Comparison of collision risks with cables and parachutists, and other aerial hazards

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Summary: *We compare the risks of several different aerial hazards, the prominence given to them on aeronautical chart and, the vigour with which disregard is pursued. Glider winch cables are found to present the same risk of collision as parachute operations.*

1 Probability of collision

The calculation of collision probabilities is a well-known problem and straightforward if the colliding bodies are well-defined solids that follow randomly-distributed paths without active avoidance.

We define each object by a datum point, about which it has a given extent, so that a collision occurs if the datum of one object passes through a region about the datum of the other. For simplicity, we approximate the extent of an aeroplane to be a rectangle into which its head-on profile will just fit, and the parachutist by a rectangle that will just contain the canopy, lines and parachutist; a winch cable is taken to have length but no width. Viewed from a stationary cable or parachutist, the aeroplane travelling with speed *v* will in a given time *t* sweep out a volume of length *vt* and cross-section corresponding to the collision-determining region, defined by the extents or profiles of the aeroplane and colliding object, as shown in Fig 1.

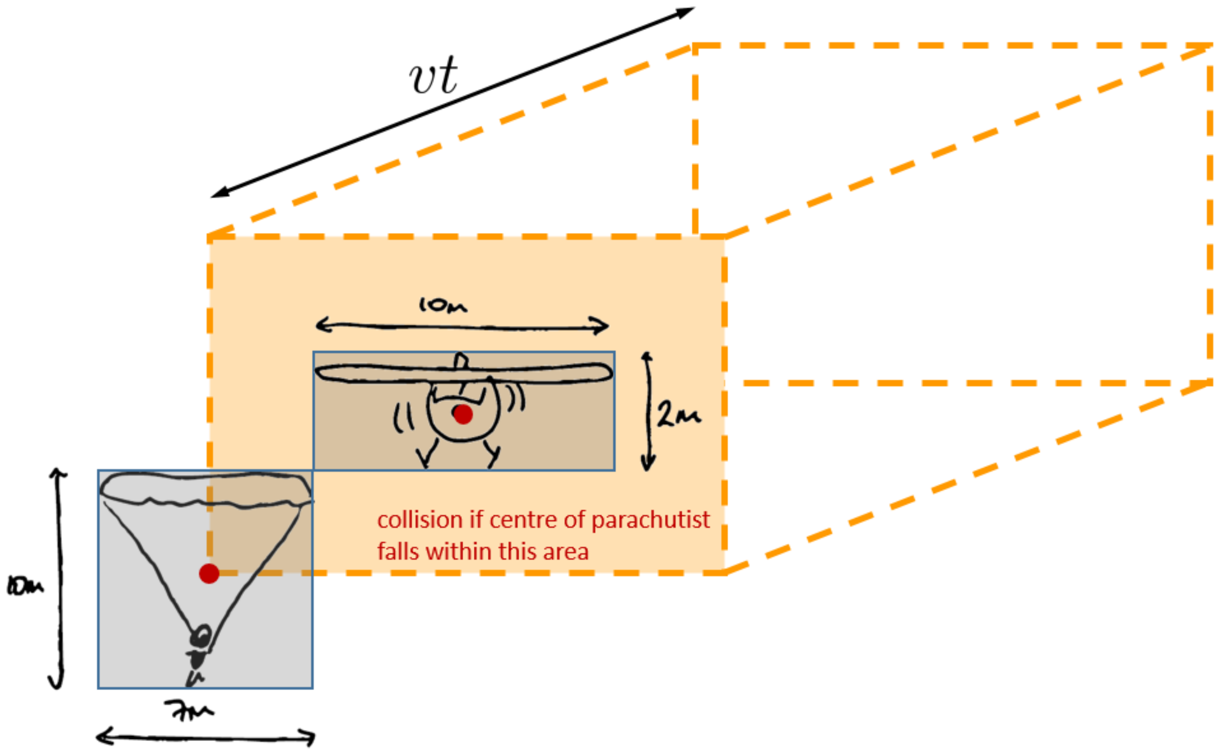


Fig 1 The object extents (grey) define a collision region (orange) which, when swept out by the moving aircraft defines the collision-determining volume (dashed): a collision will occur if the centre of the parachutist lies within this volume.

If there are *n* parachutists per unit volume, and the collision region has area A, then the probability of collision will be

$$p = nAvt \quad (1)$$

where, strictly, *v* is the relative speed of the aircraft to the parachutist. The density of parachutists may be written in terms of the number of jumps per annum N, duration τ, volume of airspace containing them *V* and period T in which all this occurs, as

$$n = \frac{N\tau}{VT}. \quad (2)$$

Writing the distance flown d in terms of the aircraft airspeed v_A,

$$t = \frac{d}{v_A} \tag{3}$$

yielding

$$p = \left[NA\tau\frac{v}{v_A}\right]\left[\frac{d}{VT}\right] \tag{4}$$

where the second bracketed term depends only upon the volume of airspace considered, the duration considered, and the distance flown in that time. For a relative risk comparison, we need only consider the first bracketed term which for convenience we give the letter *F*.

Parachute jumps are assumed to comprise a 60s freefall from 15,000' to 5,000' and then a 5 minute parachute descent to the ground (mostly spent above 500') [1]. The aeroplane is taken to have a wingspan of 10m, height of 2m relevant to collision with a parachutist or winch cable and length of 4m for collision with a free-falling skydiver. Calculation for a typical winch launch shows that an average of 350m of cable is airborne above 500' for the 30s launch duration (see Appendix). Table 1 summarizes these assumed dimensions and resulting values of *F*.

It is seen that the risks of collision with a parachutist and winch cable are similar, and ten times greater than collision with a free-falling skydiver. It would need 50 UAVs to be continuously airborne above 500' in UK airspace to present the same risk.

	no per year	width	height	duration	v/v_A	F
aeroplane		10m	2m			
parachutist	250,000 [2]	7m	10m	300s	1	$1.5\text{x}10^{10}$ m^{2}s yr^{-1}
winch cable	145,000 [3]	0	350m	30s	1	$1.5\text{x}10^{10}$ m^{2}s yr^{-1}
UAV	50	1m	0.5m	cont.	1	$1.6\text{x}10^{10}$ m^{2}s yr^{-1}
	no per year	width	length	duration	v/v_A	F
aeroplane		10m	4m			
free-fall	250,000 [2]	2m	2m	60s	1.5	$1.6\text{x}10^{9}$ m^{2}s yr^{-1}

Table 1 Parameters for calculation of collision risks.

To estimate the absolute collision probability, we may take d to be the distance flown by UK GA aircraft per year, assuming 1.1 million hours per year [4] and an average airspeed of 90 kts; the airspace to be equal to a 5,000' layer over the 150,000 km^2 land area of England & Wales, and GA activities to be uniformly distributed over an average of 9 hours per day, giving

$$\frac{d}{VT} = \frac{1.1\times10^6\times90\times1852}{150{,}000\times10^6\times5000\times0.305\times365\times9\times3600} = 7\times10^{-11}\ \mathrm{m^{-2}s^{-1}} \tag{5}$$

This would suggest one collision per year of a GA aircraft with a parachutist and with a glider winch cable.

This estimate has assumed GA traffic, drop zones and glider winch sites to be uniformly distributed across an area the size of England and Wales, and within a 5,000' height band; it is probably more localized. It has assumed an average of 9h per day, which when weather is taken into account is probably excessive. These would imply that the calculated collision rates are underestimates. On the other hand, much GA traffic is likely to be in or near the airfield circuit, or in a familiar local area where hazards are known and avoided, suggesting an overestimate. If winch and parachuting sites are similarly situated, none of these considerations would affect the relative likelihoods.

Pilots may occasionally spot winch sites and parachutists in time to manoeuvre for avoidance, but the size and dynamic nature make this unlikely. It is likely therefore that the low actual number of collisions and close encounters is because many pilots are aware of the gliding sites and drop zones, and keep clear of them. It is therefore imperative to make the risks and locations as clear and well-known as possible.

1 Summary

There is no difference in risk between light aircraft collision with a parachutist and with a winch cable.

2 Hazard portrayal and promulgation

Pilots must take into account a variety of hazards when aviating cross-country. These are depicted on aeronautical charts and on electronic flight-bags that commonly draw their information from official data sources. Chart symbology has to achieve a combination of clarity, legibility and ease of use, so some compromises are inevitable. A selection of aeronautical chart symbols is listed in Table 2.

Gliding sites are indicated on aeronautical charts by a blue circle around the letter G, resembling and consistent with the symbols for other airfields and not unlike the symbol for a bird sanctuary. Glider winch sites are revealed only by the addition of text indicating the height AMSL reached by the cables. Pilots could be forgiven for overlooking these 1.5mm-high annotations, or interpreting the symbol as a ground feature and facility rather than an aerial hazard.

At least one popular electronic flightbag package shows winch sites by an outline of a glider in turning flight with a curved line above it, giving no intuitive impression of the cable hazard.

Parachute drop zones are indicated on aeronautical chart by an intuitively obvious symbol within a somewhat larger circle.

Transmitter masts and other such obstacles are indicated by relatively intuitive symbols with heavy lines and somewhat larger digits indicating the obstacle height. They are listed in the AIP and interpreted as collision risks by electronic flightbag software.

Other aerial hazards such as Danger Areas, gas venting and laser sites and HIRTAs are depicted in magenta, emphasized in some cases by diagonal or cross-hatching. Fig 2 shows that many pilots avoid these even when they present minimal danger.

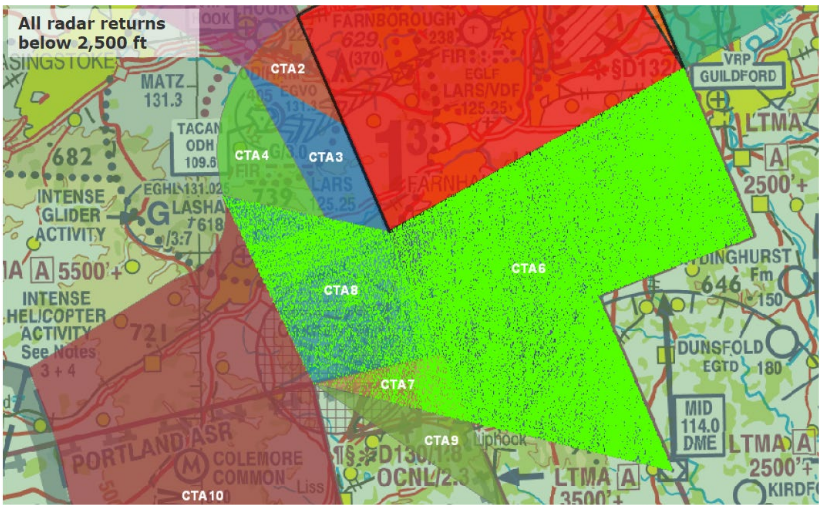


Fig 2 Radar returns show aircraft below 2,500’ routing around the Oakhanger HIRTA [5].

2 Summary

Chart and electronic flightbag representations do not make clear the presence and aerial risk of glider winch cables.

Representation of winch cables is closer to that of aerodromes (ie ground features and facilities and aircraft traffic) than to the more similar hazard of a mast or other obstacle.

Pilots route around more clearly presented hazards, even if they are less dangerous.

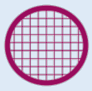
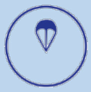
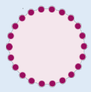
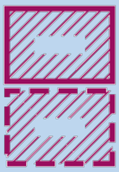
hazard	symbol	hazard
kite flying	NOTAM	2kg kite
bird sanctuary		10kg bird
BVLOS UAV	TDA	20kg drone
transmitter mast	825 (350)	500m structure
HIRTA		temporary instrument upset
gas venting	GVS/3·1	turbulence
laser site	LASER SITE/UNL	dazzle
gliding site	G	glider traffic
winch site	G /2.5	500m cable
drop zone		skydiver/parachute
FAAM aircraft	NOTAM	42t limited manoeuvrability BAe146
fast jets	NOTAM	pair of fast 28t GR4s
ATZ		aircraft traffic
restricted area prohibited area danger area		security/intrusion/espionage/ rockets/artillery/…

Table 2 Chart symbols for a selection of aerial hazards.

3 Perceived gravity of airprox

The AIP ENR section 1.1 para 5.5.4.3 states that

> *Visual sighting of free-falling bodies is virtually impossible and the presence of an aircraft within the Drop Zone may be similarly difficult to detect from the parachutists' point of view. Parachute dropping aircraft and, on occasions, parachutists may be encountered outside the notified portion of airspace. Pilots are strongly advised to give a wide berth to all such Drop Zones where parachuting may be taking place.*

Similar advice could be offered about the difficulty of spotting winch cables or of avoiding a glider in the process of a winch launch, but there is no such warning.

Generally, neither glider winch sites nor parachute drop zones are controlled or restricted: there is nothing to prevent aircraft from entering such regions. Nonetheless, pilots have been prosecuted for contravening the fundamental rules of safety.

Within the last decade, for which helpfully detailed information is available, there have been two prosecutions for entering drop zones and two for entering winch sites (see Table 3). A close airprox had occurred in each case. Notably, those in drop zones were considered to have endangered the parachutists, whereas those at glider winch sites were for the more technical offence of entering an ATZ without authorization. It is notable that no prosecutions have resulted from similar overflights of winch sites not protected by ATZs, and that the prosecutions concerned only military airfields.

year	pilot	aircraft	site	activity	offence
2019	S Coe	C152	Syerston	gliding	entering ATZ
2019	M Morris	A109	Ternhill	gliding	entering ATZ
2018	L Ingram	DR400	Netheravon	DZ	negligently causing endangerment
2012	S Rogers	BE58	Middle Wallop	DZ	negligently causing endangerment

Table 3 Prosecutions for flight near gliding and parachuting operations.

BGA records dating back to 1974 contain details of two collisions between light aircraft (one involved in gliding activities) and winch cables (see Table 4).

date	aircraft	site	consequence
8.1.77	AA-1B	Doncaster	aircraft destroyed; serious injuries
12.1.92	PA25 tug	Bowland Forest	substantially damaged in cable-induced groundloop

Table 4 Light aircraft collisions with glider winch cables.

It is not known how many collisions there have been in the UK between light aircraft and parachutists; we know of one accident (1 June 2002) in which a glider collided with a parachutist operating from the same site, killing both parties.

3 Summary
Substantially greater written and practical emphasis is currently given to avoiding parachute drop zones than to avoiding glider winch cables.

[1] https://ukskydiving.com/faq/what-height-does-the-parachute-open/
[2] House of Commons Transport Committee, HC163 *The Use of Airspace: fifth report of session 2008-09*, p233-4 (2009)
[3] Annual Statistics Oct 17 – Sept 18, *Sailplane & Gliding* pp62-3 (June/July 2019)
[4] *Strategic Review of General Aviation in the UK*, CAA (2006)
[5] NATS, *Farnborough ACP Support GA Levels Analysis* in *Farnborough ACP Appendix N* (Feb 2015)

Appendix 1 Estimate of mean winch cable length above 500’

To estimate the hazard presented by the winch cable, we have taken 6 flight logger recordings of winch launches, chosen at random from personal records. These were from 3 different launch sites (Bicester, Weston-on-the-Green, Lasham) on 4 different days. For each data point, recorded at 4 s intervals, we have determined the height and position relative to the approximate winch position (using knowledge of the customary position for the launch direction), as shown in the figure below.

For each point, we have then calculated the straight-line distance from the glider to the winch, and determined the fraction of this above 500’ AGL. The sums of these values, multiplied by their durations (ie the integrals of the cable length with respect to time) varied from 21,000 ft s to 41,000 ft s, with a mean of 35,000 ft s, equivalent to 350 m for 30 s.

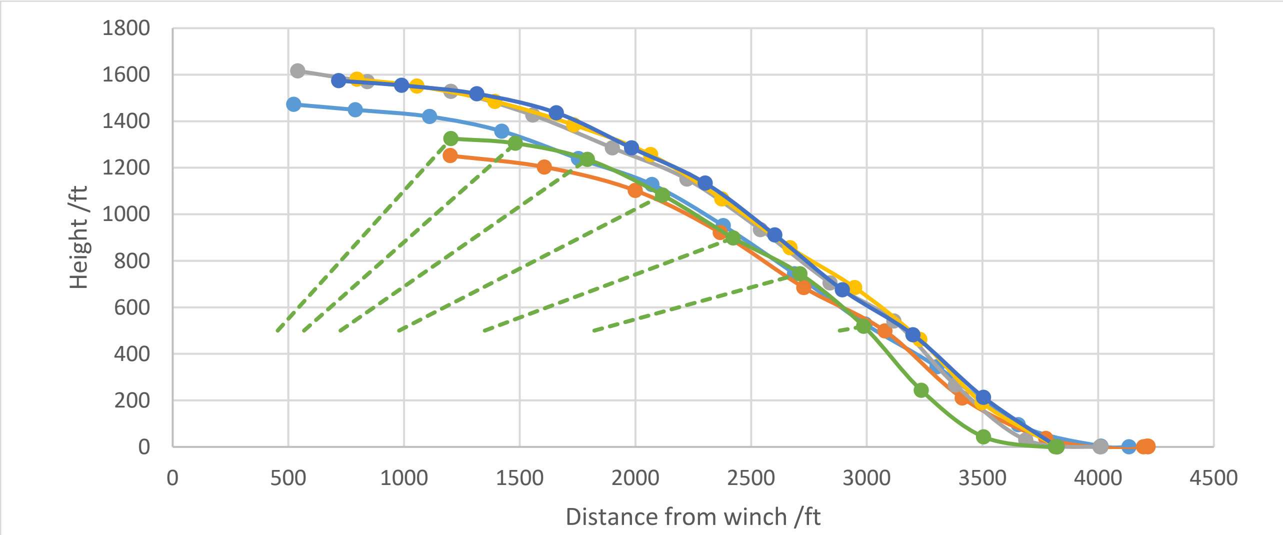


Fig A1 Flight profiles for 6 winch launches from 3 launch sites, recorded by FLARM IGC loggers. The origin is the estimated winch position in each case. For the example of the green profile, dotted lines show the sections of winch cable taken to contribute to the collision hazard.

Note that we have approximated the hazard of the inclined, moving cable to be equal to that of a static, vertical cable. A more detailed analysis would result in a slightly different risk estimate, but of the same order of magnitude; the difference would be smaller than that made by other simplifying assumptions such as the airspace volume, distribution uniformity, and aircraft dimensions.