Paraglider physics - The Art of hitting the spot every time!

I have spent many thousands of hours in powered and unpowered fixed wing aircraft, demonstrating, practicing, and teaching forced landings in all types of aircraft. One of the great benefits has been a realization of what works and what typically doesn't. To a powered aircraft pilot, a forced landing is one in which the engine fails and the pilot is forced to choose a landing spot within the glide range of his aircraft. Paraglider pilots start with an advantage. They know they will have to land unpowered from the moment they decide to commit to flight, and they spend their entire flight (or they should) contemplating their landing options. Now don't misinterpret this to mean that we should always be setting up a landing approach - otherwise you will never get to enjoy the silent beauty of unpowered flight.

It simply means that on every flight you should always have a place in mind that you can safely glide to. This should also include any maneuvering required to get to a suitable landing zone with plenty of altitude to set up a sane approach. As you get higher, you have more options to choose from, but you should still have an LZ in mind. When you decide to fly cross-country, you should have an LZ in sight, and then as you get a bit further you should have the option of flying to a field behind you, and perhaps another one ahead, or to the side. Eventually you give up fields behind you and the field ahead becomes you new LZ. In essence, you fly along from field to field in the general direction of where you want to go. While you're looking at fields, spend a bit of time assessing the winds at ground level. Are the increasing in strength, or shifting to blow from a different direction? Look aloft at the sky for signs of development or indication that the winds aloft may be increasing, or the sky may be overdeveloping. Paying attention to your surroundings helps reduce the chances of your getting suddenly “caught” by the elements.

Some pilots just can't seem to be bothered with the effort of picking LZ's as they fly along, and wait until they get very low and are forced to land before choosing a landing spot. Often this means making the best of a bad situation and dramatically increases the risk of an injury after a poorly planned approach. Other pilots seem to blissfully fly in close along a tree covered ridge line and when they hit sink unexpectedly or the lift they were counting on failed to appear, they end up practicing their tree landing and glider extraction skills. We can all increase the safety levels of our sport by being continuously aware of our surroundings and have a safe place to go if the lift shuts down or conditions dictate getting on the ground in a hurry. If you happen to notice something that other pilots may be overlooking, feel free to chime in on the radio and point it out to them. “An ounce of prevention prevents a lifeflight evacuation”.

There are many techniques that different pilots use to work their way into a landing zone, but one technique in particular works well in almost all cases, for any skill level of pilot, in any kind of aircraft. With the lower approach speeds and tighter turning radius of a paraglider over any other form of aircraft, landing on a specific point, every time is actually quite easy. This article is more on technique than the previous physics articles, but

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it allows you to use the theoretical knowledge you have gained and put it to a practical use.

Before I open the floodgates of replies let me state that I have seen many, many different approach techniques used in the past and frankly how you make your approach is less important than the fact that you can consistently put yourself in a position to make an easy landing. It is possible to make a spectacularly unstable approach and still pull off a good landing; but generally, making a well-planned stabilized approach leads to consistently good landings. There is no special trick in landing gently most every time. Occasionally, however, even the best planned approaches end up with an unforeseeable wind shear, gust, or sudden appearance of an obstacle at the last minute which may cause a firmer than planned arrival. When this happens don't judge yourself to harshly. If however it becomes a normal occurrence perhaps this article will give you the skills you need to improve your planning. Of course as a safe pilot you should also have been standing up in your harness for the last 50 feet or so, a technique designed to help you reduce the chance of getting injured when these things don't work out quite the way you anticipated.

All aircraft need to land into the wind as much as practical to reduce their forward speed at touchdown. Because of the low speeds we fly our paragliders at, wind has a greater effect on us than any other aircraft type, and not being aware of the wind or misjudging it can put us at a serious disadvantage. We need to be constantly aware of what the wind is doing in the area we are flying, where we plan to land, and even within an area several miles around our present position.

Some of the best indicators are smoke, blowing dust, flags, windsocks, and streamers; but we should be aware of some of the things that are perhaps less obvious but can help us as well. Leafy trees are ideal, since they have a shiny underside. When the wind blows on the tree it flips the leaves over and you can easily see this shiny side on the windward side of a tree, even from very high up. Bodies of water have a band of calm on the windward side where the water is protected from the wind. The size of this band and the size of waves or presence of wind streaks helps to judge the wind speed. Water birds generally feed facing into the wind, and they takeoff and land into the wind, even when it is light. Boats anchored in lakes will swing to point into the wind (but a boat anchored in a river can also swing to point into the current so be careful with this aid). Animals standing in a field generally stand facing into the wind (think about it, if you didn't wash your rear end would you want it upwind all the time?). If nothing is available on the ground as an aid, you can always fly a small square sided box pattern. If there is any appreciable wind; the drift on the crosswind legs will be apparent, and your changing speed across the ground will help you sort out where the wind is coming from.

Some other aids that should be used when available are automated weather or surface advisory systems or windtalkers, and GPS units. Some of the newer GPS units will actually compute the wind speed and then compute the wind direction from our heading and track across the ground. One thing to bear in mind is that while a GPS shows our groundspeed pilots seem to assume it is always a positive value. Just because your GPS shows a speed of say 8 MPH does not mean you are flying forward at 8MPH. You could just as easily be flying backwards, so paying attention to the course arrow to see where you are making the speed across the ground is vital as well. If you happen to be standing in the LZ when a pilot is coming in to land, and there are no really good wind indicators, be a sport, and kick up a cloud of dust to aid your fellow pilots in judging the wind. Hopefully they will do the same for you in turn.

It is important to keep an eye on the winds in the entire area where you are flying. You may be ridge soaring or thermalling at an alpine site and planning a landing in the valley. If you're not observant it is possible for valley winds to kick in, and have the winds howling through the LZ while they are fairly calm where you are flying aloft. Early detection is key in this instance because the higher you are, the more options you have available to you. If you don't realize the change until you get low on your approach you will have exhausted several possible options. Likewise if you are looking outside the general scope of your flying area you might notice Towering Cumulous type clouds in the distance and recognize the potential for them to produce a gust front that can travel to your area. It is really pretty rare for winds to just "kick up all of a sudden", yet I often hear pilots tell me about this mysterious phenomenon where the winds just suddenly picked up… There is nothing mysterious about it; they just were not paying attention to all the signs that were present.

Airspeed, altitude, and a place to go are a paraglider pilots best friends, but pilots can eliminate some potential landing spots by just flying around blindly at trim speed hoping to hit an LZ. There are a few speeds to fly at that can improve your available range of landing options, particularly if it becomes windy. Hoping for the best is never a good idea, and as pilots we should be able to maximize the ground we can cover from any particular altitude. This gives us more options to choose from.

In order to achieve maximum performance from any aircraft there are a few speeds that are essential to know. An obvious one would be the stall speed, which is obviously the minimum speed that your wing will fly before assuming a greatly increased glide angle. Most fixed wing aircraft have some type of device to warn the pilot of an impending stall. They give the pilot audible and visual warnings, and in some cases even shake the yoke in the pilot's hand and then jerk the yoke forward if the pilot fails to reduce the angle of attack. As paraglider pilots the only warning we have is the feel for the pressure in our wings, and the knowledge of the approximate brake position where we a stall will occur. We have found this from experience in many of our flights in the landing flare, or perhaps in flight during a maneuvers clinic. There is really very little to be gained by attempting to fly at a speed slower than minimum sink, or flying around deep in the brakes. Looking at the polar curve shows us that all we do is actually increase the sink rate of our glider, and expose ourselves to the risks of an inadvertent stall.

Two other important speeds to be aware of are the speeds to fly for best endurance (being able to stay aloft the greatest time for a given amount of altitude), and best range (being able to cover the greatest distance for a given amount of altitude). Most fixed wing pilots go through a demonstration of how to find these speeds, and they have a practical application for us as paraglider pilots as well. Best endurance is the speed that you would fly to maximize your airtime in zero lift. As paraglider pilots we are probably more familiar with the term minimum sink, and the speeds are the same. Looking at the polar curves from our paragliding physics part 1 and 2 articles, we found that minimum sink occurs at the point on the polar curve where we experience the minimum drag in flight. One use of flying at minimum sink is to stay airborne the longest amount of time for a given amount of height, assuming we aren't in any great hurry to go anywhere. If there is no lift, but a strong wind, we can increase the distance we can cover across the ground by heading with the wind and flying at this speed. This maximizes our airtime spent traveling with the wind and allows us to cover the greatest distance across the ground. If we need to travel into the wind, slowing down to this speed will cost us in distance we can travel into the wind, since we expose ourselves to the headwind for a longer period of time. To make headway into the wind, we need to fly at a speed that gives us the best penetration without adversely increasing our sink rate.

Best range occurs at the point on the polar that is tangent to the origin. If we have a copy of our wings polar, we could find the speed by referring to the graph. If you look at figure 1 which is a polar curve for a typical paraglider you can find the speed to fly for best range on a no wind day by drawing a line from the origin of the graph to a point that is tangent to the polar curve (see point A on the curve in figure 1) then moving up vertically to find the speed we would want to fly at. If you were trying to fly the greatest distance into a 10-MPH wind, you would draw a line from the 10-MPH mark on the speed scale that is tangent with the polar curve to find the optimum speed to fly, and the corresponding sink rate (see point B on the curve). Notice at point C how fast you would need to fly as the headwind increases. If the headwind you are flying in approaches the maximum speed of your glider obviously you need to go as fast as possible and you will still barely penetrate into the wind. Of course this also means you likely exercised poor

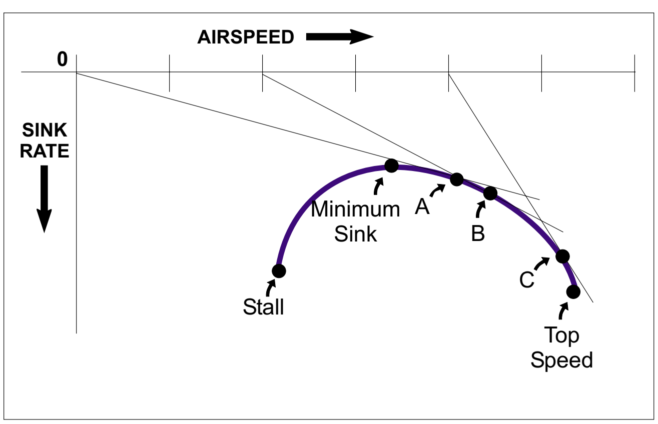

Figure 1 - Polar curve showing speeds to fly for best range

judgement in launching in the first place, or you failed to watch and notice the conditions changing as your were blissfully soaring along. Hopefully the winds will cooperate and reduce their velocity as you sink lower and they are slowed by surface friction, allowing you a few more options of landing areas. Sometimes you just have to suck it up and go on the speed bar to even make any progress. Using the speed bar to make headway in a wind is fine as long as your are high enough. Once you get closer to the ground, you need to consider if the increased risk of a leading edge tuck is worth the risk of the slightly increased speed.

If you were flying with a tail wind; you would draw a line from the left of the scale origin that would correspond to the tailwind you were flying with, except that you would never want to fly slower than your minimum sink speed for optimum results (this would increase your sink rate for no further gains in performance).

If you don't happen to have a copy of your wings polar curve and you want to find the approximate speed and brake position to fly for best range, you can determine it in flight with a simple experiment using your variometer and a speed probe. On a smooth sledder type of day, and with sufficient altitude, establish your paraglider in a descent at minimum sink. (Refer back to our paragliding physics articles part 1 and 2 if you don't remember how to find it). Note the sink rate that you experience. What you are going to do next is increase your speed in constant steps, and note the corresponding increase in sink rate. As you increase your speed the sink rate will gradually increase in incremental steps, until the point at which it will start to increase exponentially. Slowing down a little bit will place you at the speed for best range in still air.

As a practical matter, few of us ever fly around at exactly minimum sink or best glide. Understanding what we need to do to increase our performance is a great place to start. Now that you know how to go the greatest distance across the ground in any wind you should be able to expand the possible choices of where you can actually go, which of course gives you more options. Knowing whether or not you can actually glide to a spot, or clear an obstacle is the next problem that presents itself. If you are trying to figure out whether you can clear an obstacle in the distance, a ridge for example. Look beyond it for the clues that help you out. If you see more objects appearing behind the ridge, you should clear it. If objects are disappearing, you are not going to make it. If the view beyond the ridge never changes, and it remains stationary in your view you should hit it. Of course you need to use your common sense and decide if there are other potential problems to avoid from rotors, venturi effects, or simply mechanical turbulence as well.

If you are trying to decide if you will clear an object on a landing approach, a set of 400,000-volt high-tension powerlines for example, the same principle works and is graphically illustrated in figure 2a 2c. One thing to keep in mind is that altitude is your friend. Good pilots are constantly assessing the conditions they are operating in as well as their available options. If you can decide early on that you may not clear an obstacle on your approach, it gives you time to choose an alternate plan. Hoping for the best means either hitting the obstacle you were “hoping” to clear, or forcing yourself into radical maneuvering at low altitude in an attempt to avoid it. (Hint - In case you find yourself in the position shown in Fig 2c, diving under the powerlines is a bad idea. Pulling ears to land before, or turning and landing crosswind is preferable to the risk of contacting

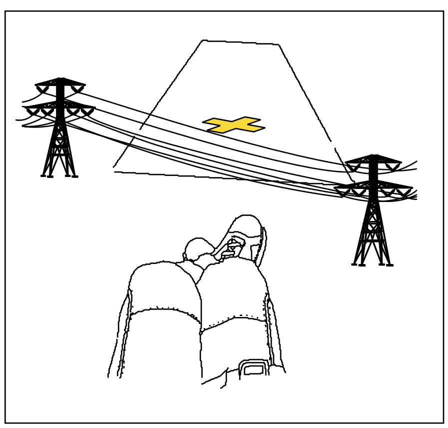

Figure 2a
Will You Make it?

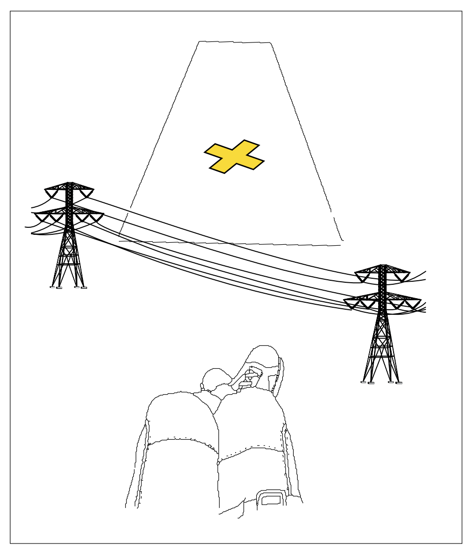

Figure 2b
If you can see more details appearing beyond the obstruction, you should make it.

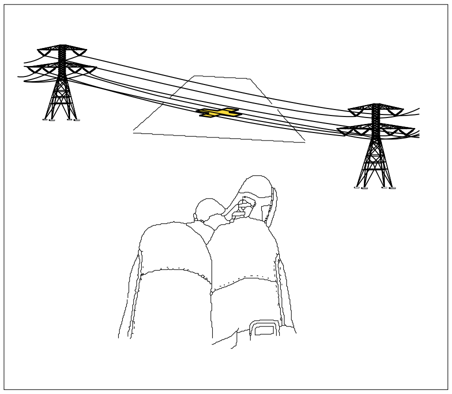

Fig 2c
If details are disappearing beyond the obstruction, you need an alternate plan.

an energized electrical wire).

Now lets keep things simple and assume you have lots of height and an abundant selection of possible landing zones and you want to develop a technique that will get you in a position to land expertly every time. First off, forget trying to emulate the either really gifted (or crazy… you decide) pilots who can death spiral down to a spot landing. Most of us can't pull it off. Likewise forget trying to copy the style of those pilots who can wank and bank it all the way to the ground, terminating in an impressive spiral dive that stores energy as they then skim across the ground for a great distance and touch down gracefully without a step. Few of us have either the skills or luck to pull this off regularly. Instead lets work on a very common approach technique that has been well proven to place you in a position to make a normal stabilized final approach and landing. Figure 3 graphically illustrates the concept.

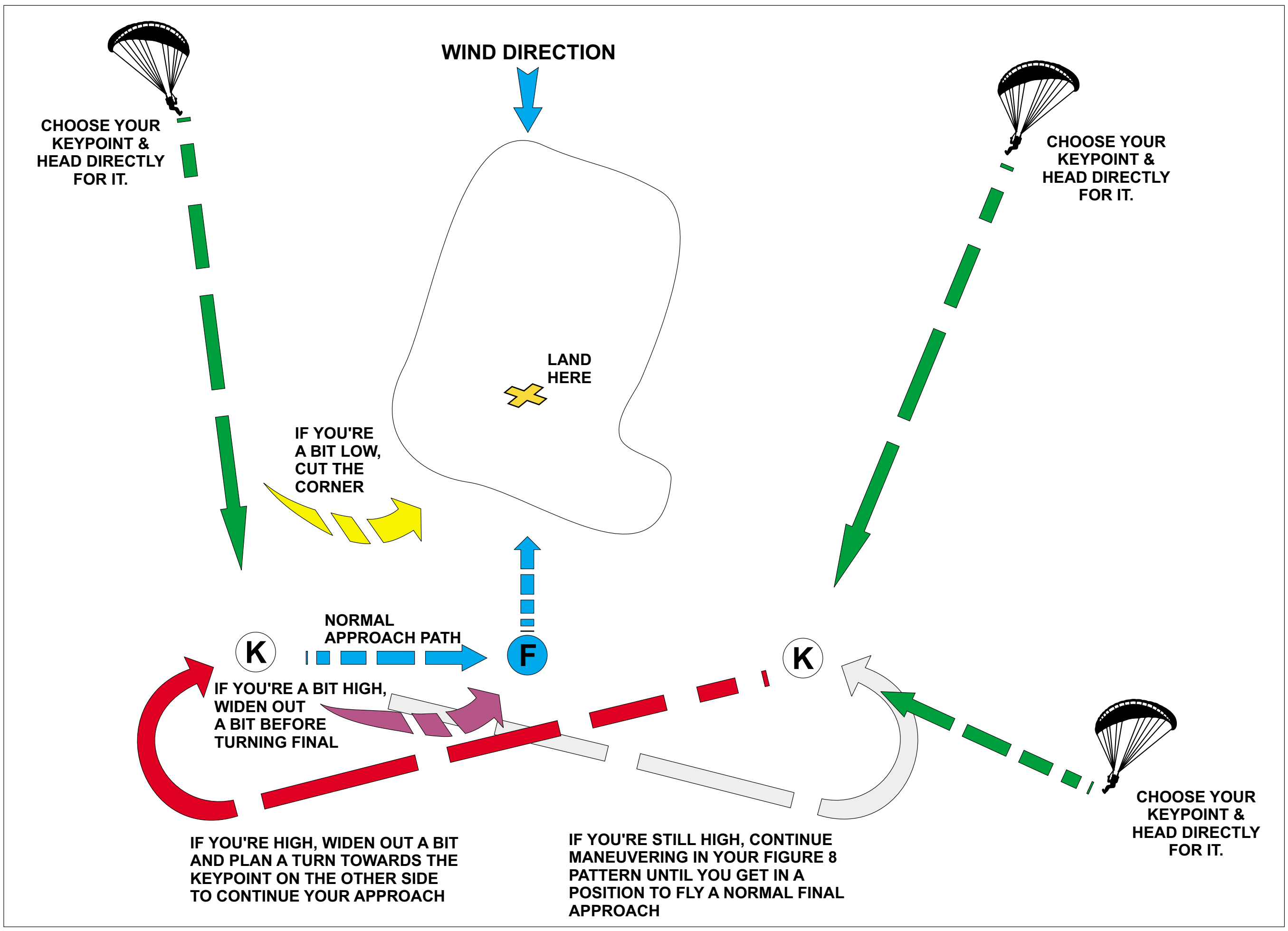

Figure 3 • Maneuvering into position to fly a stabilized final approach segment

Pick a field you want to land in and head towards it planning to arrive just downwind. Adjust your speed as necessary to give you the most effective glide so that you arrive above the field with as much height as possible. You want to pick out 2 key points, one on either side of your field and at a 45-degree angle to it. Your goal is to head directly towards the key point where you will begin maneuvering to efficiently lose altitude before turning final (refer to the green lines indicating the flight path in figure 3). If it looks like you will be a bit low as you arrive at your key point, cut the corner and head in towards your landing area (see the yellow arc from the left side of figure 3). If you arrive over your key point just a bit high, widen out just a little bit before turning final so you lose just a bit more altitude before turning final (see the purple flight path). If you are very high, widen out a bit and plan a turn so that you can turn towards the field from the other side and come in over the key point on the other side of your field (assume you arrived over the right side key point a bit high, you would follow the flight path shown in red and plan an approach as discussed earlier). As you come back over the key point you decide whether you will widen out a bit, cut the corner to final, or plan to fly out around the key point on the other side of your field and set up from the other side (shown as the gray path), or repeat your figure 8 pattern as many times as necessary to put yourself in a position to turn to make your final approach. If you fly through a thermal and balloon up, just stay in the same pattern. If you keep going up, great, as long as you stay in your pattern you can easily maneuver to land at any time and if it turns out to be a good thermal you can ride it up to cloudbase and continue your flight while looking for other suitable landing zones. If you hit sink, you should always be in a position to turn directly into the field to land safely.

Be sure to use the wind to your advantage, and make certain you adjust your crab angle so that you can fly a track that matches the figure 8's you want to fly around your key points. Pilots usually botch the approach by doing one of three things. The first and most dangerous is that they find themselves just a bit high on a windy day and try to crank a 360 degree turn on final. As they turn, the wind drifts them further away from the field and when they complete the turn, they don't have enough height to glide to it, OR they notice halfway through the turn they have misjudged the maneuver and try to compensate by cranking the turn around and end up stalling and spinning their glider from an altitude too low to recover. The simple rule is to NEVER TURN AWAY FROM YOUR FIELD, and this should not cause you any problems. Another problem arises on a windy day if pilots don't crab as they fly around the figure 8 pattern to compensate for the wind, and allow themselves to drift too far downwind. The last one is when pilots don't really choose key points to fly over, but just sort of zig zag their way down the final approach path. Usually they start with little turns and then if they hit any lift at all on the way to the field they start frantically making turns bigger and bigger as they get close to the field and find themselves to high to make a normal approach. “If you fail to plan your approach you are already planning to fail”, so don't be surprised if your landings appear less than optimal. Plan your approach, choose your key points and fly your approach to put yourself in position to make a graceful turn onto final with a smooth stabilized final approach and a gentle landing.

In some cases due to obstacles in the approach path or approach restrictions (where you need to stay to one side of the field and allow other pilots to approach from the other side) you need to modify your key positions so you have one at the normal 45degree position and another one closer in towards final. If there is an unavoidable hazard on the approach end, say a set of high tension wires you need to pass over; you should plan your key points so they are almost over the hazard to either side of the field. This way you are always in a position to turn into the field if the wind increases or you encounter sink in a shear layer as you descend.

I like to imagine a window positioned above the approach end of the field that I need to fly through in order to set up my approaches. I also pick a small postage stamp sized area on the field for EVERY landing about 1/3 of the way down the available landing area where I plan to touch down. This gives me something to aim for, and if I miss it by a few feet nobody else knows or cares, but I mentally review what I need to do to improve my performance next time. A lot of pilots would rather just choose a lane, and they line up on final to fly down this lane, touching down wherever in the lane fate chooses to plop them. I personally believe that “If you aim for nothing, you will surely hit it” and like to take a bit more control of the situation. When I'm forced to maneuver into a confined LZ, I use the exact same approach technique but plan to come in a wee bit high, and pull in big ears to lose altitude once I have the field made. This ensures that I won't undershoot the field, and if a thermal bubble pops off on short final it has little effect on my approach. Plan all your approaches, and practice flying them as if your life depends upon it. Someday it just might, but if you have spent even a modest amount of effort practicing this technique you should be able to position yourself to arrive in a position to land safely almost anywhere.

May the sun shine upon you and your thermals be fat and mellow.

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