A MONTE CARLO APPROACH TO COMPETITION STRATEGY

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The classic MacCready approach to maximize cross-country soaring speeds has many drawbacks. Pilots race to get maximum scores, not to maximize speed over a short length of a course. Maximum scores require a consistently high average cross-country speed, but absolutely no landouts in a typical contest. If a pilot refuses to accept weak lift, he will have a good time almost regardless of the speed at which he flies. This presumes that he will make it around the course, however. Real strategy is not so simple. Variables which must be taken into account other than the strength of the next thermal are the following:

1) Height of clouds
2) Distance between thermals
3) Time of day
4) Water ballast
5) Present altitude
6) Weather changes
7) Lift organization
8) Distance to goal

This list is neither complete nor arranged in order of importance. Most competition pilots recognize these factors and attempt to take them into account in their decision making. The biggest problem, however, is how to quantitatively make trade-offs between these factors.

In an attempt to model these factors, a three-dimensional model of the atmosphere was created mathematically, and simulated sailplanes were "flown" on hypothetical tasks which consisted of a start, soaring flight to a turn point, soaring flight back, and a final glide to the goal. The solar heating curve was taken into account, and after a trigger temperature was reached, thermals were created at random whose strength varied but depended on the difference between the trigger temperature and the ground temperature. These thermals were created at ground level and had a fixed horizontal and vertical extent. The thermals were of elongated vortex ring type and their typical vertical velocity distribution is shown in figure 1. These thermals ascended at a speed equal to one-half their maximum vertical velocity component in the center of the thermal, yielding several realistic phenomena. The slowing down as the top of the thermal was reached and the dropping out of the bottom of the thermal if one was too low are two such phenomena. A shell of sink surrounded each thermal to make the total vertical movement of air zero. There were four stages in the visible life of the thermal. First they were invisible; second as their tops neared the cloud base, they became wisps. Next, as their centers reached the cloud base, they became mature clouds, and finally as their bottoms reached the cloud base, the clouds began dissipating. These four states of visibility were used for pilot decisions.

Sailplane performance was based on a quadratic polar, and the two constants were taken to be maximum L/D and speed at maximum L/D. Water ballast was taken into account by increasing the speed of maximum L/D as the square root of the wing loading, which affected both cruising speed and circling speed. The thermals were centered as they were encountered, typically taking two circles to completely center the thermal. The final glide was started whenever the sailplane was within 2/3 of the maximum glide angle of the final goal, but the sailplane was allowed to climb longer if time could be saved by doing so. On a typical flight, the positions and velocities of the thermals in the atmosphere, as well as those of the sailplane, were updated every second, so that a two hour flight would typically involve 7200 updates of over 100 thermals as well as the position, cruising speed, altitude, and direction of the sailplane.

The two fundamental decisions were whether or not to circle and where to head next. All circling decisions were made by a speed-ring setting, and similarly all cruising speeds through sink or lift were determined by the same setting. The decision about direction was determined by the present state of the visible clouds and the direction to the goal. All clouds were ranked according to their stage of development, distance from the sailplane, and how close they lay to the course line.

A typical day was determined primarily by the thermal strength and the cloud base. Thermal heights were correlated with strengths by using the relationships in Charles Lindsay's pamphlet on soaring meteorology. The number of thermals which were chosen to reside in the area of interest was determined by their spacing which was taken to be 2-1/2 times their height. The actual positions were determined at random, although in some studies these positions were correlated to form cloud streets. Usually 50 sailplanes were launched through the start gate within 20 minutes of each other, each one having its strategy defined through some speed-ring setting procedure. These flights were scored by using a simple approximation to the rules for scoring national championships. Basically, the fastest flight got 1000 points, and the rest of the finishers were scored proportionately. Those who landed out got 400 points multiplied by the fraction of the task distance completed. No relights were permitted. Usually 10 days of statistically equivalent weather were flown. This is equivalent, roughly, to one national championship flown to evaluate each strategy in each weather condition.

Several simple results became immediately apparent. First, water ballast should be carried even slightly below the speed break-even point. The reason is that the ability to cruise faster and achieve a greater fraction of the sailplane's maximum glide angle in sinking air increases the chances of completing the task. Second, the sailplane is most vulnerable to landing out when low, and for both speed reasons and greatest completion probability, the first thermal after the gate is critical. A good start enhances the score even more than the time saved since the few hundred feet difference between a good start and a mediocre start can easily be the difference between landing out and completing the course.

To illustrate a particular example, namely, the effect of setting the speed ring, a typical soaring day was chosen. Cloud base was chosen to be 6000 feet, and thermals ranged from 300 to 900 feet per minute with the average being about 600 fpm. The sailplanes were launched from 1:00 to 1:20 p.m. and had speed-ring settings ranging from 60 to 600 fpm. This was done for 10 days in which the detailed thermal locations, radii, strengths, and heights were shuffled, but on average the conditions remained the same. A 100 mile out-and-return task was flown. The effect of speed-ring setting on time to complete the task is shown in figure 2. The bars represent one standard deviation on the times. One conclusion is obvious: the higher the setting, the faster the speed. The conclusion, however, that the way to win is to fly fast and accept only great lift is erroneous. The reason is shown in figure 3. The percent of task completions drops off rapidly with a ring setting above 240 fpm. The fundamental trade-off between task completion and speed is obvious. Figure 4 shows that most days were won by pilots who flew with a ring setting of 360 fpm, but the total contest was won by a pilot who flew at a ring setting of 180 fpm. The reason for this is that each of the pilots who flew at higher settings landed out at least once during the 10 days. No one who flew at a ring setting of greater than 500 fpm made it around the course even once. The statistical results shown in figures 2 and 3 were then used to predict the distributions of winners of 1250 separate 1, 5, and 10 day contests made up of 64 pilots. The pilots were split into groups of 8, each group flying at 1 of 8 speed settings ranging from 60 fpm to 480 fpm. Figure 5 shows the results. In general, the longer the contest, the more conservative the winner. This is in keeping with the words of George Moffat who felt that to win a contest, you must first keep from losing it. The greatest probability of winning a single day lay in a speed-ring setting of 420 fpm, but the chances of landing out are nearly 80%. For a 5 day contest, the greatest chance of winning came with a ring setting of 300 fpm. This corresponds to most regionals. For a 10 day contest, the greatest probability of winning in this model lies in a setting of 180 fpm. The optimum strategy would lie in that setting which over an infinite amount of time would give the best average. Due to the extremely heavy penalty for landing out, this strategy is conservative. It makes no difference whether a pilot averages 950 over 9 days and lands out once for 200 points, or whether he averages 875 over the 10 day contest by flying more conservatively. Unfortunately, the optimum long range strategy lies between 800 and 850 points per day which is too little to win a short contest. Basically, to win a championship, whether it be regional or national, a pilot must take risks in excess of optimum long range strategy and have a little luck. The crucial assumption here is that all pilots are equally capable, but that there is an even distribution of conservatism and rashness expressed by a speed-ring setting. In reality, there are many different levels of ability in any single contest and no one flies 80 knots all the way into the ground. Nevertheless in some diluted form, it is felt that the conclusion is valid. One must push and be a little lucky in order to win. The shorter the contest, the harder one must push.

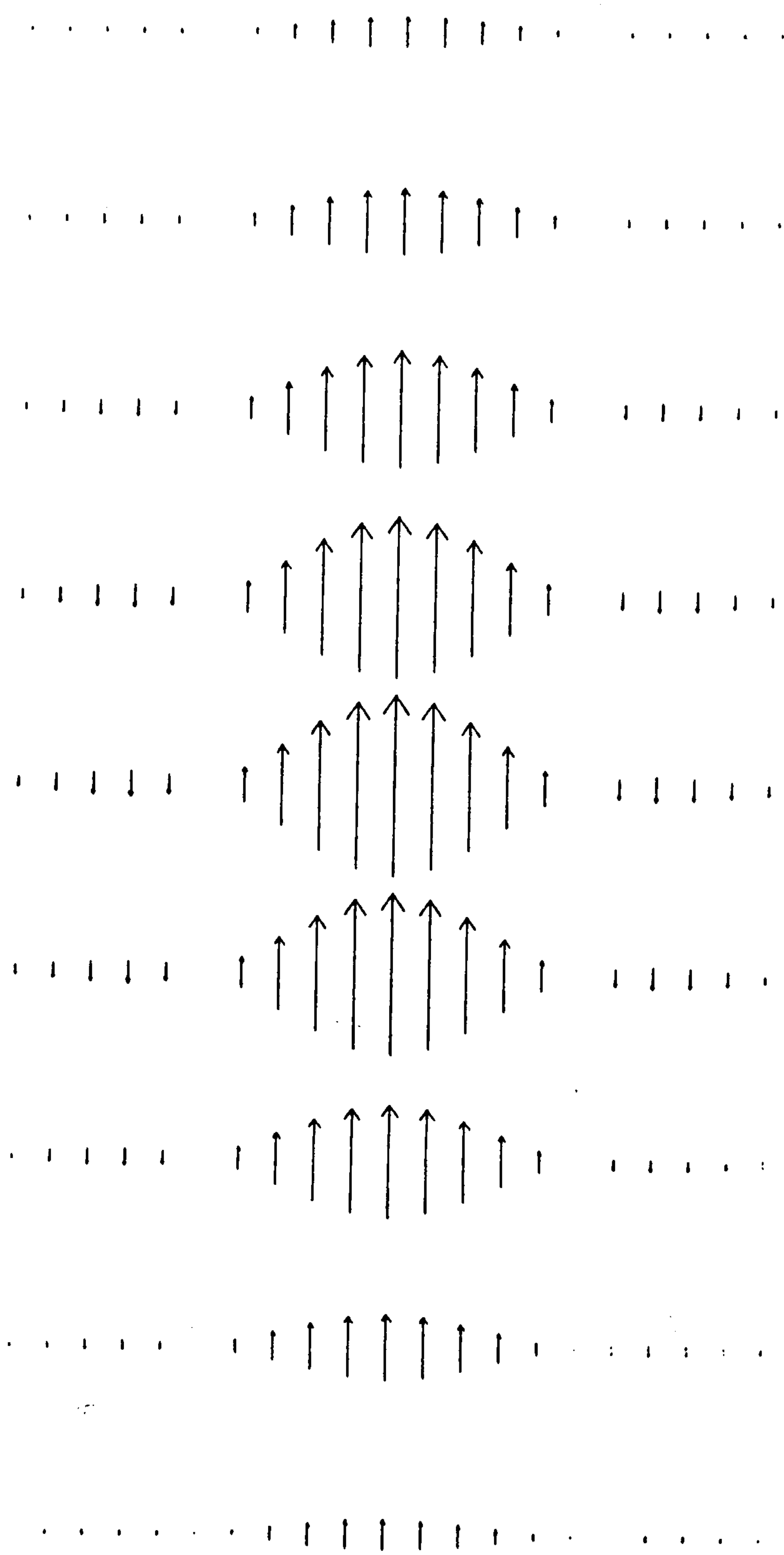

Figure 1.- Thermal structure.

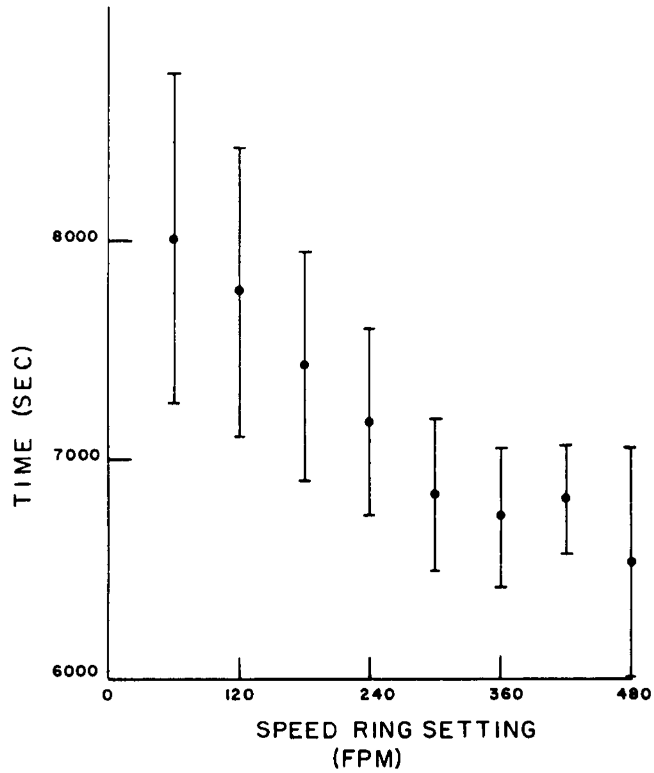

Figure 2.- Effect of speed-ring setting on time to complete the task.

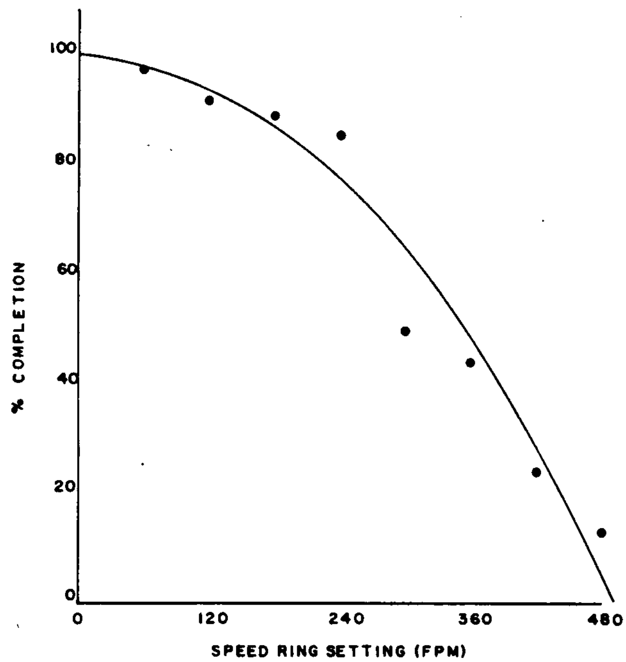

Figure 3.- Trade-off between task completion probability and speed-ring setting.

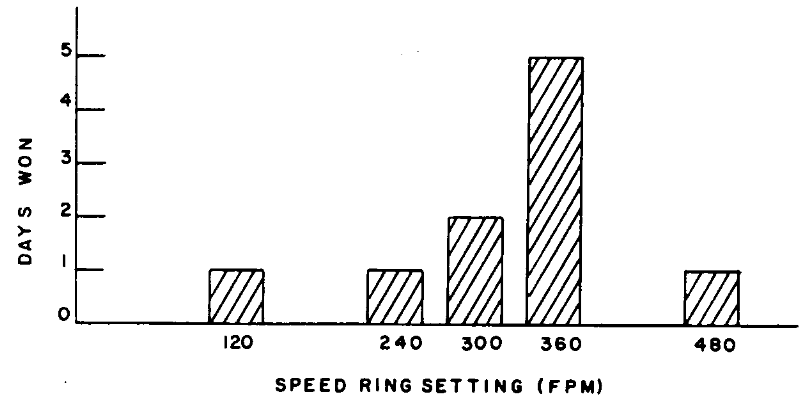

Figure 4.- Effect of speed-ring setting on number of days won.

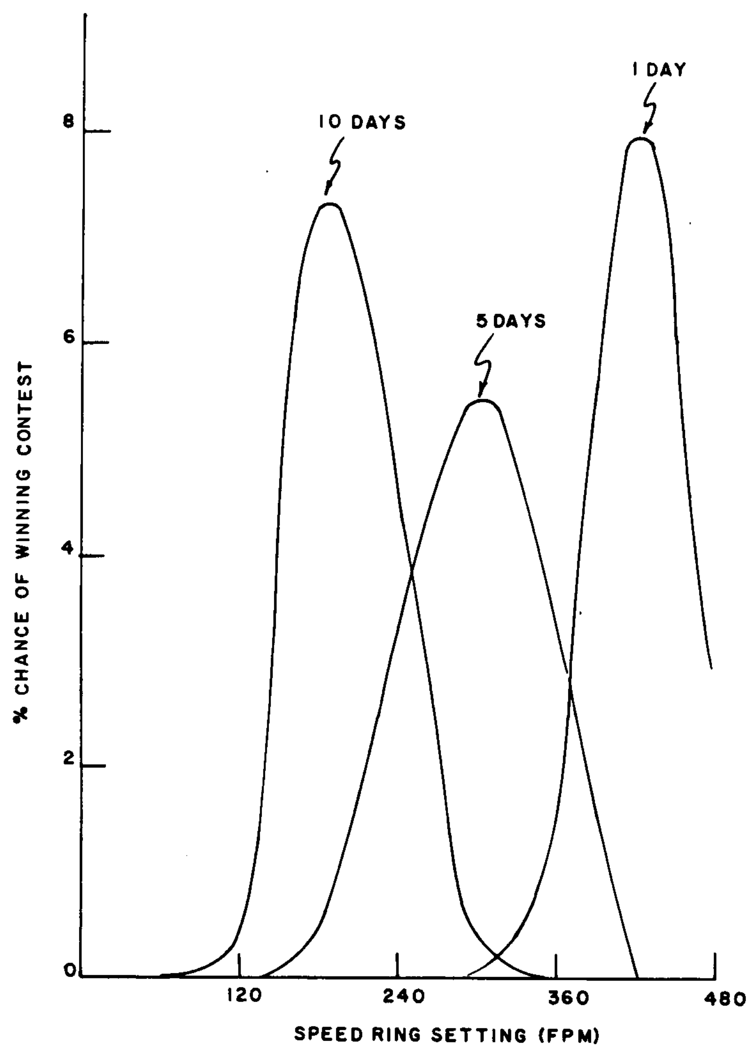

Figure 5.- Effect of speed-ring setting on statistical chance of winning.