Safety Glides
John Cochrane
Draft 2/27/2012

"I don't get it," said the pilot as his crew was picking him out of the field. "The glide computer said I could make it home with 200 feet to spare! This stupid thing must be busted."

"No," his crew answered, "you set the MacCready to zero. You were guaranteed not to make it."

"Huh?" said the pilot, "I set the MacCready to zero to maximize my glide."

Crew explained: "If you had found lift, you wouldn't have landed. If you're not in lift, you're in sink. So the only way you will land is if you find sink and no lift. By using a zero Mc setting you are guaranteeing that if you land, it won't be at the airport."

"So how am I supposed to use this bloody thing?" Good question. Read on

Our glide computers are wondrous devices, but you have to know how to interpret their calculations. They are designed to maximize speed in a contest. They tell you how far you can go on average, if lift or sink cancel out. They can also help you to assess the safety of a glide, what if lift and sink don't cancel out. But to get that help, you have to learn to speak its language and interpret its numbers.

Lesson 1: Learn to speak MacCready

Many pilots think in of glides in terms of L/D values, or feet lost per mile. The computer speaks MacCready values.

	Dry ASW 27				Wet ASW 27			
Mc	Speed	Avg	L/D	Ft/mi	Speed	Avg	L/D	Ft/mi
0	55	0	48	109	67	0	48	112
1	65	31	46	116	79	35	45	117
2	73	44	41	129	89	51	41	127
3	80	53	36	146	97	62	37	141
4	87	60	32	163	105	69	34	156
5	93	65	29	181	113	76	31	170
7	104	74	24	218	127	85	26	201
9	114	82	21	254	139	93	23	230

Table 1. MacCready table for ASW27. Mc gives the MacCready value. Speed gives the still air speed-to-fly, in knots. L/D gives the still-air glide angle. Sink gives the sinking speed in knots. Avg gives the cross-country average speed, in miles per hour.

Table 1 gives MacCready values for an ASW27. For example, in 3 knot thermals, (Mc 3) you fly 80 knots dry and 97 (yes) knots wet. You achieve a 36:1 glide in either case, through still air. Your average speed is 53 mph dry, and 62 mph wet.

These translations are helpful for thinking about MacCready values. If you think you will achieve about 53 mph (excluding the final glide), then input Mc 3 on the task planning page of your computer. If you want the glide computer to tell you 80 knots in still air, but adjust for lift and sink, then input Mc 3.

And, if you want the computer to calculate a 36:1 glide or leave 146 feet per mile, then input Mc 3 in your computer. (The MacCready input page of flight computers should include these numbers!)

Though the table advertises translation, I think it's better to learn to speak MacCready. Learn to express daring vs. caution, and codify your experience, in terms of a "MacCready zero" glide, a "MacCready 3" glide and a "MacCready 5 glide" instead of L/D or feet per mile.

 L/D and feet per mile are drastically affected by wind. The computer takes care of that for you, so a MacCready 3 glide is the same thing upwind or downwind. MacCready numbers transfer readily from glider to glider, while the other numbers depend on the glider's performance. A "MacCready 3 glide" in a Nimbus 4 is about the same level of aggressiveness as in a Discus, but the L/D and feet per mile are wildly different. And *everything* in cross-country soaring is keyed to MacCready values, from what thermals to take, how fast to fly, how aggressively to take upwind turnpoints, how big course deviations to take and so on.

Lesson 2: Decouple the glide computer and the speed director

Suppose that, studying the above table (or its equivalent in your computer), you input MacCready 5. The computer will now calculate a 30:1 glide to the chosen point, adjusting for wind.

The computer will also tell you to fly at 93 knots dry or 113 knots wet. It presumed you asked the contest final glide question: how fast do I go through still air to use up this altitude. But that's not your question. You want to maintain the 30:1 profile for safety, in case you run in to sink. You want to fly much slower. Yet you want to adapt to lift and sink along the way. If you just set Mc 5 your speed director will be screaming its sink tone, "speed up," and giving you no useful information about lift and sink along the way.

(You *are* flying with an audio speed- to-fly-vario, right? Every glider needs one, even the club ASK21. How else can you maximize glide through lift and sink, or even know about gentle lift and sink when you're gliding?)

What to do? Answer: *decouple the speed director from the glide computer*. While flying in Northern Illinois, for example, I typically set the speed director (vario) to Mc 2 and the glide computer to Mc 4. As I descend towards the safety altitude, I'll lower the speed director towards Mc 1 and then Mc 0,

stretching my glide and helping me to slow down and milk lift. I keep the glide computer on Mc 4, where I make my decisions about whether to go on or divert to an airport.

Our instrument makers should do this for us. Glide solutions to alternates should use a separate "safety" MacCready value unaffected by changes in the "speed" MacCready value.

Lesson 3: You may have to use much higher values than you think

Table 1 gives surprisingly high MacCready settings. 30:1 sounds like a reasonable, maybe even a daring safety glide angle. Nobody ever cruises at MacCready 5. The standard safety recommendation in the Alps is 20:1 plus a reserve. You need to set MacCready *ten* to see that glide angle.

Get used to it. For safety-related glide calculations, you may use MacCready values that are much, much, larger than those you would use for speed, thermal, or other considerations.

The reason for high MacCready values is that our gliders are so good. They sink so little in still air, that even small amounts of sink has a disastrous effect on glide angle.

Table 2 presents the numbers. I assume the pilot is desperate, flying at the MacCready zero setting. How bad is his glide in sink? The answer is: terrible. If you fly through steady 1 knot sink, your speed director will tell you to speed up to 65 mph. You will achieve a L/D of 27. Yes, 27. If you fly through steady 2 knot sink, your speed director will say to speed up to 73, and you will achieve a 19:1 glide.

Netto	Dry ASW 27				Wet ASW 27			
Sink	Speed	L/D	Ft/mi	Vario	Speed	L/D	Ft/mi	Vario
0	55	48	110	1.1	67	48	112	1.4
0.5	60	34	155	1.8	73	35	149	2.1
1	65	27	198	2.4	79	29	184	2.7
1.5	69	22	237	3.1	84	24	217	3.4
2	73	19	275	3.8	89	21	247	4.1
3	80	15	344	5.2	97	17	304	5.6
5	93	11	466	8.2	113	13	404	8.7

Table 2. Effect of sustained sink on achieved glide. Speeds are Mc 0, i.e. speed to fly for maximum glide angle. L/D gives the achieved glide angle. Ft/mi is feet lost per mile. Vario is the sink rate of the glider.

So, if you want to protect yourself against steady 2 knot sink all the way to your landing, Table 2 says that's a 19:1 glide, and Table 1 says you have to set the glide MacCready at 10. *Ten!* Even to protect yourself against one knot sink all the way to landing, Table 2 says 27:1 glide, and Table 1 gives a MacCready setting of 5.

Lesson 4: Angle plus reserve and the square root rule.

These seem like huge MacCready settings to most contest pilots. Most of us have spent decades flying Mc 2-3 final glides, and though they don't always work out, blowing a final glide once a decade on Mc 3 doesn't suggest we need Mc 5 or 10 to stay safe.

That experience is correct – sometimes. The question is, how much altitude must we leave to control the probability of a landout. The answer is a square root of the distance to go.
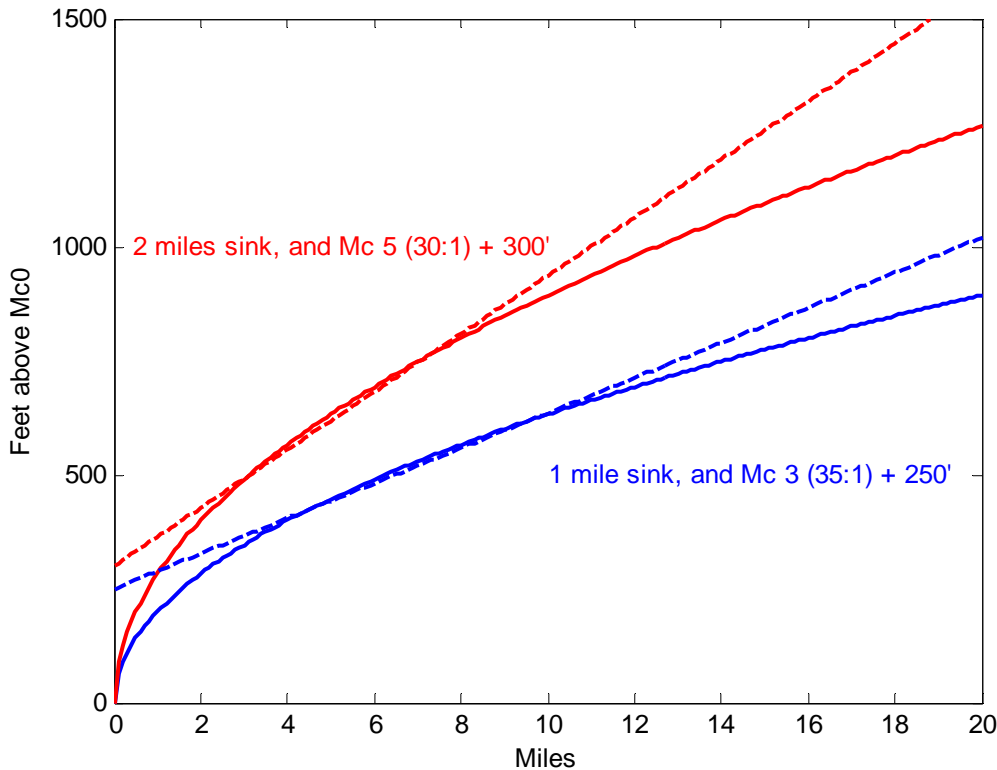

Figure 1. Safety glides, with 2% chance of not making it.

Figure 1 illustrates the square root rule. To calculate the solid blue line, I assume that in each mile you fly, there is a 33% chance of losing 100' or more and a 2% chance of losing 200' or more. The vertical axis shows how many feet over the Mc 0 glide you need in order to keep a constant 2% chance of landing out in these conditions. At 1 mile out, you need 200'. At 10 miles out you don't need 10 x 200' = 2000'. You need the *square root* of 10 times 200', or about 630 feet. At 20 miles out, you don't need 20 x 200' = 4000', you need the square root of 20 times 200', about 900'

Why? The chance of losing 200' in one mile is 2% (by assumption). But the chance of losing 200' *in every single mile* on the way home is next to nothing – that's the chance of a coin coming up tails 10 times in a row.

4

(Techies: I assume that height loss in each mile is normally distributed with a standard deviation of 100 feet. I'm finding the lower two-standard deviation risk band. The standard deviation of a sum of T independent random variables is the square root of T times their individual standard deviations.)

A square root is hard to keep in your head, and our glide computers don't program square root profiles. But they do program higher glide angles and margins, and we can use those to approximate the square root rule. The dashed blue line in Figure 1 shows that a 250' margin and Mc 3 glide nicely approximates the square root pattern. Now you know why we use both higher glide angles and reserves to control the probability of landouts.

What can go wrong here? Rivers of sink. (If you don't know about these, follow me sometime.) I assumed that each mile was a new coin flip, so if you're in sink there is a good chance of getting out of it in the next mile. This is really the diametrically opposite calculation from Table 2, which assumes that sink, once found, lasts all the way home. Reality is in between, and depends on the day.

To illustrate, the red line in Figure 2 keeps everything the same, but now any lift or sink lasts for two miles. To blow it from 10 miles out, now you need only 5 coin flips to come up all tails, which is much more likely. The result is still a square root rule, but you need more altitude at every step of the way. It is better approximated in the last 10 miles by MacCready 5 plus 300'.

In both cases, when you're further out, you use a flatter glide with a larger margin. When you're closer in, you need a steeper glide but less reserve. There is a lot of debate about reserve vs. steeper angle in planning safety glides. The right answer depends how far out you are.

If you want a lower probability of not making it, the curves all shift up. If you can accept a greater probability of not making it, the curves shift down.

Lesson 5: The Real World

What values should you use in the real world? That depends.

First, it depends on the cost of not making it to your desired landing spot, and consequently what probability of not making it you can accept. If you're flying over good fields, the cost of a landout vs. making it to an airport is only inconvenience.

On a final glide over good terrain, the cost is rather severe loss of contest points. In halfway decent conditions, the speed MacCready of 3-4 or so will be enough. In weak 1-2 knot lift, it's worth building up a bit more margin, maybe flying the final glide at Mc 3 or 4 rather than the Mc 2 of the last thermal.

In rougher terrain, the cost of landing out can be glider damage, but not personal injury. This argues for a good deal higher values, in the Mc 5 region. Sometimes you're crossing totally unlandable terrain, where failing to make your goal will mean injury or worse. That argues for a very high probability standard. When the instructor in the French Alps tells you to use 20:1 plus reserve, he ain't kidding. That

means MacCready ten, plus reserve, a value you may not know that your instrument can use. If you use values like that, you will routinely get to your goal with gobs of extra altitude. Yes, that's the point.

Second, it depends on the weather. We're not thinking about what the day is like on average. We need to think about how bad the worst-case scenario can be.

No lift is good news. Where there is no lift there is no sink! When the wind dies, the cirrus clamp comes in, and the smoke all goes horizontal, you know that the chance of finding unexpected sink is very small. Now you can consider those long Mc1 or Mc2 glides.

By contrast, paradoxically, booming days require more caution. Where there is lift, there is sink.

It's not so much the strength of sink that matters, it's how long the sink can last. Punchy sink you can get out of is not so bad. Organized rivers of sink that go on for miles are the real danger.

Streeting puts joy in a pilots' heart. Streets of lift mean streets of sink, though. And, as you descend to the lower levels, staying connected to the clouds is harder and the chance of hitting one of those rivers is greater. If it's blue, or a goal that is cross wind add to the danger. Wave suppression and high winds also signal rivers of sink.

In sum, the worse the terrain the more cautious you need to be (obvious), and the better the soaring weather the more cautious you need to be (less obvious).

What next? I really would like to get some traces and quantify how bad sink can get, how variable glides really are, in different weather conditions and parts of the country. What, really, is the worst that a 10 mile glide can be? That's a big project; perhaps this article will inspire someone else to do the programming. In my dreams, my glide computer will give me a quantitative assessment of just how bad the sink can be, based on sampling the air for the last hour or so, and give a quantitative guide to picking these safety margins.