COLLISION POTENTIAL IN SAILPLANE COMPETITIONS

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INTRODUCTION

During the past few years, I have noticed an apparent increase in the risk of collision at our U.S. National 15-Meter Contest. This prompted me to identify and examine the parameters that influence collision risk and to quantify them to the degree possible.

This paper builds on the excellent work on collision probability published by Admiral Nicholas Goodhart in 1963. (ref. 1). This work evaluated the risk of Glider/Airliner collisions over the United Kingdom. At that time they were averaging about 30 airliners and 0.35 gliders airborne over all of Southern England (about 25,000 square miles). By using a series of reasonable assumptions, Admiral Goodhart was able to show that glider/airliner collisions should be separated by several hundreds of years. The Air Ministry apparently found the risk acceptable because gliders are still flying over Southern England.

In contrast to the rather sparse population of airliners and gliders over the U.K. in the early 60's, a typical National Contest in the United States has up to 70 gliders concentrated wtihin a few miles of the start gate (sometimes all in one or two thermals). The gliders stay in close proximity for about an hour before the start gate opens. I decided to apply Admiral Goodhart's techniques and compare his results to collision risk associated with a typical U.S. Nationals during the interval prior to the start of the day's task. This paper describes the methods and my assumptions and gives the results of that comparison as well as a parametric look at relative collision risk in terms of contest size, lift distribution, and some alternative rule options.

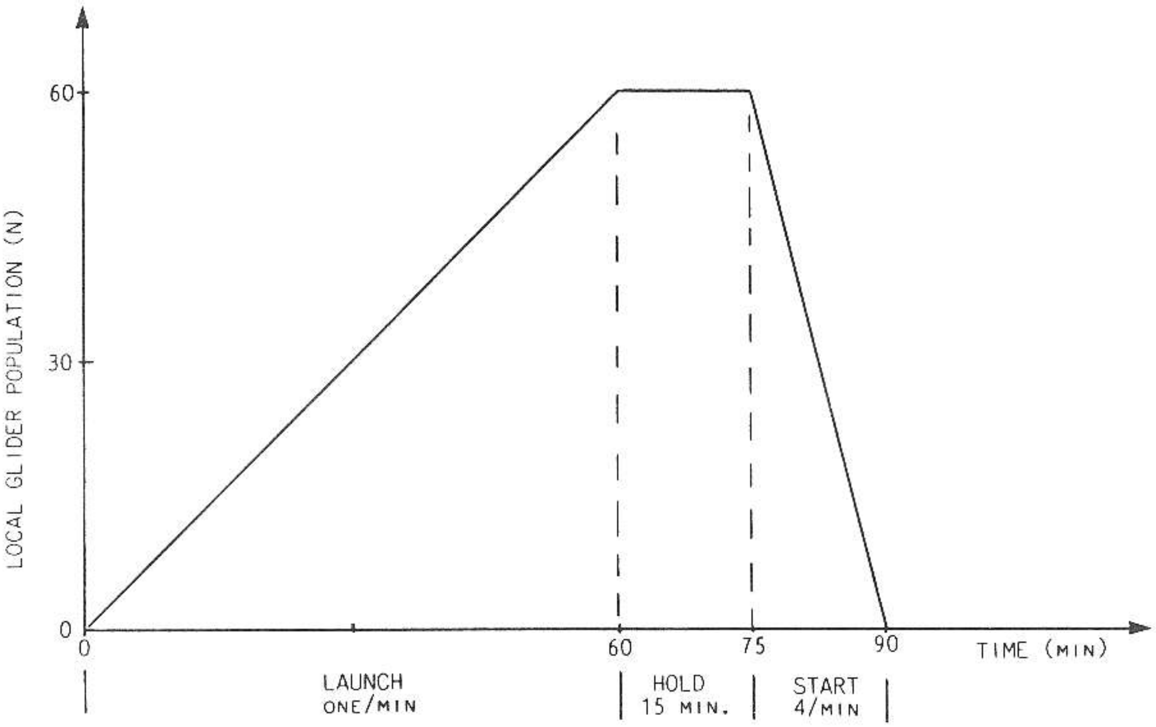
RISK ANALYSIS

The technique for establishing collision risk is based on probability theory. We start with the concentration of gliders operating within some volume of air space. Within that volume we first examine the random potential for conflict as if all pilots were flying blind, with no regard for each other. This establishes the expected number of times that some evasive action will be required. i.e. the number of chances for human error. If the concentration is very low, we will seldom be called on to see-and-avoid. If the concentration is high, we must maneuver to avoid collision more often and the situation is inherently riskier. In our daily flying experience, we often modify course to create a more comfortable separation. This is not what I am discussing here. Only rarely must we maneuver to avoid an actual collision. Fortunately, it is still a big sky.

It is relatively easy to apply probability theory to establish potential for random collisions. That is a purely mathematical process. It is far harder to assess the actual risk. Actual risk is defined as a probable number of collisions to be expected. This would be expressed as collisions per thousand participant-hours, collisions per contest, or some similar measure. Fortunately, in soaring, we do not have sufficient collision experience to quantify our actual risk. We are forced to rely more on the mathmatics and look at how many opportunities for collision we create in our soaring activities. If we reduce the probability that gliders will encroach on each other's airspace, then we reduce the number of times we must rely on our human ability to see-and-avoid.

The potential for random collisions depends on the following factors:

(1)	The volume of air space in use.	(V)
(2)	The collision cross-section (area) of participants	(A)
(3)	The speed of participants	(S)
(4)	The length of time they'remain exposed	(T)
(5)	The number of participants in the airspace	(N)



LOCAL GLIDER POPULATION VS. TIME
DESIGNATED START CONTEST
PRE-START PHASE

FIG. 1

The product of collision cross-section and speed A(S) is the rate at which one glider sweeps out volume. The factor A(S)/V is the fraction of the total volume swept by one glider per unit time. We can borrow from the kinetic theory of gas dynamics (ref. 2) to derive the expected number of collisions. Since I assume that all of the sailplanes move at about the same speed, the expression $A(S)\,(2^{1/2})\,{}^{(N)}\!/_{V}$ gives the number of times that one particular sailplane should encroach on the envelope of any other during a unit of time. Now we must realize that every sailplane is a target for every other sailplane and that it takes two to collide. If we multiply by ${}^{N}\!/_{2}$ we get the potential number of collisions between any pair of gliders per unit of time. Finally, multiplying by the duration of exposure (T) we get a very useful expression

$$P=A(S)\,(N^2)\,{}^{(T)}\!/_{2^{1/2}}\,(V)$$

Where: P is the expected number of random collisions if the pilots make no attempt to see-and-avoid. I call this the collision potential.

Now let us choose values for each of these variables that will relate all of this to a typical large contest situation. Then we can calculate collision potentials.

(1) The volume of airspace actually used prior to opening the start gate depends largely on the distribution of lift at a contest site. I have used two cases to examine the effect of lift distribution.

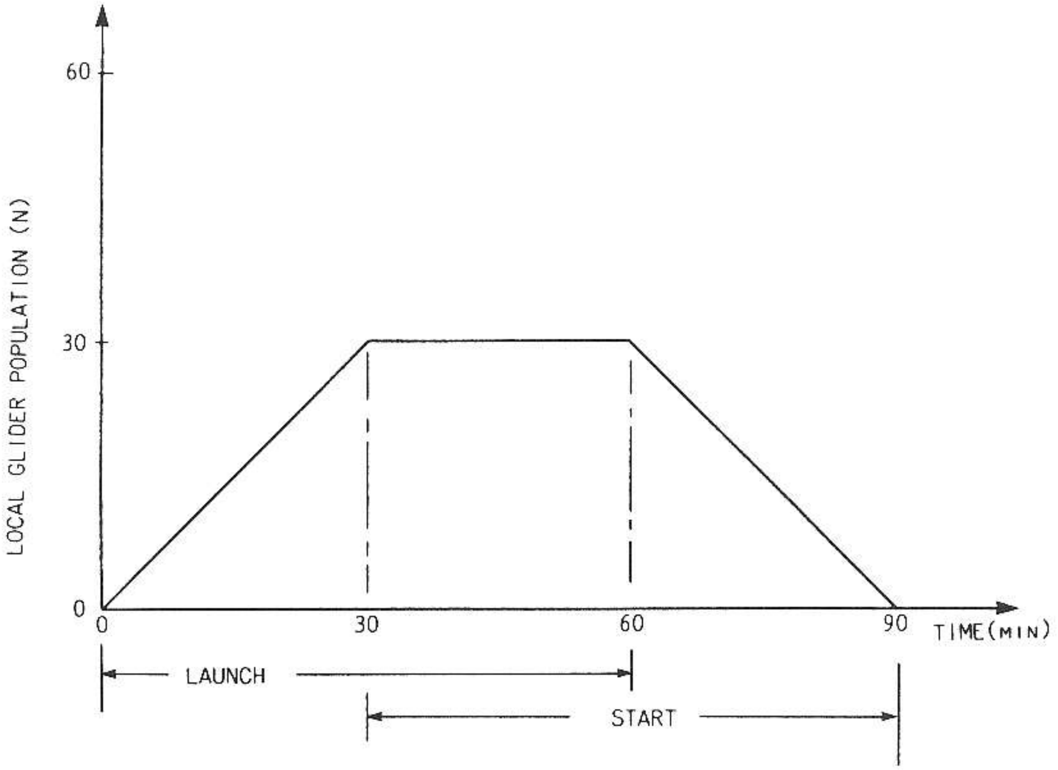
A. Abundant lift will let the contestants spread out. For this case I assume that they will distribute evenly over a circle of 5 mile radius and that most will be no lower than release altitude nor higher than 1000 ft. over the gate (a total depth of 4000 ft). This results in a control volume of $8.76\ (10^{12})$ cubic feet.

B. Sparse lift will require the contestants to share a few thermals within range of the gate. For this case, I assume that the contestants share only three thermals that are each 1000 ft. in diameter and are populated from release height to 6000 ft. This results in a much smaller total control volume of $9.43\ (10^{9})$ cubic feet. We immediately see that sparse lift, by these assumptions, can increase traffic density by about 900 times. Thermal tops below 6000 ft. AGL would further increase density.

(2) Collision cross section: This is very difficult to define with any accuracy. I have simply modelled a glider as a line equal in length to wing span. Then I assume that in each potential collision pair we have one ship in a 30 degree bank (vertical projection is one half span) and the other flying with wings level. Thus, two ships will collide if they are separated less than one span horizontally and one-half span vertically. For 15 meter ships this results in a collision cross-section of about 50(25)=1250 square feet.

(3) Speed: Prior to start, some gliders are thermalling and some are cruising between thermals. I assume that participants average about 60 knots or 6000 feet per minute air speed. This, combined with the collision cross-section gives a swept volume rate of $6000(1250)=7.5\ (10^{6})$ cubic feet per minute.

(4) (5) Exposure time and number of participants are closely related to each other in the situation under study here. During the interval prior to starting a race, gliders are entering and leaving the local airspace in a fairly well defined manner. We launch at a rate determined by towplane availability and performance, usually about one per minute. Under our current rules, in a designated start contest, the entire



LOCAL GLIDER POPULATION VS. TIME
30 MIN. FORCED START CONTEST
PRE-START PHASE

FIG. 2

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fleet must fly locally until 15 minutes after the last launch and then most pilots tend to start quickly when the gate opens. Typically the start rate is about 4 ships per minute. Thus, for a typical 60 ship race, the local glider population looks about like **Figure 1**. The number of gliders in the air space is a function of time. Therefore, the product $N^2(T)$ that appears in our equation for collision potential must be replaced by the integral expression $\int(n^2)dt$. Thus, our expression for collision potential during one day of a national contest becomes

(1) $P_0 = A(S)\int(n^2)dt / 2^{1/2}(V)$

THE EFFECT OF LIFT DISTRIBUTION

We are now in a position to evaluate equation one using the local glider population shown in Figure 1. We will do this first for the case of abundant lift and then for sparse lift. The integrated portion of the expression is the same for both situations. We integrate by parts over the entire pre-start interval to get $\int(n^2)dt = 1.44(10^5)$ glider-squared minutes.

Using this result in equation (1) we get

$$P_0(\text{abundant lift}) = 1250(6000)(1.44)(10^5) / 1.41(8.76)(10^{12}) = 0.087$$

$$P_0(\text{sparse lift}) = 1250(6000)(1.44)(10^5) / 1.41(9.43)(10^9) = 81.2$$

The ratio of these two results show that only one contest day of launching into sparse lift where the entire fleet must loiter in three local thermals presents as much potential for collision as about 900 contest days with well distributed abundant lift in the local contest area. Stated another way, flying one contest day in really marginal lift conditions represents as much risk of collision as ten or twenty years of contest flying with abundant, well distributed lift.

Recognizing this fact, we may consider steps to mitigate the situation. For example, we might decide to cancel days when the sniffer can not climb to gate altitude or finds only one or two thermals in the local area. Alternatively, on these days, we might modify our rules to encourage dispersion of the fleet immediately after launch. Possibilities here include calling a distance task rather than a race, starting a race immediately upon release from tow, or forcing a start within some fixed time after launch.

FORCED START

We can use the calculated collision potentials to examine the benefit of these alternatives. For example, the 30 minute forced start rule has been tried in several Western U.S. contests. These rules allow each contestant only 30 minutes in which to start on course. Point penalties are assessed for exceeding the interval and the clock can only be restarted by landing. For a 60 ship race, the local population profile for the forced start looks about like **Figure 2**.

The launch again proceeds at one ship per minute until all 60 are launched. The starts, however, begin after only 30 minutes and ships enter and leave the airspace at the same rate so the local population holds constant until the launch ends. The local population decreases as the remaining contestants climb to gate altitude and start on course.

Using this new population profile, we can again apply eqn. 1 to evaluate collision potential for the forced start. Integration over Fig. 2 gives: $4.5(10^4)$ glider-squared-minutes.

So: $P_0 = {}^{1250(6000)(4.5)(10^4)}/_{1.41(8.76)(10^{12})} = 0.0273$

Comparing this to our base case result of 0.087 (current rules with abundant lift), we see that the forced start can reduce collision potential to about one third that of the designated start. Starting immediately upon release is better but it produces only a slight further reduction in collision potential.

CONTEST DURATION

So far we have confined our calculations to only one contest day. Knowing the collision potential for one day, we simply multiply by nine (9 day contest) to get the collision potential (P_c) for an entire nationals. For our base case of current rules and abundant lift:

$P_c = 9p_0 = 9(0.087) = 0.783$

This tells us that during a 60 contestant nationals with 9 days of good lift we will expect there to be nearly one opportunity for collision. Given a reasonable degree of pilotage, the actual risk of collision should be orders of magnitude less. Even with two large Nationals per year, we should expect to go for several years between collisions in a U.S. Nationals.

CONTEST SIZE

Note that in our equation for collision potential, the number N appears squared. From this, we expect that contest size is a critical factor in determining collision potential. To examine this, we express collision potential as a function of the number of contestants. Assuming abundant lift, current rules, and nine contest days we integrate over the population of Figure one and combine constant terms to get:

$P_c = 5.47(10^{-6})[{}^{N^3}/_3 + 15N^2 + {}^{N^3}/_{12}]$

Figure 3 shows a graph of this pre-start collision potential vs. the number of contestants (N). The square law effect is apparent. For example, increasing contest size from 60 to 70 contestants increases collision potential by about 50%.

CONCLUSIONS

In this paper I have shown that the concept of collision potential can be useful for analyzing and comparing the risk of alternative situations in today's competition flying.

One important result is that if our flying is done with good lift that allows dispersion of the fleet prior to starting we should expect to go several years between collisions during our large national size contests. While this is far more often than the glider/airliner collision potential found by Goodhart, it is probably consistent with risk inherent in other action sports.

The number of contestants has an important bearing on the risk. Compared to a nationals, the average regional contest with 20-30 or fewer per class, and sequential class launching, has insignificant risk, as long as the lift is dispersed. Risk increases dramatically with number of contestants so that a modest increase from 60 to 70 contestants will increase risk by over 50%.

Lift distribution has by far the greatest influence on the potential for collision during the pre-start phase of a contest. Marginal lift that forces all ships to concentrate in a few thermals can increase collision potential by two or three or-

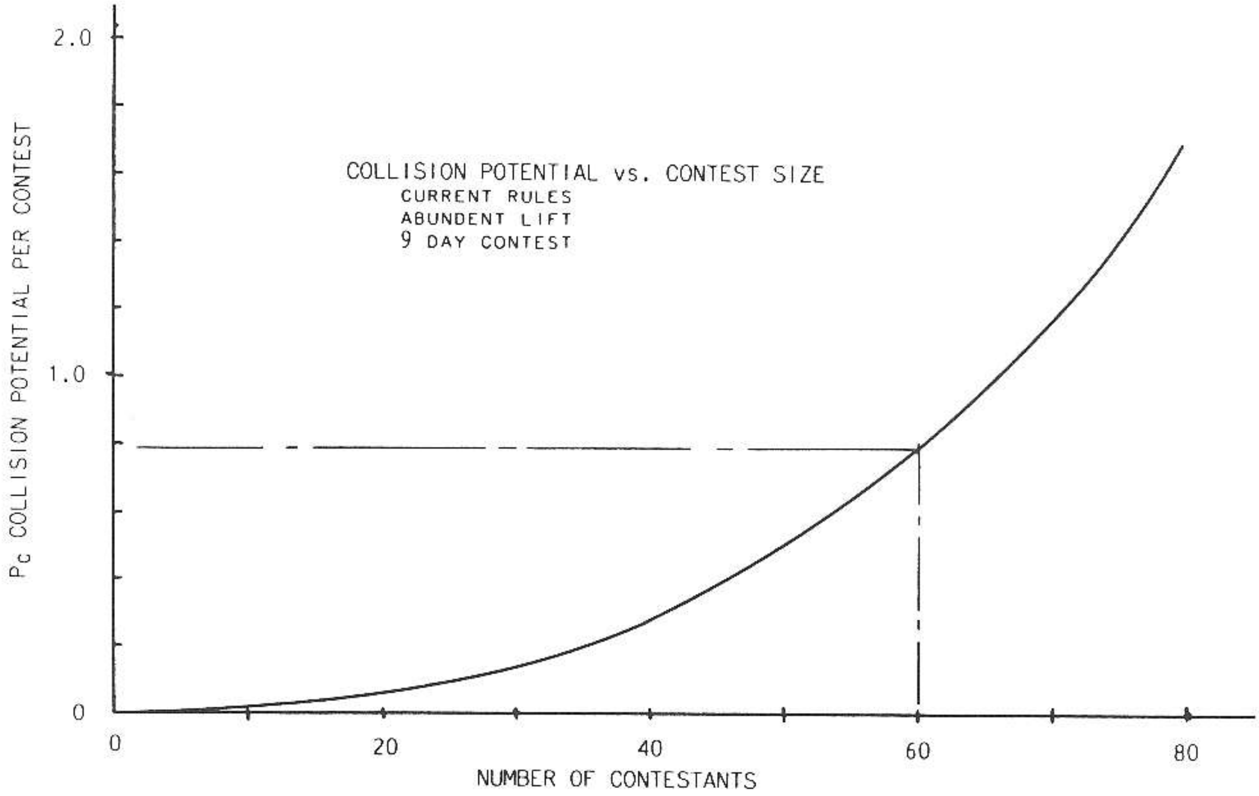

FIG. 3

ders of magnitude. Thus, just one day of poor lift can change the probability of collision from one in several years to much greater than one per contest. If we continue to fly on marginal lift days in large contests with the current designated start rules we can expect to average one or more collisions per year.

In this paper, I have confined my calculation of collision potential to the rather well-organized pre-start portion of the contest day. We should not forget that there are other situations that promote crowding. These in general are less predictable and are harder to analyze but perhaps no less serious.

The current practice of continuous gaggle flying increases our cross-country speeds dramatically, but it also tends to concentrate sailplanes during the entire flight.

Each turn point is also a point of increased sailplane density.

The lone cloud midway on course draws sailplanes like a magnet. Further, we are tempted to hang on to this lift until we are nearly flying blind. If we do, we lose the ability to see-and-avoid so that actual collision risk becomes identically equal to the calculated collision potential. You can very easily drop your survival odds dramatically in this situation.

Learn to recognize these situations; recognition of risk is an essential prerequisite to minimizing risk.

On rare occasions we can expect to encounter a confluence of factors that greatly increase the collision risk. The combination of large contest enrollment (70 ships), sparse lift in the local area, restricted altitude range, and aggressive tasking which force group starts and group flying all came together at the 1984 15-Meter Nationals at Ephrata, Washington. The result was 3 mid-air encounters, including one minor scrape, three ships with major damage, and one fatality. It was obvious to those of us who participated that the risk had increased dramatically.

It is imperative that contest pilots, competition rule makers, and especially the task setters realize the importance of risk management. Contest size should be controlled, and pilots must recognize risk-prone situations. Most importantly, designated start races should not be used when sparse lift restricts the distribution of gliders. Alternatives such as the forced start, start at release, distance, or even rest days are far more appropriate.

As competing pilots, we have to share thermals so we must treat them as community property. If at any time, the traffic density increases to the point where you are forced to maneuver to avoid immediate collision, then the risk has become unacceptably high.

REFERENCES

(1) Goodhart, N. 1963. The probability of collision between a commercial aircraft and a glider. Sailplane and Gliding, Feb. 1963.

(2) Vincenti, W., Kruger, C. 1965. Introduction to Physical Gas Dynamics. John Wiley and Sons.