apps.dtic.mil/sti/pdfs/ADA626043.pdf.

[7] M. Simons, *Sailplanes 1965 – 2000*. Bonn, Germany: EQIP Werbung and Verlag GmbH, 2004.

[8] C. Ortner, "Puchacz spin accidents – news," Google group message, https://groups.google.com/g/rec.aviation.soaring/c/PhIvwvg2b0E.

[9] UK Aircraft Accident Investigation Board, "AAIB Bulletin No: 1/2005," AAIB, Report, pages 90-110, 2005, https://assets.publishing.service.gov.uk/media/5a7f013940f0b62305b84880/B1-2005.pdf.

[10] R. Johnson and D. Carswell, "Additional Spin Testing of the SZD-50-3 Puchacz Trainer," *Soaring Magazine*, June 1994.

[11] EASA, "Certification Specifications, Acceptable Means of Compliance and Guidance Material for Sailplanes and Powered Sailplanes (CS-22)," European Aviation Safety Agency, Tech. Rep. Amendment 3, 2020, https://www.easa.europa.eu/en/document-library/certification-specifications/cs-22-amendment-3.

Appendix A

Crashes involving LoC continues as the largest category of fatal crashes in gliding

Several sources supported the contention that the number of fatalities or fatal crashes involving loss of control (spinning) of gliders continues to be the largest proportion of all fatal crashes or fatalities, at approximately 40-50%.

1. In 2017 the National Transportation Safety Board (NTSB) fact sheet on General Aviation accidents [A1] reported that "From 2008 to 2014, nearly 48% of fatal fixed-wing GA accidents in the United States resulted from pilots losing control of their aircraft in flight. During this time, LOC in flight accounted for 1,194 fatalities."

2. The BEA (French civil aviation accident investigation and analysis bureau) Safety Study 1999-2001 [A2] reported that out of 117 gliding accidents studied "Loss of control in flight (on take-off, in cruise or during landing) appears in nineteen accidents, which caused nine deaths and six injuries." This equates to 16% of the total accidents and 9 out of 20 total deaths, or 45%.

3. In a report to the OSTIV Training and Safety Panel 1992 [A3] Dr. Herbert Pirker of Vienna analysed 1272 glider accidents from the 1980-85 annual reports of the former Department of Aircraft Accident Investigation (FUS) of the German Federal Aviation Office (Braunschweig, Germany) to find that 91 accidents (7.1%) were reported as involving loss of control and 30 (43%) as out of the total 70 fatal crashes.

4. A British Gliding Association (BGA) submission to the UK parliament in 1999 on gliding safety [A4] showed that 8 out of 39 (20.5%) fatal accidents in the UK between 1987 and 1998 had "stall/spin" attributed as the "Cause". However, this study also used a category called "Launch failures" (10 fatal accidents) which may have included a substantial number of additional accidents where loss of control occurred. As an upper bound, 18 out of 39 represents 46% of all fatal accidents.

References for Appendix A

[A1] National Transportation Safety Board, "2017 Fact Sheet – Loss of Control," 2017.

[A2] Bureau d'Enquêtes et d'Analyses pour la sécurité de l'aviation civile, "Safety Study, Glider accidents 1999 – 2001," 2002, accessed: 2018-06-11. [Online]. Available: https://www.bea.aero/etudes/glideraccidents19992001a/glideraccidents19992001a.htm

[A3] H. Pirker, "How we could reduce fatal gliding accidents by about half," 1992, OSTIV Training and Safety Panel presentation.

[A4] P. Hearne, "Submission to UK Parliament "Gliding Safety 1999"," British Gliding Association, 1999, accessed: 2018-06-13. [Online]. Available: https://publications.parliament.uk/pa/cm199899/cmselect/cmenvtra/275/275ap46.htm