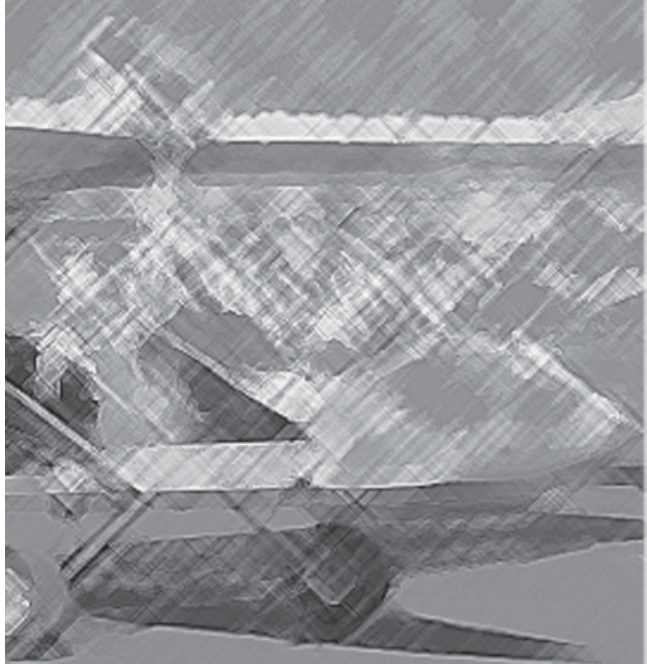


**ADVANCED
SPORT PILOT
AERODYNAMICS**

Chapter 9



9. Advanced Sport Pilot Aerodynamics

“Aerodynamics is not the black art revealed only to a chosen few. It can be understood by almost anyone, if properly explained.”

-Hubert Skip Smith

This chapter delves a little deeper into the subject of aerodynamics and some topics of particular interest and importance to sport pilots. Without a basic understanding of aerodynamics you may find this section at times, well... confusing.

We are convinced that an understanding of aerodynamics and the physics involved are as important to sport pilot safety as any other single area. That said, this chapter will help step it up a notch with regard to these principles.

Nose-Over, Dive-In

Nose-over, dive-in, (NODI) is a phenomenon which first became apparent in the 70s and 80's. Many accidents were attributed to it before there was even an understanding of what was occurring. The acronym NODI began showing up in accident reports with quotes from witnesses that sound something like “. . .the aircraft was on final approach and then just suddenly went straight down and impacted the ground.” It wasn't until many years later that the ultralight industry recognized some of the reasons these accidents were occurring.

As we move to seek an understanding of this phenomenon, we must share some history. With the advent of ultralights came a typical design profile, which incorporated a thin under camber airfoil of a tube and fabric type design. These aircraft were very low mass, very high drag, and typically equipped with an unreliable two stroke power plant. (Today, we have reliable time-tested, two-stroke engines.) These were the fledgling days of the ultralight industry and a great deal of experimenting, testing, and learning was going on.

Given the unreliable engines that were the norm in the early

days, the numbers of engine failures were very high. Brian can remember, on group ultralight outings, expecting at least one engine failure out of the group during the weekend. Subsequently learning the appropriate engine off (dead stick landing) technique was essential.

As a result of the high drag configuration of the aircraft, when the engine failed the necessity to maintain airspeed resulted in an exaggerated and extremely nose low attitude. This was necessary in order to retain not only the required airspeed above stall but also to retain the additional energy to be used during the round out and flare to a landing.

If the pilot was at a very high nose attitude and the engine failed at a low altitude, the ability to achieve a low enough nose attitude was dependent on how quickly the pilot could respond after the engine failure. At low altitudes this technique could destroy the airplane if not done properly. At higher altitudes where there was plenty of room to deal with an engine off landing the necessity for a sudden nose pitch over was rare.

At the same time, because of the learning curve, there were many ultralight pilots with little experience or knowledge and even private pilots flying ultralights with only a rudimentary understanding of the aerodynamics involved. Additionally, many of these individuals were modifying their aircraft with items such as big wheels and tires, hydraulic brakes, ballistic parachutes, extra fuel tanks, baggage compartments, floats, and a myriad of other add ons. These modifications if done improperly could compromise the aircraft's structure, and equally important was how these nonstandard modifications would affect the center of gravity. Because of the design of many of these aircraft the locations available to install all of these goodies were typically located aft of the center of gravity (CG).

One of the other unique design characteristics of many of the early ultralights was the large horizontal stabilizer and elevator. The result was two fold: The additional stability provided in flight was a positive characteristic, but at the same time it would mask the flight characteristics associated with a tail-heavy configuration. Actually, many pilots even today fly ultralights that are closer, if

not outside, the aft center of gravity envelope. As the fat ultralights are transitioned to experimental light-sport aircraft (ELSA) status, we expect to see a lot of these problems corrected because of the mandate to have the aircraft weighed and have a weight and balance report completed prior to certification.

Under normal flight conditions this characteristic has seldom created a problem. However, as we will see later, it contributes to this phenomenon known as “NODI”.

Aerodynamically, the stall characteristics of an airfoil are derived primarily from its design. Good stall characteristics are typically associated with a thick, round nose, airfoil as shown below.

Since the early ultralights necessitated simple lightweight construction, many designers opted for the thinner, pointier leading edge airfoil typical of the tube, fabric, and wire construction of the 70s and 80’s.

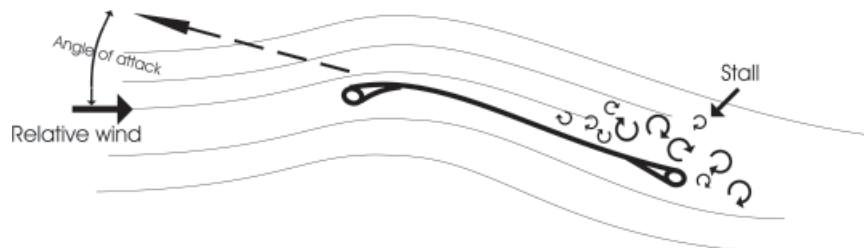


The design of the airfoil, the weight limitation imposed by FAR Part 103, the power plants, and the materials available at the time all contributed to the basic design characteristics that we saw prevalent during this era.

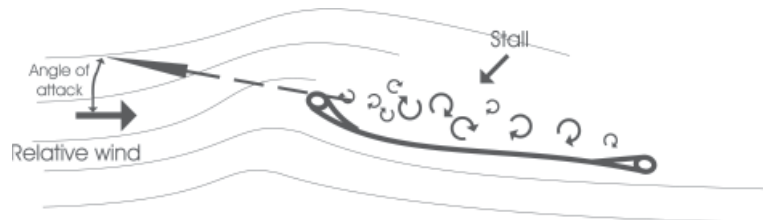


Because of the relatively light wing loading of these type of aircraft, this type of airfoil design was efficient and sufficient for the job at hand. Even the stall characteristics were mild. However, this was primarily due to the light wing loading of the aircraft. The stall angle of attack of this airfoil ended up being somewhere around twelve to fifteen degrees.

Now let’s imagine the wing bolted on the airplane upside



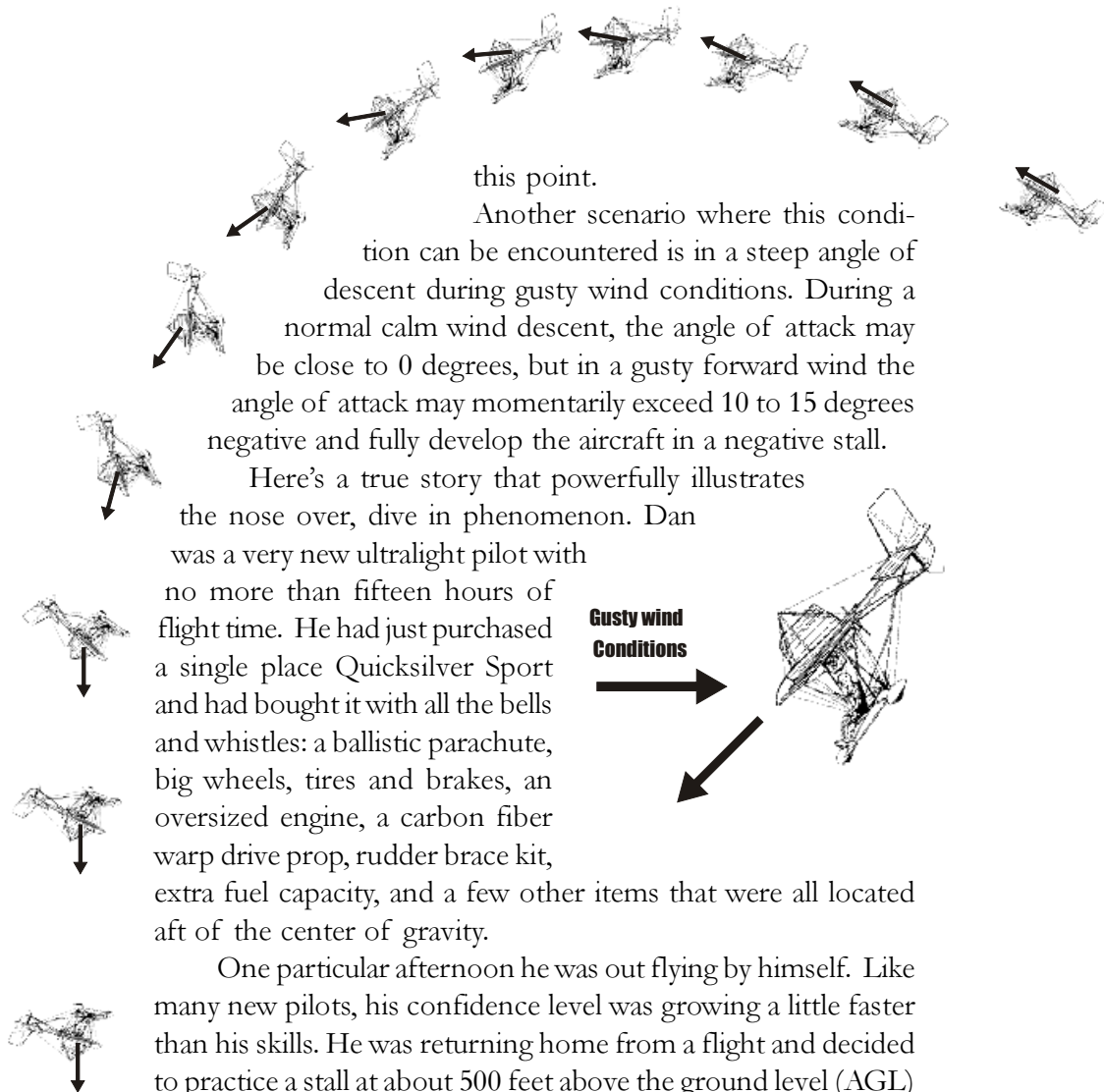
down. This wing would not be very efficient for the aircraft and, more importantly, it would stall somewhere in the neighborhood of 0 to 5 degrees angle of attack.



Obviously we are not going to be flying the aircraft around with the wing bolted on upside down, but in the event that we should pitch forward relatively quickly, even at as little as 0 degrees negative angle of attack, we can start the process of stalling the wing with a negative angle of attack.

If the aircraft were pitched excessively forward and the angle of attack became excessively negative, it would be possible to find ourselves in a negative stall and if the condition of the aircraft were configured with the center of gravity (CG) aft of the aft limit this potential problem is exacerbated. The condition could be extreme enough to cascade into an uncontrollable inverted stall.

One scenario begins with a steep climb out and the engine fails, then the pilot pitches abruptly forward in order to lower the nose for the upcoming emergency landing. As the aircraft proceeds to a nose down pitch attitude, the pilot becomes weightless and starts feeling the sensation of being pitched out of the aircraft. His hands on the control stick and the throttle are the only things that he has to brace himself against. This pushes the stick further forward, pitching the aircraft further negative. At this point the engine will stop completely, if it hasn't already, as the fuel is displaced to the top of the float bowl. The result is even less control over the elevator, which, by this time, is at a sufficient angle to also be stalled in the negative pitch attitude. The aft center of gravity takes over and continues to pitch the aircraft even further negative. Once the aircraft is beyond a certain point, both the wing and the horizontal flying surfaces are stalled the chance for recovery is minimal. Only altitude and a forward center of gravity will help at




this point.

Another scenario where this condition can be encountered is in a steep angle of descent during gusty wind conditions. During a normal calm wind descent, the angle of attack may be close to 0 degrees, but in a gusty forward wind the angle of attack may momentarily exceed 10 to 15 degrees negative and fully develop the aircraft in a negative stall.

Here's a true story that powerfully illustrates the nose over, dive in phenomenon. Dan was a very new ultralight pilot with no more than fifteen hours of flight time. He had just purchased a single place Quicksilver Sport and had bought it with all the bells and whistles: a ballistic parachute, big wheels, tires and brakes, an oversized engine, a carbon fiber warp drive prop, rudder brace kit, extra fuel capacity, and a few other items that were all located aft of the center of gravity.

One particular afternoon he was out flying by himself. Like many new pilots, his confidence level was growing a little faster than his skills. He was returning home from a flight and decided to practice a stall at about 500 feet above the ground level (AGL) when the aircraft pitched forward, went inverted, flattened for the last 200 feet before he impacted the ground completely inverted.

A witness reported to Brian that he had seen Dan's aircraft go down, Brian immediately flew out to investigate. About a mile from the airport he spotted the ultralight inverted on the ground with no sign of movement. Brian returned to the airport in a panic and called 911. As he was on the phone describing the location to the



dispatcher, he saw Dan walking down the road toward the airport. This was obviously a tremendous relief. Brian canceled the 911 call and then spent the next two hours discussing what had happened with Dan. This incident was another classic case of the aircraft being loaded aft center of gravity and going into a flat inverted stall: NODI.

Dan's procedures for practicing stalls had been partially correct. His mistake? There were several. First, he should not have been practicing stalls, nor was he trained to practice stalls, at less than 1500 feet AGL. Second, he assumed that his aircraft would handle the same as the aircraft he had received training in. Third, he had the aircraft loaded aft CG, so when it stalled, the stall break was fairly dramatic.

As the aircraft stalled, he pitched forward to recover from the stall. Then Dan was thrown forward as the aircraft went into negative "G." And since he was holding the flight controls and the throttle, both controls went forward with him. Due to the oversized engine and the high-thrust line, the aircraft's pitching moment was accelerated. The controls were more sensitive because of the aft CG. Once the aircraft was over-rotated into an inverted stall, the horizontal stabilizer and elevator were also at such a high angle of attack that they were rendered ineffective.

Under normal flight conditions, in an upright configuration, even if the aircraft were stalled in a positive direction, the engine would still continue to run and the airflow would be accelerated over the tail surface. It would be a simple process to change the pitch attitude and recover from the stall. However, when the aircraft pitches negative, the fuel also goes negative in the float bowl and the fuel pickup is exposed to air. Without fuel to the carburetor, due to the negative configuration, generally no more than two seconds will elapse before engine stoppage. Once that happens, the aircraft virtually loses all airflow over the horizontal stabilizer and the elevator.

After modifications and repairs to his aircraft, Dan continued to fly. He took several hours of dual instruction and worked hard to regain his confidence, developing his skills simultaneously. Fortunately for him the aircraft he had purchased was strong enough

to withstand a complete vertical descent to the ground.

The conditions on board the aircraft are easily recreated from the perspective of an experienced outsider. The first clue was evident in that the pilot did not have the state of mind to pull the handle on the ballistic parachute. The level of fear rendered him completely incapable of performance. We would venture to guess from years of experience and by observing how pilots react in similar circumstances that not only is this reaction common but totally expected. To be able to continue to think clearly through an incident like this you would have to have had many years of experience and training in adverse and emergency situations. If this was to occur at a safe altitude, say 1500 feet, a new pilot may have had time to deploy the parachute. However at 500 feet this scenario took only a few seconds from stall to impact. Not pulling the chute allowed the aircraft to hit the ground completely inverted. In this case the outcome was only minor injuries. Needless to say Dan was one very lucky pilot.

Now the conditions in which the “NODI” can occur are limited and for the most part a thing of the past. Most ultralight designers never had a problem with the original designs but rather the pilots who modified them outside of the original operating limitations.

The V_x Dilemma

Flying lightweight, low drag aircraft isn't just about learning new skills, it's about understanding an entire new concept of energy exchange. Several real dangers come with the advent of the new sport pilot rule and one is the potential for an increase in the number of accidents related to “the V_x dilemma.” Unlike general aviation and heavier experimental aircraft, the amount of kinetic energy available for exchange during an approach to landing in a lightweight ultralight-type or sport aircraft can be significantly different.

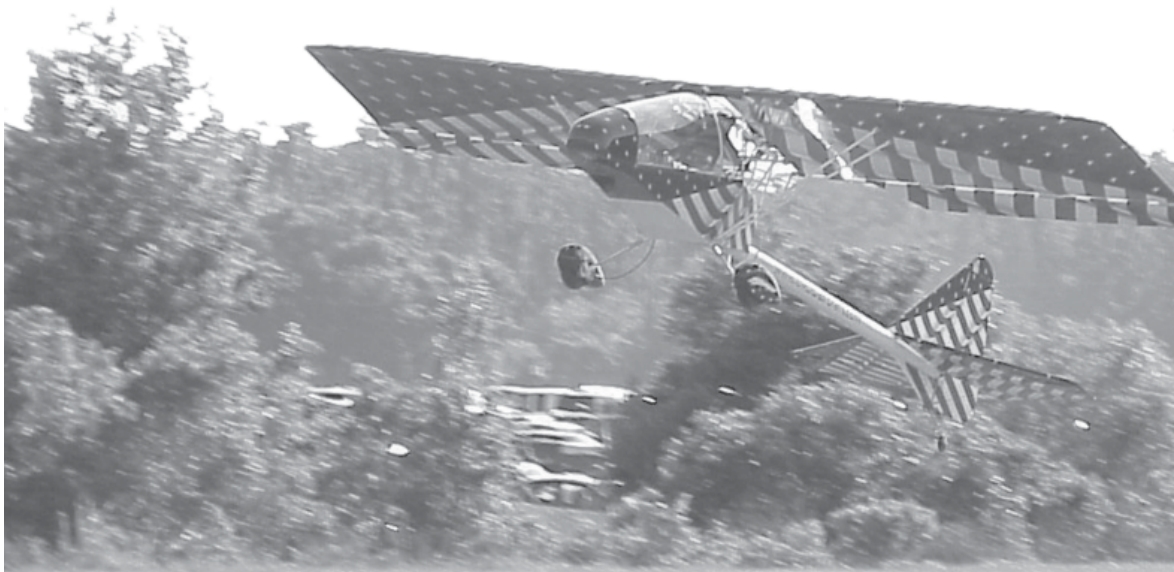
Let's imagine, for the purposes of our discussion, that we organize all aircraft falling along a continuum with lightweight ultralight type aircraft with a particularly high drag coefficient on the

far right and large aircraft such as a Boeing 747 on the opposite end. All other aircraft will be positioned according to their weight verses drag profile somewhere in-between.

Kinetic energy, stored in the form of airspeed, is the aircraft's mass times the speed. On the left of the graph we have aircraft that are very heavy but with a relatively small amount of drag for



its size. On the right we have a very light aircraft with a tremendous amount of drag for its size and weight. The problem that we will be addressing here is applicable to the aircraft located on the right side of our graph.



During the V_x climb out (best angle of climb) we are climbing at an airspeed below the minimum speed for making a successful power off landing. Let's step through what happens if the engine fails during this critical segment of the climb.

Position #1:

Because we are talking about aircraft that have low mass, high drag configuration, at the moment of engine failure the aircraft begins to start a rapid deceleration.

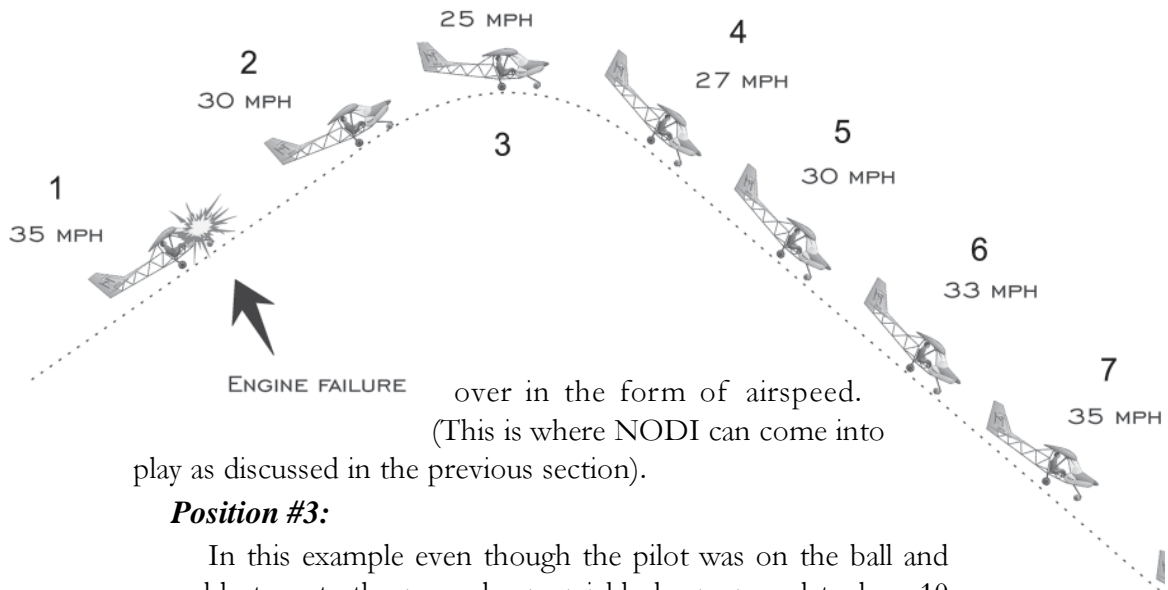
Position #2:

There are two factors working against the pilot: first, the high drag starts slowing the aircraft and second, the steep upward angle of climb also promotes the deceleration process.

This is where an immediate nose forward pitch attitude is needed to conserve any amount of kinetic energy that may be left

Engine Failure on Takeoff

During V_x climb



Position #3:

In this example even though the pilot was on the ball and was able to get the nose down quickly he managed to lose 10

m.p.h. airspeed in very short order.

Position #4:

Because of the very high drag configuration, the aircraft needs to be placed in a very steep pitch attitude in order to start building up airspeed. In this example you can see that there simply was not enough altitude available to convert into airspeed (kinetic energy) before the aircraft impacted the ground.

Position #5:

Had the pilot pushed the nose over to a steeper attitude he may have increased his airspeed slightly but would have found the resulting angle even more difficult to pull out of.

Position #6:

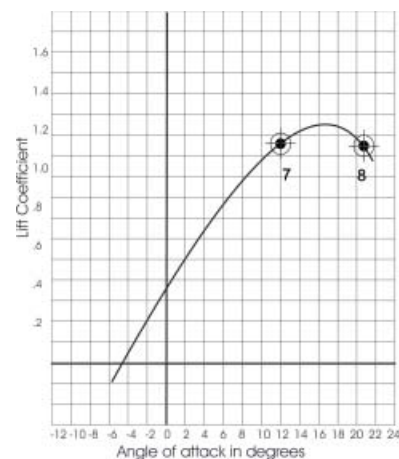
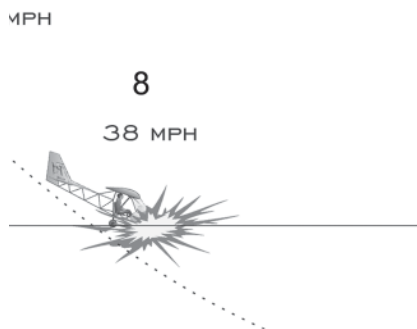
Had he started the flare sooner he would have found himself closer to the stall and actually increasing the rate of descent towards the last segment of the attempted flare. In any case damage to the aircraft and or injury to the passengers is inevitable.

Position #7:

Looking at the position of the angle of attack on the C/L chart it is easy to see that increasing the angle of attack at this point will make only a small impact on the increase in available lift.

Position #8:

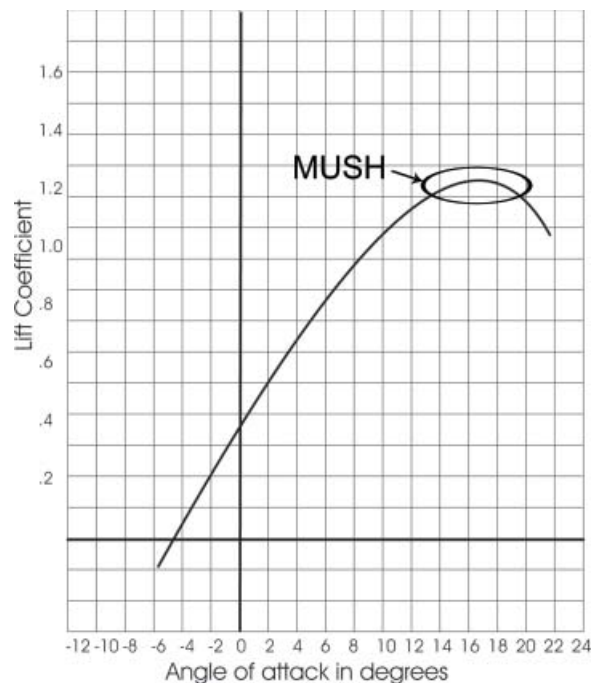
In a last ditch effort to keep from hitting the ground the pilot pulls back on the stick only to exceed the critical angle of attack. At this point it becomes irrelevant as the aircraft impacts the ground.



This dilemma is common to other type aircraft as well, however, it is more prevalent with high drag, low mass aircraft. Additionally, we see more instances of engine failures for a variety of reasons that contribute to the numbers.

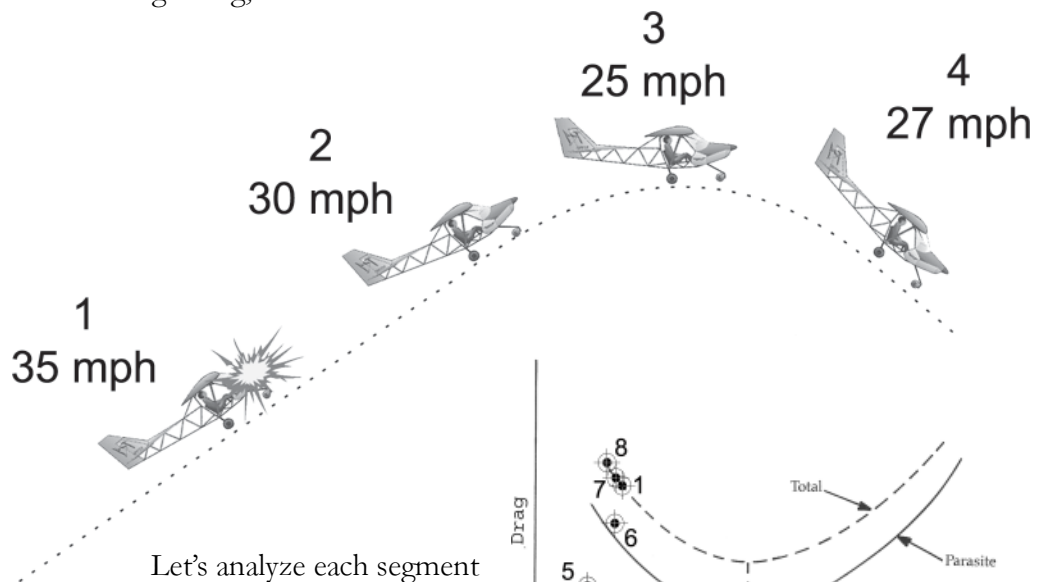
This setup during the landing phase of the approach can also be arrived at by simply allowing the airspeed to bleed off during a normal approach. This high-sink-rate-unable-to-flare condition is often referred to as the “mush.” In the mush we can be on a descent to a landing and be close to the top of the coefficient of lift curve on an airfoil and yet be many degrees, in terms of angle of attack, away from what would be identified as a stall.

As illustrated in the diagram below, notice that from about 13 degrees angle of attack until stall there is very little increase in the coefficient of lift, unlike when we are at a higher airspeed and lower angle of attack. At 2 degrees angle of attack notice that even a few degrees angle of attack increase gives us a significant increase in the coefficient of lift.



Sample Problems

The following series of diagrams will help to illustrate the problem we've been discussing. For our purposes the graphics and performance numbers have been altered to better illustrate the concept. The performance figures are approximate and emulate a typical high drag, low mass aircraft.



Let's analyze each segment of the scenario.

Position #1:

At the point of engine failure the aircraft is climbing at V_x (maximum angle of climb.) This places the C_L at a fairly high angle of attack. For the sake of this example, we will say about 12 degrees. If we look at the position in relationship to the drag curve we will see that we are on the induced drag side of best lift to drag. This additional induced drag is also what contributes to the slowing effect once the power is no longer there. Lowering the nose, reducing the angle of attack, will reduce the amount of induced drag.

Position #2

The pilot has started the (push over) and as can be seen on

the C_L curve, the angle of attack is being reduced and the amount of induced drag is going to be reduced also. But we still have the vertical velocity and the aircraft continues to slow down.

Position #3

Having reached the top of the parabolic arc, we are producing very little lift or induced drag. The angle of attack may be slightly negative at this point. At this point, the airspeed may even be below what we would normally consider stall speed. However, since we are at a small angle of attack, we really are along way from stalling the aircraft. Remember that stalling the aircraft is really exceeding the critical angle of attack. If we were to pull back on the stick at this point, we could easily place the aircraft in a stall. Whether the aircraft is in a stall or not is really irrelevant at this point as it is not producing any significant amount of lift. The

