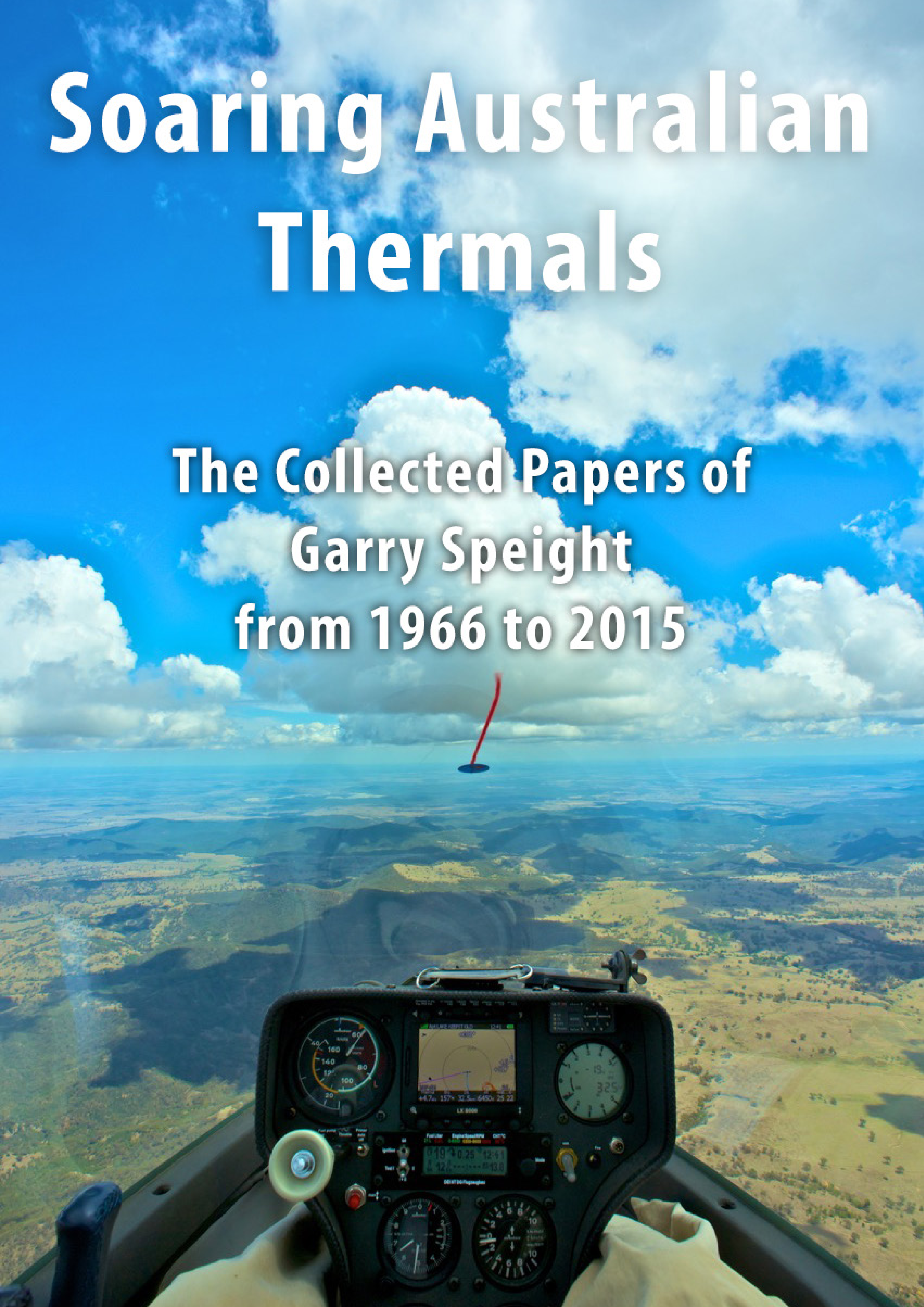
Soaring Australian Thermals

The Collected Papers of Garry Speight from 1966 to 2015



Rules For Leaving Thermals

By Garry Speight

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In a letter to S&G (October 1982, p230) I criticised a paper about MacCready theory by*1 Litt and Sander that had been summarised by Frank Irving (see "How Glider Pilots Get There Faster", S&G, June 1982, p.120). I said that Litt and Sander's model was so unrealistic as to be quite unhelpful. I have had to revise that opinion, which was expressed in the heat of enthusiasm about applying probability theory to cross-country soaring.

The assumption in the Litt and Sander analysis that bothered me most was that all the thermal strengths and inter-thermal distances were known to the pilot in advance. I now take Frank Irving's point that this assumption is acceptable if its use can lead to insight for real cross-country situations.

A more valid criticism of Litt and Sander's paper is that the analysis was not carried through to worthwhile conclusions.

Rules for Known Thermals

I will discuss the third of their four cases; the case in which the flight is confined between upper and lower altitude limits (as on a flight over a plain and under a sharp inversion) and each thermal has a known strength that is constant at all heights.

Litt and Sander conclude that the MacCready speed to fly between the thermals and the height to climb in each thermal should be chosen according to a set of seven rules. These rules embody a number of alternative procedures depending on the relative strengths of the current thermal and the next thermal and the distance between the thermals. Most pilots would find it difficult to memorise these rules and quite impossible, while flying, to recognise which rule is appropriate to the situation.

In a letter published in the October 1982 issue of S&G next to my own, Jan de Jong pointed out that the rules derived from the model can be reduced to four only. Jan de Jong's reformulated rules not only satisfy his stated aim of making them easier to remember but they are also well-structured, so that it is easy to follow their logic and to single out the controlling factors.

For convenience, I repeat Jan de Jong's reformulated rules here:

A. In any thermal, climb only high enough to reach a stronger thermal at Min altitude by flying with a MacCready ring setting equal to the present climb rate.

B. If there is no stronger thermal that can be reached following Rule A, climb to Max altitude and proceed with the highest feasible MacCready ring setting with which, at or above the Min altitude a thermal can be reached with a climb rate equal to or larger than that MacCready ring setting.

A1. In the last thermal climb only high enough to reach the finish at the Min safety altitude by flying with a MacCready ring setting equal to the climb rate in the last thermal,

B1. If the finish cannot be reached following Rule A1, climb to Max altitude and proceed with the highest feasible MacCready ring setting with which the finish at the Min safety altitude can be reached.

One can see that the rules refer to two kinds of distinction: whether there is a stronger thermal ahead, and whether one is aiming to reach a thermal or to reach the finish line.

On the question of the presence of a stronger thermal ahead, de Jong gives alternative rules that do not at first seem to be closely related to each other.

Rules For Leaving Thermals

Following Rule A, if there is a stronger thermal ahead the present rate of climb is the key. It controls both the inter-thermal speed and the height to leave the present thermal. One can see, however, that the inter-thermal distance is also involved, because the glide angle that is determined by the inter-thermal speed relates the height to the inter-thermal distance.

By Rule B, it seems that the present climb rate is irrelevant when there is no stronger thermal ahead. Instead one takes the thermal right to the top. Then one sets the ring on the strength of the next thermal or, if to do that would yield too steep a glide angle, one sets it on a lesser value that will give just enough range.

The two rules actually have a lot in common. The ring setting is equal to or less than the strength of both thermals in each case. Also one acts to ensure that the glide intersects the next thermal at or above the Min altitude.

The two rules can, in fact, be combined in a single rule by making a slight change to the original Litt and Sander model: one that does not materially alter the assumptions but merely specifies what happens at the top of a thermal. I propose that the glider's rate-of- climb at the very top of each thermal should diminish from its otherwise constant value to become the still air sink rate over a small but finite time period.*2

The effect of this change to the model is that, even in the case that there is no thermal ahead that is stronger than the present thermal, if one climbs to the very top there is *always* a stronger thermal ahead. As the thermal strength falls through low values of lift, more and more thermals qualify as "stronger". (In the limit, even the ground of an outlanding field is rising faster than the glider is when the thermal lift has fallen below zero sink!)

By this means the situations specified in Rules A and B are no longer distinguished. The rules may be replaced by a single equivalent rule:

When thermalling, as soon as it becomes possible to reach a stronger thermal by cruising towards it with a ring setting equal to the present rate-of-climb, leave the thermal and cruise at that ring setting.

This rule is a re-wording of Rule A, It is equivalent to Rule B because:

1. One should climb to Max altitude, since only then will the weak thermal ahead be stronger than the current rate-of-climb;
2. The meaning of the phrase "highest feasible ring setting" is specified by two conditions:
   a. Not higher than the strength of the next thermal;
   b. Not so high as to drop short of the next thermal.

These are both covered in the new rule, Condition (a) by the word "stronger" relating the next thermal to the current rate of climb (which specifies the ring setting), Condition (b) by the words "possible to reach".

The very good sense that can be brought out by developing the results of Litt and Sander's paper is evident in the rule given above. Cross-country speed depends directly on the strength of the thermals used for climbing. Clearly one should move on as soon as a stronger thermal comes within range at MacCready speed, and not before.

It is clear from the rule that the ring setting depends not only on the thermal strengths, but also on the inter-thermal distance. It is not surprising that this point comes up, for it is a consequence of the altitude constraints that Litt and Sander were studying.

Final glides

It remains to examine the significance of Jan de Jong's Rule A1 and B1, that refer to final glides. He rightly emphasises the formal similarity between these rules and the rules applying to the rest of the flight. The only significant change is that the words "the finish" replace the words "a stronger thermal" or other words referring to the strength of the thermal ahead. Rules A and B and the equivalent rule above specify how to increase one's cross-country speed by moving on to a stronger thermal as soon as it comes within range. One should continue to do this until there is no stronger thermal between the glider and the goal of the flight. It is clearly not possible to increase one's speed by making use of a thermal that is beyond the goal. The object then is simply to maximise the speed to the goal using the current thermal and the following glide. Even if there is a thermal right at the finish line, its strength is irrelevant and does not appear in the rules.

Rules A1 and B1 then also come down to a single rule; the well-known final glide rule. This rule may easily be incorporated in the other rule given above.

Combined rule

It is possible in this way to condense the advice arising from studying Litt and Sander's model into just one rule:

When thermalling, as soon as it becomes possible to reach either a stronger thermal or the finish line by cruising towards it with a ring setting equal to the present rate of climb, leave the thermal and cruise at that ring setting.

In a race on any day when the strength, location and height of every thermal is known, the pilots who follow this rule will dead heat for first place, at a speed which can be stated before the race begins. Each pilot could have calculated, as part of his flight plan, the height at which he should leave each thermal and the ring setting that he should adopt.

How the ring setting varies

The ring settings in Litt and Sander's examples are different for every inter-thermal glide. It is important to know what these settings relate to. First, they increase with thermal strength. The setting is always equal to, or less than, the strength of the weaker of the two thermals — the present thermal and the next to be used. Second, they decrease with increasing thermal spacing: whenever the thermals are too widely spaced to be reached at a ring setting equal to the rate of climb, a lower setting must be used. Third, the ring settings increase with the altitude at which the thermal is left. Both of the other two effects contribute to this. The stronger the thermals, the higher the ring setting. The higher the ring setting the steeper the glide angle and the higher the altitude required to get to the next thermal. Similarly, if a ring setting lower than the strength of either thermal is needed to get from the top of one thermal to the bottom of the next, the higher the top of the thermal is the steeper the glide angle and the higher the ring setting can be.

Thus, the ring setting varies directly with thermal strength and with altitude, and inversely with inter-thermal distance. We can be fairly sure that these relationships hold in real life as well as in Lift and Sander's model.

The variation of ring setting with attitude is particularly important. While one can perhaps get away with assuming that the thermals are all the same strength or the same distance apart, it is clearly ridiculous to assume that one flies at a constant altitude.

Critical rate-of-climb

On a cross-country flight, the pilot does not know where the thermals are, or what their strength is. Instead of setting the MacCready ring according to a known thermal strength and distance he must select the Max thermal strength that he considers he is very likely to meet before running out of height. Whereas in conditions of known thermals the use of the MacCready ring simply serves to maximise the speed, in real life it has another function of far greater importance: it distinguishes useful thermals from useless ones. As soon as one meets a thermal exceeding the MacCready setting, and not before, one should break off the cruise and circle. This is Anthony Edwards' Critical Rate-of-Climb principle, stated in S&G, October 1964, p364, as: set the ring to the rate-of-climb above which one would elect to circle. He has recently ("Proof of the Threshold Theorem", August issue, p.159) given a geometric proof that, once a ring setting has been selected, the cross-country speed will be increased by circling in lift that is greater than the ring setting and decreased by circling in lift that is less than the ring setting.

For real conditions the clause 'cruise at that ring setting" (until you get to the next thermal) should be replaced by "fly to that ring setting". This means not only cruise at the optimum speed, but also to circle if, and only if, one meets a thermal greater than the ring setting.

A practical rule

We now have the material for a realistic rule for leaving a thermal (and, incidentally, for commencing to climb in the next one):

When thermalling, as soon as it becomes almost certain that one can reach a stronger thermal or the finish line by cruising towards it with a ring setting equal to the present rate of climb, leave the thermal and fly to that ring setting.

Acceptable risk

In this rule the phrase 'almost certain" is not precisely specified, and should be varied in the light of experience. At least in Australian summer weather, I am inclined to suggest "odds 200 to 1 on" that one can reach a stronger thermal. One must be rather careful not to over-estimate the chance of finding a thermal within range for it it is not there one will be out of the race — aux vaches. "Two hundred to one on" sounds very safe, but it must be realised that this chance applies to every glide, and there may be more than twenty glides between acceptable thermals in one flight. This brings the likelihood of outlanding up to one in ten. It is up to the pilot to decide whether such a risk is acceptable or not. Any pilot who considers that the odds of Russian roulette (5:1) are good enough for each of twenty inter-thermal glides has only *one chance in forty* of getting home.

Implications

This rule for leaving a thermal is, I believe, correct. It gives valuable advice about this particular decision. It also expresses the things that a cross-country pilot needs to think about, in using energy from the sky to drive his sailplane:

• the need to find a better thermal
• the probability of finding such a thermal
• the dependence of thermal search range on MacCready ring setting
• the way the ring setting determines the acceptability of thermals
• the equivalence of the rule for thermal search and the rule for final glide.

*1 "Litt, F. X., and Sander, G., "Optimal Flight Strategy in a Given Space-Distribution of Lifts with Maximum and Minimum Altitude Constraints", OSTIV Publ. XV, (Chateauroux 1978)."

*2 For sink to occur, them must be a violation of Litt and Sander's stated assumption that the thermal characteristics do not change with time. However, I wish to eliminate the option of loitering on top of a thermal in zero sink, so I am postulating that if you try to do that the thermal will go away, and you will sink.