Balked Landings, Part 1

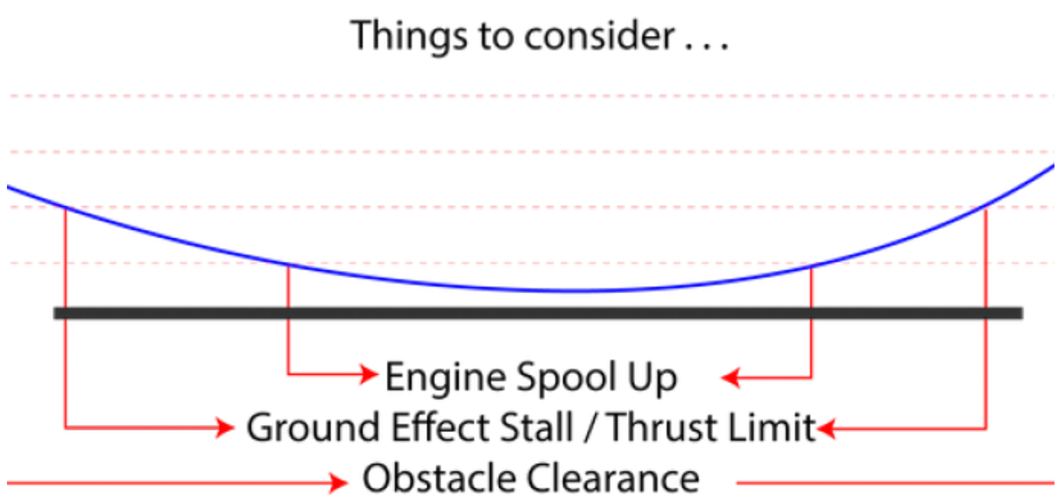
James Albright September 16, 2021

G450 Just prior to touching down, Santa Monica Municipal Airport (KSMO), California. Photo credit: Matt Birch, http://visualapproachimages.com

We practice some maneuvers in the simulator because they are just too dangerous to do in the airplane. For these, our performance must be automatic, almost unthinking, reactions that get us out of harm's way until we have a few moments to catch up with the airplane. Consider an engine failure right at V_1. Our reaction requires the right balance of multiple smooth but swift control inputs to keep the peas from rolling off the plate. Rudder must be added immediately to maintain track, and the need for rudder increases dramatically as the nose comes off the runway. Pitch control becomes critical, as we must capture V_2 to $V_2 + 10$ with one less engine's thrust. Navigation depends on keeping the aircraft coordinated. Only once all this is done can we take a mental step back and survey the situation. If we practice this repeatedly in the simulator, we have a fighting chance of getting it right in the aircraft. Provided we keep our cool.

You might say the same thing about a missed approach initiated at minimums. The aircraft is headed downhill, and we want to reverse that while mentally switching from "I'm arriving" to "I'm departing" and getting the navigation right. Again, we practice this until it becomes automatic. You can probably add a rapid loss of pressurization at high altitude, a thrust reverser unlocked in flight, and just a few other flight maneuvers to this list of "immediate actions." What about balked landings?

We practice those in the simulator all the time in the Gulfstream GVII. The pilot flying (PF) using the enhanced flight vision system (EFVS) spots the runway at 200 ft. above it, even though the pilot monitoring (PM) does not. He continues to 100 ft. If authorized to take it to touchdown, the PM spots the runway on his EFVS "heads down" displays and the crew goes further. Even without the technology, the crew might find themselves with the necessary visual cues to land when the pesky simulator instructor touches a button, and a truck pulls out onto the runway. "Go around!" The crew goes around and saves the day. The instructor pats them on the back and vectors them around for the next approach, having checked off yet another training requirement. An unintended consequence of all this is that pilots are conditioned to think they can do this routinely without too much trouble; this thought is reinforced in the debrief when nothing more is said about it. But can they? It turns out that there is a lot more to consider than merely going around; in reality, a balked landing is more complicated and riskier than a simple missed approach.



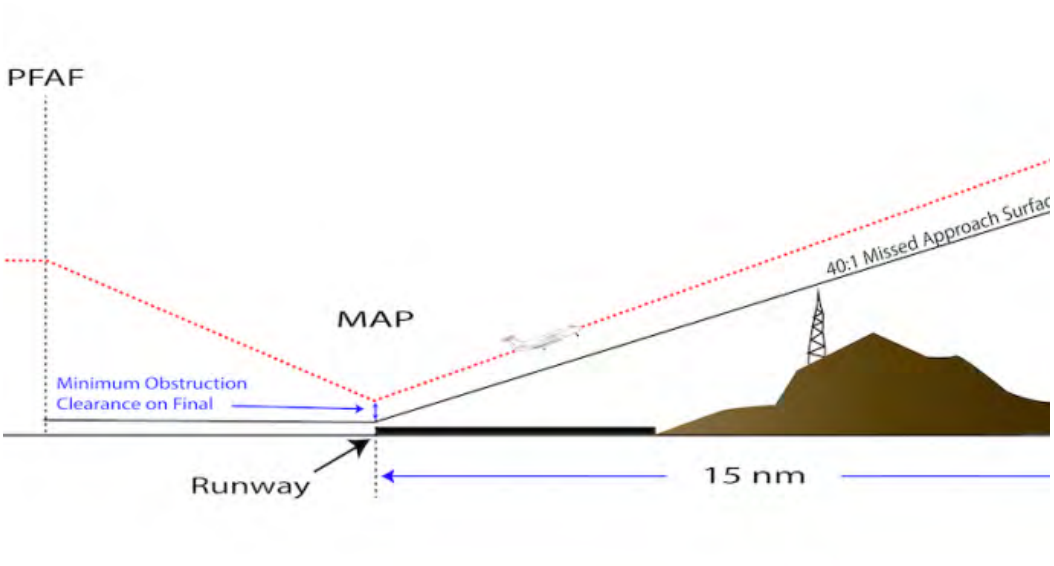
Balked landing considerations. Illustration credit: James Albright

What do you have to worry about? The second you dip below the published decision altitude (DA) or go beyond the published missed approach point (MAP), lots. Your missed approach path has been checked against obstacles, provided you begin the missed approach no later than the DA or MAP. Once you've gone beyond those points, you could have a problem. We are taught early on that ground effect is a good thing, and that is mostly true. But it can be a very difficult thing to climb out of. Unless you are protected by a very intelligent flight idle system, bringing your throttles to idle significantly changes the balked landing decision process.

You cannot balk a landing, go through rote procedures and be guaranteed success. You need to have exceptional situational awareness if you hope to beat the obstacles, the influences of ground effect and the lag in your engine spool-up time.

Obstacle Clearance

When does a missed approach become a "balked" landing? I think of going beyond the DA as a decision to land, and reversing that decision means you intend to balk the landing. Going missed approach before the DA assures you of obstacle clearance, provided you follow the procedure. Once you've gone beyond the DA, you might clear the obstacles. But maybe not.



The TERPS missed approach obstacle clearance surface. Illustration credit: James Albright

The U.S. Standard for Terminal Instrument Procedures (TERPS), FAA Order 8260.3E, requires that a missed approach procedure be established for each instrument procedure. A MAP is specified that "may be the point of intersection of a specific glidepath with a DA, a navigation facility, a fix or a specified distance from the PFAF." There is a surface that begins over the MAP that rises at least 1-ft. vertical for each 40-ft. horizontal, or as needed to clear any obstacle for 15 nm. The location or altitude of the MAP may need to be adjusted to ensure no obstacles penetrate the missed approach surface. While it is more complicated than that, as pilots we know that if we begin our missed approach no lower vertically and no later horizontally than the MAP and climb at the minimum rate of climb or higher, we will be guaranteed obstacle clearance.

If you descend below a published DA or initiate your missed approach beyond the MAP, those guarantees go away. In theory, once you go beyond those points, you are no longer on approach, you are landing. But that theory only holds true partially, as the following examples show.

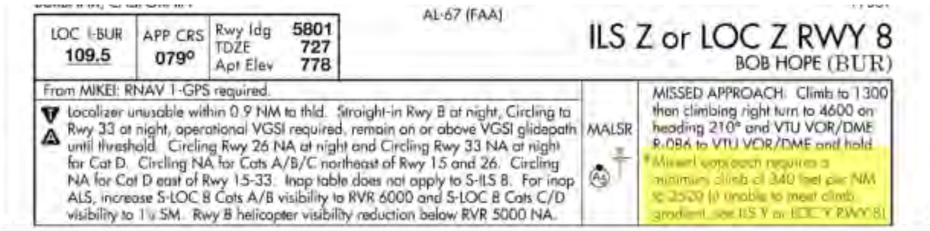
Let's say you are on an instrument landing system (ILS) approach and at the 200-ft. DA you spot the approach lights and nothing more. Under 14 CFR 91.175(c) you can continue to 100 ft. above the touchdown zone elevation (TDZE); you are still "on the approach." If you spot the red terminating bars or the red side row bars you can land. If you don't, you go around. But what about obstacle clearance?

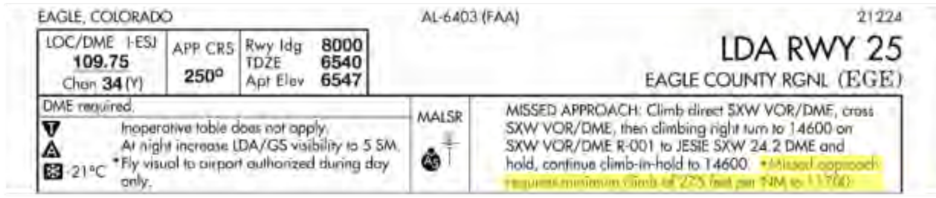
If you are trained, equipped and authorized to use an EFVS under the provisions of 14 CFR 91.176(a) you could take the aircraft even lower before deciding to go around. Once again, obstacle clearance is no longer guaranteed.

But you don't need an ILS or EFVS to be put into this situation. From any approach, and after you've made the decision to land, you could find yourself just about ready to touch down when you spot a vehicle or animal on the runway, or an aircraft malfunction convinces you to balk the landing.

In all three cases, for most airports, you probably won't have a problem. If the normal departure procedure is obstacle free, "chances" are the missed approach procedure will be as well. But how do you know? In the planning stage, there are a few places you can look to alert you to a problem so you can come up with a plan.

First, a well-designed procedure will tell you flat out that you will have a problem. The Juneau International Airport





Four types of missed approach obstacle clues. Credit: FAA

(PAJN), Alaska, LDA X Rwy 8 does just that: "CAUTION: Any go-around after passing MAP will not provide standard obstruction clearance." Second, when there is a potential problem, a procedure might steer you toward a more doable option. The Bob Hope Airport (KBUR), California, ILS Z or LOC Z Rwy 8 missed approach text warns you of the steep missed approach climb gradient but also tells you to see the ILS Y or LOC Y Rwy 8 if you're unable to meet that requirement. Third, sometimes just seeing a higher-than-standard gradient to a high altitude tells you obstacles could be a problem, as with the Eagle Country Regional Airport (KEGE), Colorado, LDA Rwy 25. Finally, sometimes a clue is in the FAA's Terminal Procedures Publication, letting you know there's a preferred "one way in and out" route common in many valley airports, such as McCall Municipal Airport (KMYL), Idaho, or Aspen-Pitkin County/Sardy Field Airport (KASE) in Colorado.

Obstacle Clearance Options

If you know the missed approach procedure will not guarantee obstacle clearance if executed below the DA/beyond the MAP, it may be a good idea to devise an alternate plan based on the runway's standard instrument departure (SID) or a published obstacle departure procedure (ODP).

FOLLOW THE PUBLISHED MISSED APPROACH PROCEDURE FOR THE ILS or LOC DME RWY 25: CLIMB TO 14,500 FT DIRECT TO SXW VOR/DME, THEN CLIMBING RIGHT TURN OUTBOUND VIA SXW R-001 TO ORNTH THEN CONTINUE CLIMBING TO JESIE INT/D24.2 SXW VOR/DME AND HOLD.

BALKED LANDING LIMITS Vapp/ga=160KIAS MAX

TMPC	A/I OFF	CWL A/I	CWL+WNG A/I
-20	60000	59000	56000
-10	60000	59000	56000
0	60000	59000	56000
10	60000	59000	56000
15	60000	NA	NA
20	59000	NA	NA
25	56500	NA	NA
30	54000	NA	NA
35	51000	NA	NA

MISSED APPROACH LIMITS CLIMB 300FT/NM TO 12000MSL

TMPC	A/I OFF	CWL A/I	CWL+WNG A/I
-20	64500	63500	57000
-10	64500	63500	57000
0	64500	63500	57000
10	64500	63500	57000
15	62000	NA	NA
20	59000	NA	NA
25	55500	NA	NA
30	53500	NA	NA
35	NA	NA	NA

*** LANDING FIELD LENGTH LIMITS ***

RUNWAY LENGTH SLOPE	WIND KTS	DESTINATION APT - FLPS 39 FAR 60% FCTR DRY	WET	FAR 80% FCTR DRY	WET	** ABNORMAL FLAPS LANDING ** FLAPS 20 DRY	WET	FLAPS 10 DRY	WET	FLAPS 0 DRY
	-10	75300	75300	75300	75300	75300	75300	75300	75300	75300

Gulfstream GV airport analysis, Eagle County Regional Airport (KEGE). For illustration only.

Some runway analysis companies will offer balked landing procedures with aircraft and weather limitations, or simply give you the aircraft configuration and environmental limits of the published procedures if executed as late as the runway touchdown zone. The procedure shown in the illustration is for a Gulfstream GV on approach to Eagle County Regional Airport.

With either option, you must remember that a clearance for an instrument approach is also a clearance to fly the published missed approach. It does not include a clearance to fly any alternate procedures unless you let ATC know your intentions ahead of time and they approve them. There is a school of thought that if you must balk the landing, you can declare an emergency and ATC will have no choice but to give you your way. Do you really want to have to do that with everything else going on during a balked landing? Do you really want to rely on everyone else getting out of your way? My advice: If you need alternate balked landing procedures, let ATC know before you are cleared for the approach.

Also, if your balked landing procedure is different than your published missed approach, you might consider entering it into your FMS as a "secondary flight plan" if you have that capability. If you plan on doing this, you should be well practiced at making the change. When you are low to the ground and your workload is high is no time to learn how to do this.

Finally, remember that sometimes you cannot do what you want to do and must simply raise your weather minimums or reduce your approach weight to make it possible. If you cannot guarantee obstacle clearance after going below the approach's published minimums, then don't do that until you are certain you can land.

The next part of this article will examine ground effect.

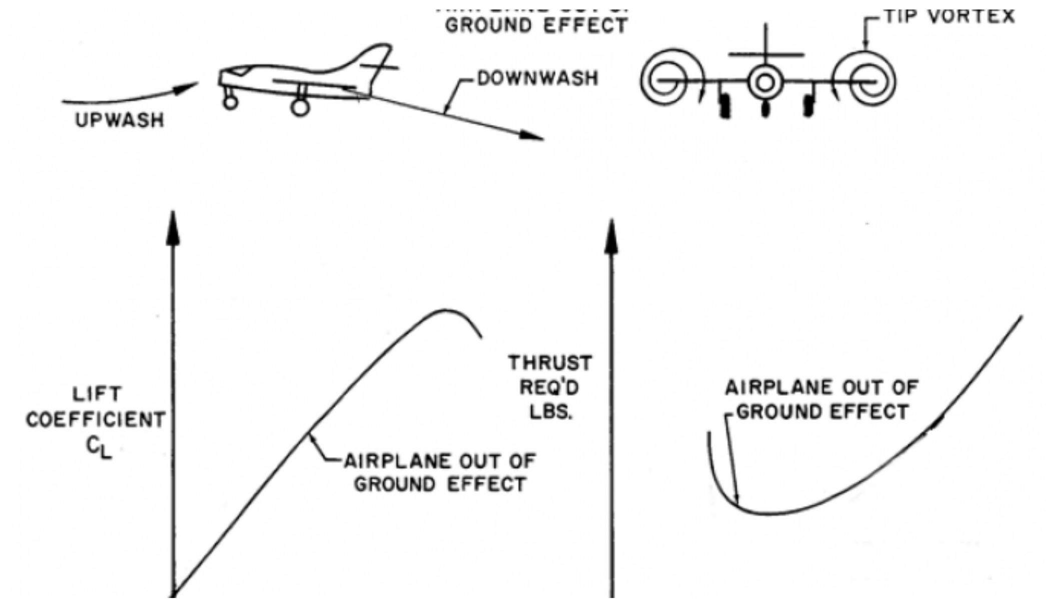
Balked Landings, Part 2

James Albright September 17, 2021

Credit: Photo credit: Adobe Stock/Alex Stemmers

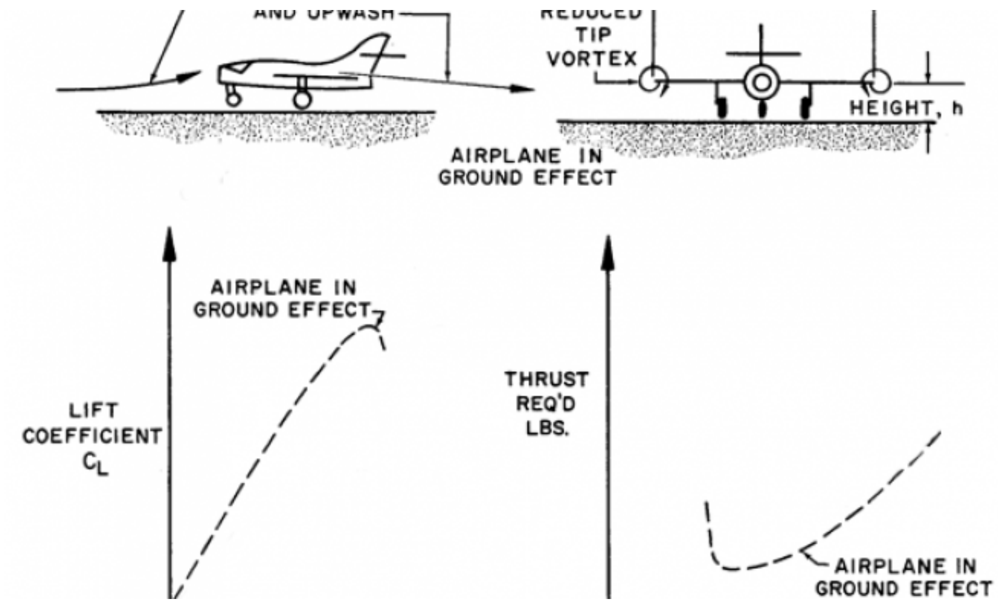
If you missed the first part of this article series, start here.

Most of us are taught early on that once the aircraft is within one-half wingspan height above the runway, we lose some drag because the wingtip vortices no longer wrap completely over the wing, reducing induced drag. And that is true. But it is only half the phenomenon. When you are in ground effect, you essentially have a different and more efficient wing. To understand a wing's performance in ground effect (IGE), you must first consider it out of ground effect (OGE).



ing performance out of ground effect. Credit: *Aerodynamics for Naval Aviators*

You may have seen the vortices around your wingtips on a humid or misty day and have an intuitive understanding that wingtip vortices are formed when higher pressure air below a wing flows around the wingtips into the lower pressure region on top of a wing that is developing lift. You have more pressure under the wing than over it, so the pressure below wants to wrap around to the top. Of course, the wing is moving forward, so this movement from bottom to top tends to trail aft. The downward force of the vortices not only subtracts from the upward force, but it also increases induced drag on the wing. It makes the wing less efficient.



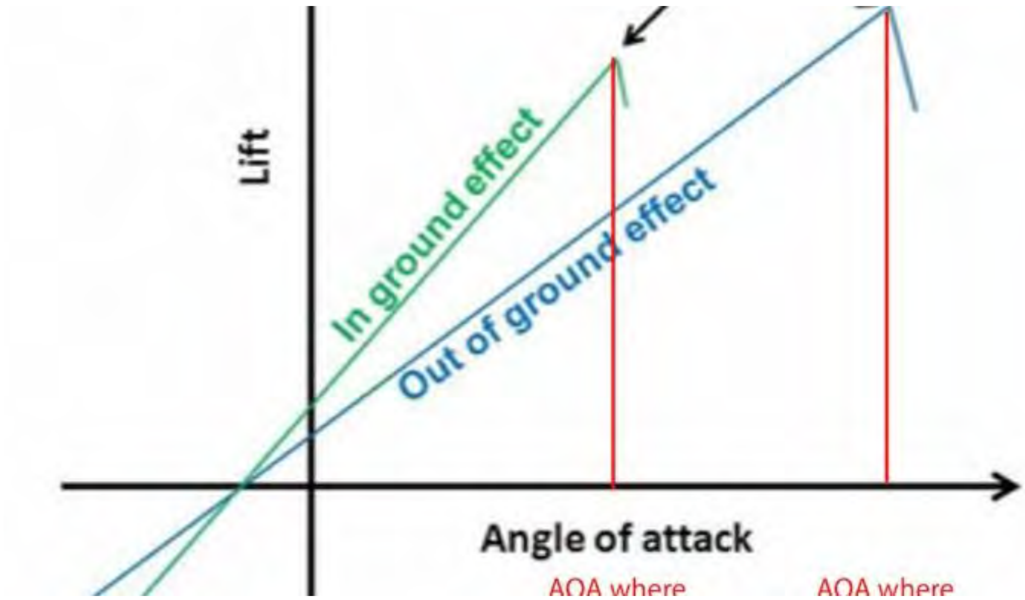
Wing performance in ground effect. Credit: *Aerodynamics for Naval Aviators*

If you had an infinitely long wing, you wouldn't have any wingtip vortices and the wing would seem to produce greater lift with less induced drag. But you don't need an impossibly long wing, you just need to fly low enough to interrupt the vortices so fewer of them reach the top of the wing. To the pilot, flying in this ground effect appears to have made the wing more efficient, because it really has.

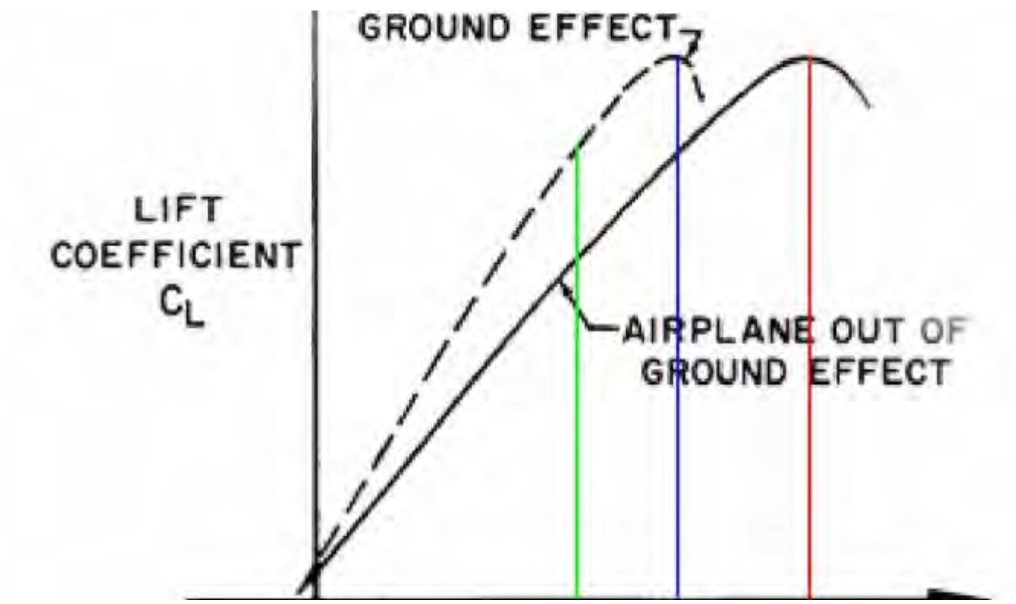
If you place the IGE and OGE coefficient of lift to angle of attack (AOA) curves together, you will notice that the IGE curve moves to the left. Looking at the C_L to AOA chart (on the left), you see that flying at a given AOA, you get more lift when IGE than OGE. The wing is more productive when in ground effect. But looking at the Thrust Required to Velocity chart (on the right), we see that for any given velocity, it takes more thrust to fly OGE.

The consequence for us in the balked landing situation is that we could find ourselves just barely climbing while in ground effect, and once we do climb out of ground effect, we may not have enough thrust available to maintain airspeed.

There is research that indicates the C_{L}-$_{MAX}$ (the peak of the curve) remains the same, but there is also research that shows it is lower when IGE. An April 2, 2011 crash of a test Gulfstream G650 showed that for some cases, the C_{L}-$_{MAX}$ when IGE is reduced compared to OGE. The aircraft will stall at a lower angle of attack when in ground effect. This is important to us in a balked landing situation.



In-ground-effect versus out-of-ground-effect stall AOA. Photo credit: NTSB



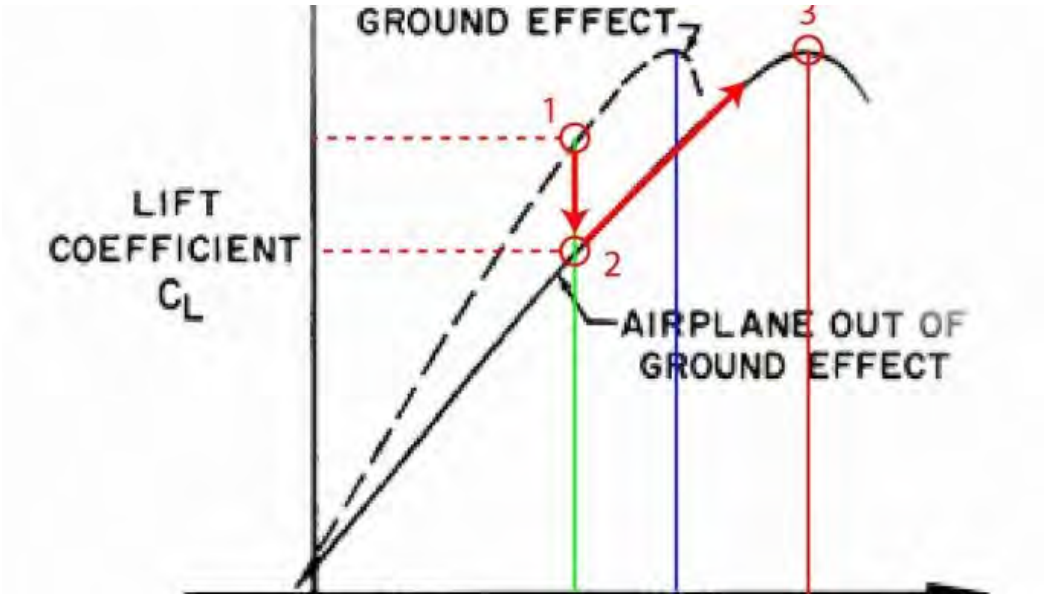
IGE to OGE hypothetical. Credit: *Aerodynamics for Naval Aviators*

How slowly are you willing to fly after balking a landing? We quite often rely on our approach reference speed, commonly called V_{REF}, as the speed we know will keep us safe. It is usually based on 1.23 times the stall speed of the aircraft. But that stall speed is based on the stall AOA, which is determined while flying out of ground effect. So, if you are balking a landing and are IGE, the V_{REF} you think will keep you above the stall might not, since it is based on being OGE.

Let's examine a hypothetical aircraft that just balked its landing while in ground effect. Suppose the C_{L}-$_{MAX}$ while IGE is 10 deg. and that equates to 115 KCAS in this situation (blue in the diagram). Suppose also that the C_{L}-$_{MAX}$ while OGE is 14 deg. and that equates to 100 KCAS in this situation (red in the diagram). In this situation, your V_{REF} will probably be 123 KCAS (1.23 times the OGE stall speed). If you are just barely climbing IGE at 123 kt. (the green line in the diagram), you might think you have a 23% margin above the stall and be tempted to pull back farther on the stick. But until you leave ground effect, your true stall speed is 115 KCAS. If you pull back farther than 115 KCAS while IGE, you will stall the aircraft.

The lesson here is to give your V_{REF} a healthy margin when in ground effect.

Can you be flying below the stall in ground effect and then stall simply by climbing out of ground effect? If you look at the C_L curves while sitting in the safety and comfort of your desk, the answer appears to be no. But keep in mind all this is happening very fast and the change from IGE to OGE may be a split-second transition. It gets very



IGE to OGE hypothetical. Credit: *Aerodynamics for Naval Aviators*

dicey. Perhaps another hypothetical is in order. (Actually, the same hypothetical, but just as the aircraft leaves ground effect.)

This time around, let's say you maintain your calculated V_{REF} of 123 KCAS all the way to the point your ground effect stops (Point No. 1 on the chart). You may argue that ground effect doesn't switch off from on and that's true. But it happens very fast. As it is happening, your C_L drops from the IGE line to the OGE line and the airplane wants to stop climbing and you feel it sinking (Point No. 2 on the chart). So, you pull back on the stick. If you do this just right, you will regain the original C_L and perhaps a little more. But how well calibrated is your hand? All this happens very fast and the chance of overshooting your pull and ending up at $C_{L\text{-}MAX}$ while OGE is very high (Point No. 3 on the chart).

When you leave ground effect you have two performance "obstacles" to overcome: You will have a loss of lift coefficient and an increase in induced drag. As with our previous hypothetical, having a healthy margin above V_{REF} is key. In either case, you must focus on airspeed before you can climb when balking a landing when in ground effect.

Before you accuse me of piling on one hypothetical after another and you would never find yourself in this situation, let’s look at two more complications in the balked landing scenario: engine spool-up time and flight director guidance.

The next and final part to this series will examine engine spool-up time and flight director guidance.

AVIATION WEEK Intelligence NETWORK

Balked Landings, Part 3

James Albright September 28, 2021

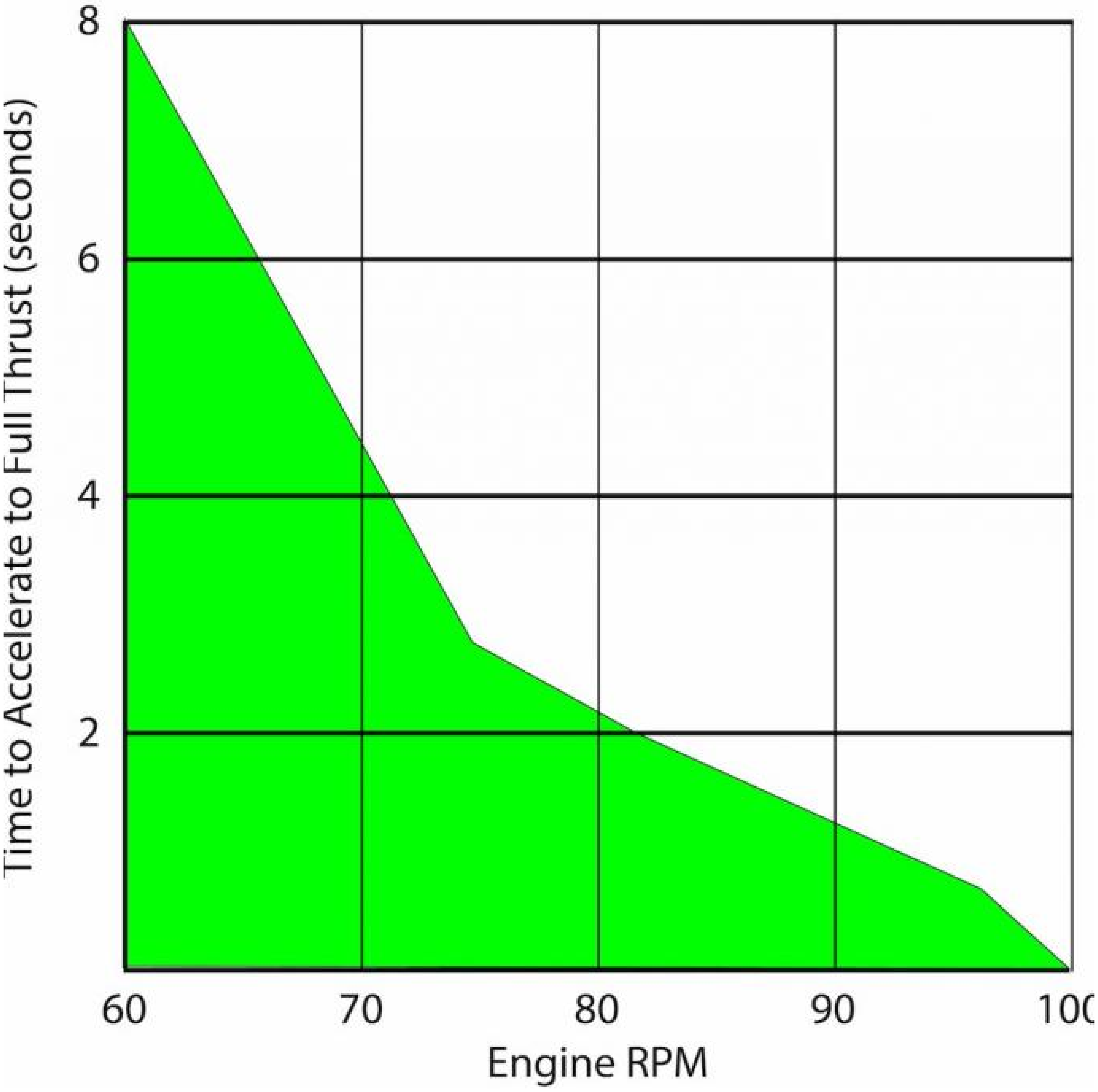
Photo credit: Adobe Stock/Maksym Dragunov

In case you missed them earlier, here is the first and second part of this article series.

Engine Spool-Up Time

Most jet engines achieve their highest efficiency and are most responsive to throttle or thrust lever movement at high rpms. The engine will more quickly accelerate 5% rpm from 90 to 95% rpm, for example, than from 50 to 55% rpm. It is not uncommon for some engines to take as much as 8 sec. to accelerate from idle to full thrust.

Modern engines with full authority digital engine control (FADEC) tend to have flight idle systems that keep the engine at a higher speed in case a last-second decision to go around during a landing is made. Even without a FADEC controlling the engine, some aircraft employ weight-on-wheel, throttle gates, soft detents or other systems to force a "flight idle" minimum speed. But with some of these systems, once the pilot decides idle is called for, the system delivers just that. This is precisely what happened to the crew of an Air Canada Regional Jet (CRJ-100ER) in 1997, while



Caption, optional: Hypothetical jet engine acceleration times. Image credit: James Albright

attempting to land at Fredericton Airport, New Brunswick (CYFC), Canada. The pilot found himself high on glideslope after descending below the DA and pulled both throttles to idle. The aircraft ended up slower than the published flight boundaries for a go-around and it took nearly 8 sec. for the engines to achieve go-around thrust. The aircraft failed to go around and was destroyed. Incredibly, all 42 on board survived.

If you don't have a very good flight idle system--one that understands you may decide to return to the air--you should be wary of pulling the throttles all the way back until you are assured that you have landed. But even with a good flight idle system, there is one more balked landing "gotcha" to worry about.

Flight Director Guidance

I am not aware of any current flight directors that consider aircraft energy state in and out of ground effect. I believe most, if not all, are designed to command a go-around from an altitude above ground effect and assume normal engine spool-up time. We are trained to immediately pitch up to those flight director command bars while advancing our throttles to go around or equivalent thrust, assuming the pitch and power will allow us to climb and accelerate. As we've seen, the thrust requirement and in-ground-effect stall AOA could deny us the ability to climb or accelerate. Following the TO/GA cues during a balked landing might be the wrong thing to do. At the very minimum, you should monitor your airspeed and climb rate when balking a landing.

A Balked Landing Survival Guide

As your simulator experiences have taught you, most of your balked landings will present no problems: Just follow missed approach procedures and trust the simulator instructor will get you vectors for the next approach. But in the airplane, you cannot rely on the person behind the curtain. You will need to have exceptional situational awareness if you hope to beat the obstacles, the influences of ground effect and any lag in your engine spool-up time.

Step 1: Plan ahead!

Clearance for an approach includes clearance for the missed approach, but that only gives you obstacle clearance assurance if you begin the procedure at or before the DA/MAP. You should inspect the missed approach procedure against the runway obstacle departure procedure and other data to see if you could have a problem. If so, you need to come up with an alternate procedure in case you need to balk the landing after the DA or MAP.

Step 2: Commit!

Once you've decided to balk the landing, do that. Second guessing yourself eats up runway you need to complete the landing or robs you of distance ahead and precious altitude needed to beat the obstacles.

Step 3: Back up the automation!

Simply pressing TO/GA and hoping the automation takes care of you isn't enough. If the wheels touch down, even for a second, your aircraft might take actions contrary to your decision. In the case of an Emirates Boeing 777 accident in 2016, for example, the pilot decided to balk the landing by pressing TO/GA and pitching the nose up. He assumed the autothrottles would increase thrust; however, the weight on wheel system told the engines to remain at idle until the pilots figured that out. But they were too late. Balking a landing is very much like a missed approach, only more so! Make sure your thrust is set.

Step 4: Allow for spool-up time!

If your engines don't have an intelligent flight idle system and you have somehow ended up below a normal approach thrust setting, you may not get the thrust you need in a timely manner.

Step 5: Understand V_{REF} may not be enough!

As we've seen from looking at lift curves, you could stall at a lower AOA when flying IGE. As we've seen from looking at thrust required curves, you will need more thrust to fly the same airspeed when OGE than IGE. If the aircraft is barely climbing and accelerating in ground effect, remember you will need a larger margin above V_{REF} before leaving ground effect.