Departure Obstacles

Strategies for **avoiding things** that can **snag and grab**

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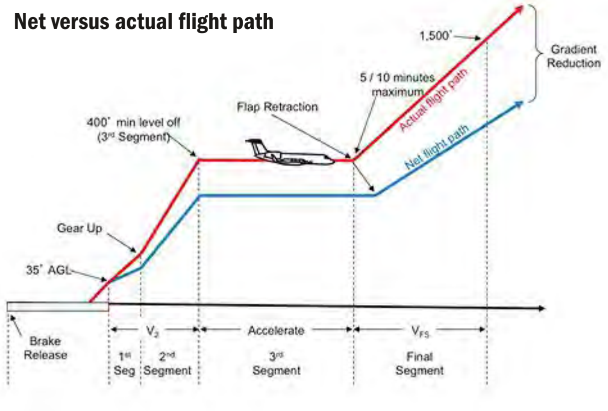
I was in Aspen, Colorado, about 15 years ago, sitting in the FBO with at least 10 other crews all doing the same thing: looking at the overcast. The obstacle departure procedure for the Aspen-Pitkin County/Sardy Field Airport (KASE) simply says, "use SARDD DEPARTURE." That departure procedure requires the weather be at least 400-1 and mandates a climb of at least 460 ft./nm all the way up to 14,000 ft.

"If we can't see the obstacles," I explained to our CEO and lead passenger, "we have to out-climb them. We are too heavy to do that so we have to wait until the weather improves."

Net versus actual flight path



Just then we heard the roar of another corporate jet rolling down the runway. Everyone rushed to the windows as the airplane disappeared into the low overcast. Was that crew acting recklessly or were we crews in the FBO missing something important?

There are at least three strategies for dealing with airport departure obstacles, each valid in its own way but each with limitations that must be understood to maximize safety margins. And therein lies the problem: The rules are spread across at least seven FARs, two documents from the International Civil Aviation Organization (ICAO), a U.S. Advisory Circular and the U.S. Standard for Terminal Instrument Procedures (TERPS), also known as FAA Order 8260.3B. But once you understand the competing regulatory issues, you can dispassionately sift through the strategies and pick one that works for you. That process begins with looking at how your airplane's performance gets reported in your Airplane Flight Manual (AFM).

Takeoff Climb Performance

The takeoff performance data in your AFM may not be designed as you might think.

First off, the takeoff path of the airplane must assume the loss of the critical engine. The U.S. rules for transport category aircraft are covered by 14 CFR 25, Section 25.111. Internationally, these rules are covered by ICAO Annex 8, Part IIIA, Paragraph 2.2.3.

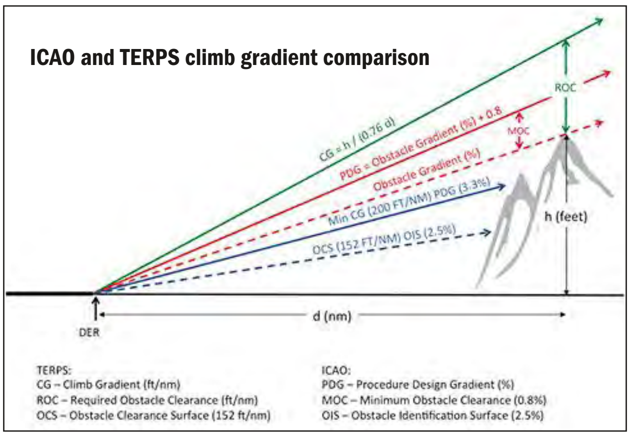
Secondly, the "net" takeoff flight path reflected by AFM performance data represents the actual takeoff flight path reduced at each point by a gradient of climb equal to 0.8% for two-engine airplanes, 0.9% for three-engine airplanes and 1.0% for four-engine airplanes.

These reductions are found in 14 CFR 25.115. ICAO Annex 6 requires a net takeoff path be used. In either case, these numbers reflect a margin of safety. A margin of 0.8% for a two-engine aircraft doesn't sound like much and it isn't: just 0.008 x 6,076 = 48.6 ft./nm. There is, however, another margin to consider.

Procedures Based on All Engines Operating

Unlike aircraft takeoff performance data, obstacle departure procedures are designed assuming all engines operating (AEO). The U.S. rules are given in TERPS, Volume 1, Paragraph 201: "Criteria are predicated on normal aircraft operations for considering obstacle clearance requirements." ICAO has a similar provision in Document 8168, Volume II.

Both ICAO and TERPS specify a minimum climb gradient for all departure procedures. ICAO calls this the minimum procedure design gradient (PDG) and says it can never be less than 3.3%. TERPS calls this the minimum climb gradient (CG) and says it can never be less than 200 ft./nm. These values are about the same, since 200 ÷ 6,076 = 0.033, which is simply another way of writing 3.3%.



ICAO and TERPS also specify a surface below the aircraft's path that identifies a zone where obstacles cannot penetrate without having to change the climb gradient. (There is an exception for low, close-in obstacles but more on that later.) The ICAO obstacle identification surface (OIS) starts at the departure end of runway (DER) and inclines upward by 2.5%. The TERPS obstacle clearance surface (OCS) also starts at the DER and inclines upward by 152 ft./nm. The values are about the same, since (152 ÷ 6,076 = 0.025, which is 2.5%.

If you take the minimum climb gradient and subtract the obstacle surface you get the safety margin between the two. Under ICAO, the minimum obstacle clearance (MOC) is 3.3 - 2.5 = 0.8%. Mathematically, MOC = 0.008 x d, where d is the distance from the DER expressed in feet. Note that this value does not change with the climb gradient. MOC is 0.008 x 6,076 ft./nm = 48.6 ft./nm, no matter how steep is your climb gradient.

Under TERPS, the required obstacle clearance (ROC) is 24% of the climb gradient. Mathematically, ROC = 0.24 x CG. For the minimum climb gradient of 200 ft./nm, you have an ROC of 0.24 x 200 = 48 ft./nm. But as you steepen your climb, you also increase your ROC.

If an obstacle, other than a low, close-in obstacle (more on that later), penetrates the OIS/OCS, the procedure's climb gradient must be raised to preserve the MOC or ROC. Under ICAO, the 0.8% MOC is added to the gradient created by the obstacle. If, for example, a line from the DER to the obstacle is 5%, the procedure design gradient is raised to 5.8%.

Under TERPS, the climb gradient is adjusted to the following formula: CG = h ÷ (0.76 x d), where h is the height of the obstacle in feet and d is the distance from the DER in nautical miles.

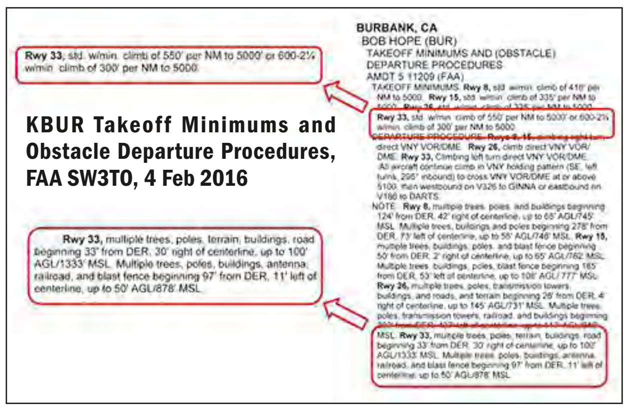
Let's say, for example, we have an obstacle that is 1,500 ft. above and 5 nm (30,380 ft.) away from the DER. The obstacle has a gradient of 1,500 ÷ 30,380 = 0.0494, or 4.94%. The ICAO MOC is always 0.8%, so our PDG is 4.94 + 0.8 = 5.74%. Our height above the obstacle would be (0.0574 x 30,380) - 1,500) = 244 ft. Under TERPS, the climb gradient is h ÷ (0.76 x d), or 1,500 ÷ (0.76 x 5) = 395 ft./nm. (That's 6.5%, much higher than the ICAO PDG.) So our ROC = 0.24 x 395 = 95 ft./nm. At 5 nm, our height above the obstacle will be 5 x 95 = 475 ft., almost double the ICAO margin.

Low, Close-In Obstacles

While ICAO and TERPS cast a very wide net when considering most departure obstacles, both seem to ignore obstacles known by the seemingly innocuous term "low, close-in obstacles."

TERPS and ICAO do not adjust climb gradients, takeoff minimums or procedures for any obstacles that are not higher than 200 ft. within the first nautical mile from the DER. TERPS, Volume 4, Paragraph 1.3.1 requires only that "the location and height of any obstacles that cause such climb gradients" be annotated. The same "catch" exists in ICAO Document 8168, Volume II, Paragraph 2.

In either case, a note is published to help us identify and plan to avoid these obstacles, but these are rarely written with enough specifics to help the pilot.



KBUR Takeoff Minimums and Obstacle Departure Procedures, FAA SW3TO, 4 Feb 2016

Consider, for example, the note associated with Runway 33 at Bob Hope Airport, Burbank, California (KBUR). There are "multiple trees, poles, terrain, buildings, road beginning 33 ft. from DER, 30 ft. right of centerline, up to 100 ft. AGL." For anyone who has used that runway, finding a 100-ft. AGL target 33 ft. from DER would seem an easy task, except that it doesn't exist. The poorly worded sentence provides the pilot with very little useful information.

The FAA offers a digital obstacle file for the U.S. at **http://www.faa.gov/air_traffic/flight_info/aeronav/digital_products/dof/**, but these are very large, cumbersome, and take a good computer to really digest. If you wanted to try, you would see that the file covering KBUR is 790 pages long and includes these two gems:

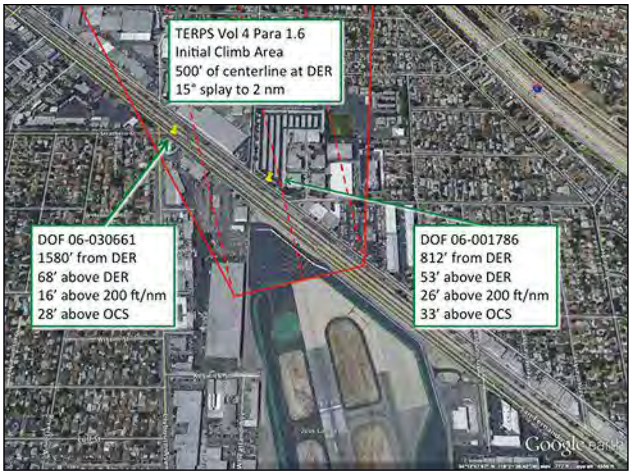
06-030661 O US CA BURBANK 34 12 56.17N 118 21 50.28W POLE 1 00050 00846 R 2 C U A 2013106

06-001786 O US CA BURBANK 34 12 52.00N 118 21 41.00W POLE 1 00048 00831 L 1 A U C 2014152

So, if you were able to find these two obstacles out of the thousands given, and if you plotted them, you would see exactly the location of two of your low, close-in obstacles. The most critical appears to be 53 ft. above and 812 ft. from the DER, almost on centerline.

Is this a problem? Let's say it is raining, the weather is above standard and you are permitted to leave with the minimum climb gradient of 300 ft./nm to 5,000 ft. That comes to 300 ÷ 6,076 = 0.0494, or 4.94%. If the maximum weight for this climb gradient requires a ground run following an engine failure that

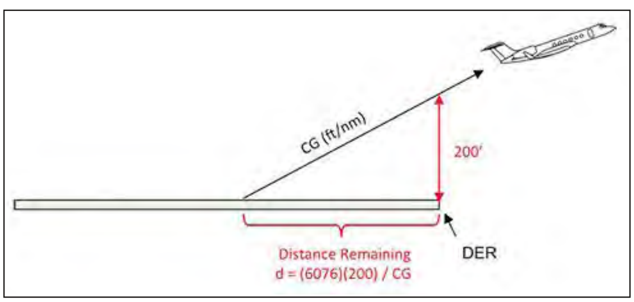
GOOGLE EARTH IMAGE



Two low, close-in obstacles at KBUR

equals the runway available, you can expect to cross the DER at 15 ft. (for aircraft that have wet runway performance data). A 4.94% gradient across a distance of 812 ft. results in a climb of 0.0494 x 812 = 40 ft. If you cross the DER at 15 ft., that means you are at 40 + 15 = 55 ft. when you cross the pole marked as DOF 06-001786, which is 53 ft. above the DER. You have a clearance of only 2 ft. A call to the airport manager might be useful, but without a very good database of terrain and obstacles, the only way to guarantee low, close-in obstacle clearance is to cross the DER at or above 200 ft.

If, for example, your planned weight at Burbank produces an engine-out climb gradient of 600 ft./nm, you will need to have at least (6,076 x 200) ÷ 600 = 2,025 ft. beyond your planned takeoff run to guarantee that you will clear any low, close-in obstacles.



Low, close-in obstacle avoidance, the "Brute Force" method.

Of course giving up such a large chunk of runway can be unnecessarily prohibitive if the low, close-in obstacles aren't really that close. A sound strategy for dealing with departure obstacles must consider all obstacles, even those TERPS and ICAO choose to ignore with nothing more than a nebulous note. Unfortunately, most strategies are blind to the issue.

Aspen-Pitkin County/Sardy Field SARDD THREE Departure, FAA SL-5889

Strategy: OEI Performance for AEO Procedures

Not too many years ago most pilots would tell you that the only way to legally and safely depart a mountainous airport was to use your aircraft's one engine inoperative (OEI) performance charts to meet the AEO departure procedure's gradient.

In the Gulfstream G450, for example, the AFM restricts us to only 47,000 lb. gross weight when leaving Aspen on the SARDD THREE Departure at 20C and 7,000 ft. pressure altitude — that's just barely enough fuel to fly for an hour and without any kind of safe fuel reserve. Armed with that information, the pilot would be forced to wait out the weather.

This strategy grounds the aircraft for obstacles that are miles away laterally and perhaps gives too generous a vertical margin as well. While they are maximizing their distant obstacle clearance, the published obstacle departure procedures do not consider low, close-in obstacles when establishing weather minimums or minimum climb gradients.

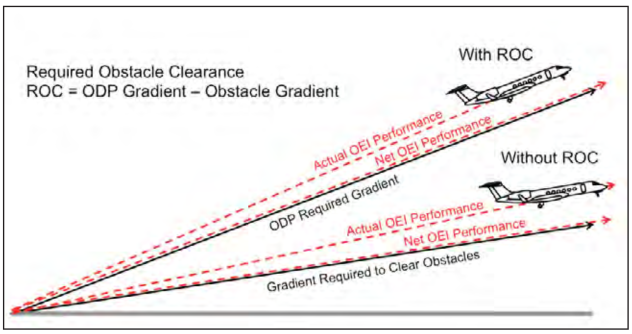
Strategy: Reduce Vertical Margins

Another technique is to keep the net takeoff path safety margin (between 0.8% and 1.0%, depending on number of engines) and remove the TERPS 24% ROC or the ICAO 0.8% MOC.

In the Aspen example, the required climb gradient is 460 ft./nm. You can remove the ROC by multiplying the CG by 0.76 (1 - 0.24), which means you only need to climb at 460 x 0.76 = 350 ft./nm. An ICAO departure will also be given in ft./nm but should also have the value given as a percentage. If not, divide the ft./nm by 6,076 ft. to get a percentage. An ICAO departure with a 460 ft./nm example becomes 460 ÷ 6,076 = 7.6%. To remove the MOC, subtract 0.8. Your new climb gradient target is 7.6 - 0.8 = 6.8%.

Using this strategy can be problematic because there is math involved and the principles can be confusing. Commercially available programs can automate the process, but these too, in my opinion, can be confusing. When entering the obstacle departure procedure gradient in one such program, you are asked to note if the procedure is designed under ICAO or TERPS. If you select ICAO, the program subtracts the 0.8% MOC from what it calls the "gross gradient" to produce a "net gradient." Likewise, if you select TERPS, the program multiplies the "gross gradient" by 0.76 (1 - 0.24) to produce a "net gradient." Selecting TERPS in our Aspen example yields a takeoff gross weight of 55,720 lb., an increase of over 8,000 lb.

Pilots may be misled into thinking they are only giving up their FAR Part 25 net takeoff path and still have the more



The impact of removing required obstacle clearance from performance computations

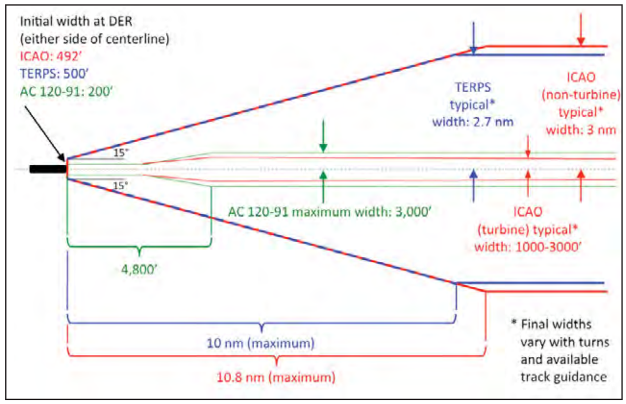
generous TERPS ROC. This isn't the case. TERPS and ICAO Document 8168 do not use the terms "gross gradient" and "net gradient" to describe ROC and MOC. Using this program your climb gradient ends up being equal to the obstacle height plus only the net takeoff flight path factor. (For a two-engine airplane, that comes to only 48.6 ft. for every nautical mile traveled.)

Let's say we are dealing with an obstacle right at the maximum allowed without having to increase the climb gradient, which comes to 152 ft./nm. So, we could conceivably have an obstacle at 5 mi. that is 5 x 152 = 760 ft. higher than the DER. Loading the airplane to achieve the required climb gradient of 200 ft./nm means we will be at 5 x 200) = 1,000 ft. plus the net flight path difference of 5 x 0.008 x 6,076 = 243 ft. We would clear the obstacle by 1,000 + 243 - 760 = 483 ft. If we elect to load our aircraft with more fuel and passengers so as to achieve only the 152 ft./nm climb gradient, our margin is cut in half.

This strategy also leaves untouched low, close-in obstacles and ignores one more factor in the departure obstacle avoidance problem. We often think of obstacles vertically: We have to out-climb what is directly beneath us. But we must also consider the lateral dimension.

Strategy: Airport Obstacle Analysis

Obstacle departure procedures are designed with very wide lateral tolerances under both ICAO and TERPS. Those minimum climb gradients could be unnecessarily high because they are considering obstacles miles away from course centerline. Perhaps this was necessary back when an aircraft climbing into a cloud deck was lucky to be within a mile of course centerline. What about today? If you have an airplane with

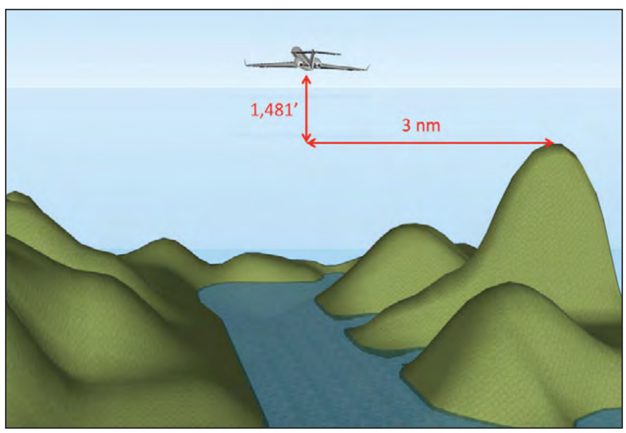


ICAO and TERPS lateral obstacle consideration area comparison

an instantaneous readout of "position uncertainty" you very seldom see your airplane more than 0.05 nm off course. That's just 300 ft.! While departure procedures continue to be built off these wide lateral areas, we as pilots are allowed to narrow our gaze if we have a plan.

TERPS procedure construction can be very complicated; the lateral margins vary with distance from the departure end of the runway. The lateral margin starts at 200 ft. either side of runway centerline and quickly expands by thousands of feet to as much as 3 mi. ICAO procedure construction mimics TERPS in many ways and becomes almost as wide. Unless the procedure says otherwise, the climb gradient on these procedures could be based on obstacles that are miles away.

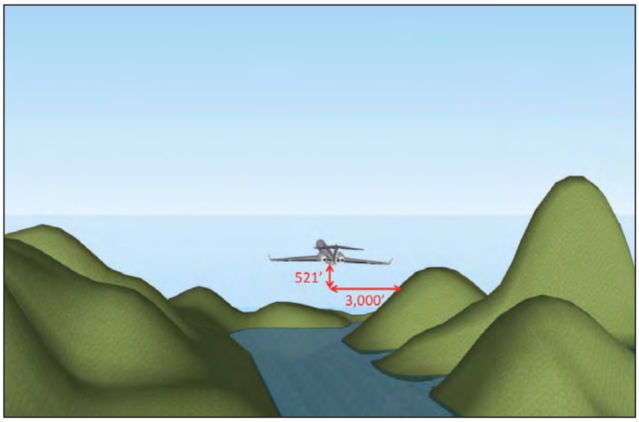
ICAO Annex 6 narrows the lateral margin that must be considered by large (more than 5,700 kg, about 12,500 lb.) turbine aircraft. The margin can be as tight as 1,000 ft. but will be no



Example vertical/lateral clearances under TERPS at 10 nm

more than 3,000 ft., depending on course guidance, turns and distance from the runway. U.S. Advisory Circular 120-91 provides a method of applying an obstacle clearance area that is narrower than the TERPS area and is almost as narrow as the tightest ICAO margin. If an aircraft can maintain course within 3,000 ft., the required climb gradient can drop significantly, and that can allow much higher payloads.

Let's say you are departing in a two-engine aircraft from an airport that leads into a valley with what looks to be a challenging obstacle departure procedure. The SID says you need to climb at 400 ft./nm to an altitude that is 4,000 ft. above the departure end of the runway. Looking at the chart it appears the greatest problem will be around 10 nm after takeoff about 3 nm to the right. The departure takes you right down the middle of the valley, so if you lose an engine on takeoff how high above the obstacle will you really be?



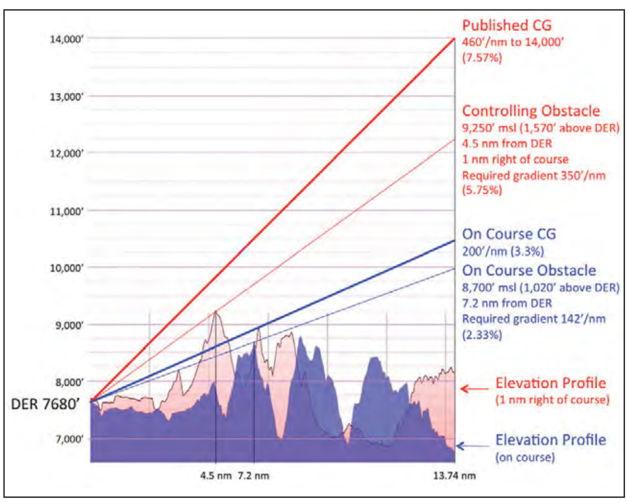
Example vertical/lateral clearances under TERPS at 10 nm

The procedure required obstacle clearance is ROC = 0.24, CG = 0.24 x 400 = 96 ft./nm, which means at 10 nm it will be 960 ft. A two-engine aircraft will also have the net flight path margin of 0.008 x 10 x 6,076 = 486 ft. While TERPS assumes the departure begins at DER on the runway, your aircraft manuals are usually predicated on 35 ft., which means you will cross almost 3 nm abeam the obstacle at an altitude 960 + 486 + 35 = 1,481 ft. higher than the obstacle.

Now let's say we narrow our lateral boundaries to the maximum provided in AC 120-91, just 3,000 ft. from either wingtip. We can increase our payload since we no longer have to out-climb the more distant obstacles and will give up the TERPS 24% ROC.

That means we will cross 3,000 ft. abeam another obstacle at an altitude 486 + 35 = 521 ft. higher than the obstacle.

Using terrain-mapping software, such as Google Earth, we can draw the Aspen SARDD obstacle departure procedure course line from the DER all the way to the completion of the procedure. We can also diagram the borders of the obstacle clearance area and discover the most challenging



Comparing "on course" versus "1 nm right" SARDD departure obstacles, using Google Earth elevation profile feature

obstacles are about a mile right of course.

The published climb gradient is 460 ft./nm, which comes to 460 ÷ 6,076) = 7.57%. The DER is 7,680 ft. We will reach 14,000 ft. in (14,000 – 7,680) ÷ 460 = 13.74 nm. A theoretical controlling obstacle height can be derived from the TERPS formula: CG = h ÷ (0.76 x d). Solving for the height of the obstacle we see that h = 0.76 x d x CG = 0.76 x 13.74 x 460) = 4,804 ft. Our obstacle gradient appears to be 4,804 ÷ (13.74 x 6,076) = 5.75%.

Google Earth allows us to trace the departure procedure and produce a terrain elevation profile for an on-course departure (shown in blue) and for one that deviates to the right inside the TERPS obstacle clearance area until it is 1 nm to the right (shown in red). Right of course we see an obstacle at 9,250 ft. MSL, 4.5 nm from the DER. This obstacle will be 9,250 – 7,680 = 1,570 ft. above the DER. We can compute its gradient: 1,570 ÷ (4.5 x 6,076) = 5.74%, pretty close to our theoretical gradient.

We can repeat this process for what appears to be the most challenging obstacle if the airplane were to remain precisely on course, a peak of 8,700 ft. found 7.2 nm from DER. The peak is 8,700 – 7,680 = 1,020 ft. above DER. The gradient of this obstacle is: 1,020 ÷ (7.2 x 6,076) = 2.33%. This is less than the TERPS 152 ft./nm OCS, since 0.0233 x 6,076 = 142 ft./nm. If you could remain on course you would only need the minimum 200 ft./nm climb gradient.

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 --  ASE -KASE --            TAKEOFF PERFORMANCE                  --  ASE -KASE --
                              GULFSTREAM G-450                           ASPEN, CO
  ELEVATION 7838            RR TAY MK611-8C  ENG            ASPEN-PITKIN CO/SARDY
                              AFM REVISION 40

                          TAKEOFF FLAPS 20.0 DEGREES

   ** RWY33DP    REQUIRES USE OF ATTACHED SPECIAL DEPARTURE PROCEDURE **
   ** RWY33DP1   REQUIRES USE OF ATTACHED SPECIAL DEPARTURE PROCEDURE **
   ** RWY33DP5   REQUIRES USE OF ATTACHED SPECIAL DEPARTURE PROCEDURE **

  RUNWAY           33DP         33DP1        33DP5        33
  TORA(FT)         8006         8006         8006         8006
  TODA(FT)         8006         8006         8006         8006          CLIMB
  ASDA(FT)         8006         8006         8006         8006
  SLOPE(%)        -1.97        -1.97        -1.97        -1.97          LIMIT
 TMP  EPR A/I
 DGC  OFF/ ON              RUNWAY/OBSTACLE LIMIT WEIGHT / V1

 12 1.73         72139/140    72139/140    67399/141    58929/132      74600.
 14 1.73         71900/140    71900/140    67373/141    58905/132      74600.
 16 1.73         70983/139    70983/139    66389/140    58106/131      74600.
 18 1.72         70052/138    70052/138    65330/139    57306/130      74600.
 20 1.71         69279/137    69279/137    64192/138    56367/129      74600.

  HW   +LBS/KT     68           65           56           63
  TW   -LBS/KT    404          405          233          219
 QNH   +LBS/.1     233          232          225          204
 QNH   -LBS/.1     381          381          340          378
 CWL AI ON-LBS    490          340          510          450            0
WNG+CWL AI-LBS    730          580          930          780            0
SPLRS INP-LBS/V1  710/ 3       710/ 3        50/ 1        0/ 0
ASKD INOP-LBS/V1   NA/**        NA/**        NA/**        NA/**
ACCEL ALT(MSL)   10400        10400        10350        11340

                *** OBSERVE STRUCTURAL LIMITS ***             30Jan16
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Extract of aircraft performance group example output, Gulfstream G450, Aspen

Of course this kind of analysis is impractical without the benefit of extensive terrain databases and sophisticated software. Many major airlines have been using these systems for years. One such system is available from Aircraft Performance Group) (APG, **http://www.flyapg.com**) available with a subscription and in many commercial flight-planning services.

Plugging our Aspen example into the software yields a significant increase in gross weight, nearly an extra 20,000 lb., which would be enough to make the East Coast. The program has the added benefit of factoring in low, close-in obstacles. But this software must also be used with care.

The software sometimes uses unpublished procedures that require additional steps in the event of an engine failure. You would have to file one procedure with the intent of using it under normal conditions. In the event of an engine failure, you may have to reprogram flight management systems or other avionics while letting ATC know you are deviating from the filed procedure. This is certainly possible but not something with which you should burden yourself while dealing with an engine failure in mountainous terrain.

The example "33DP" procedure, however, precisely mimics the SARDD THREE procedure. In fact, it is more precise, offering bank angles, a turn based on position and not altitude, and a specific time to begin flap retraction and acceleration. We can, as a result, have confidence that we can load our G450 to 69,279 lb. and: (1) be able to stay clear of all obstacles in the event of an engine failure if we stay within 3,000 ft. of our filed and planned course, (2) not have to worry about changing departure procedures in the event of an engine failure, (3) have enough fuel to make it to our destination on the east coast and (4) avoid all low, close-in obstacles.

There still remains one loose end that the regulations do not address and that most proponents of increasing departure weights fail to recognize. If you increase your weight above the point where OEI performance will meet the AEO climb gradient you know you are OK if you lose an engine because you have (1) ensured you clear all obstacles by required vertical and lateral margins, and (2) you do not have to meet the departure procedure climb gradient because you have a failed engine. But what if you don't lose the engine? If your AFM does not have AEO takeoff climb path data, how can you be sure you will meet or exceed the procedure's minimum climb gradient? The FAA is silent on this subject other than to say it is something you need to consider.

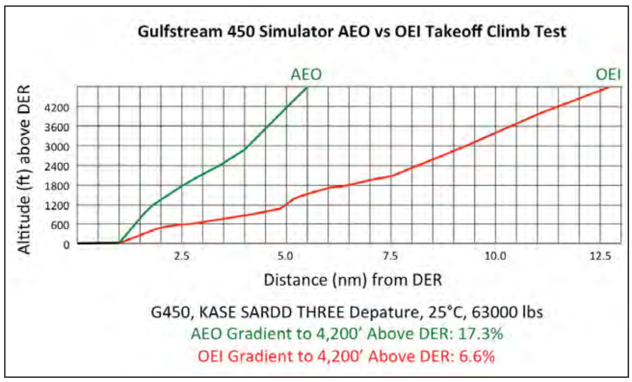
Meeting AEO Climb Gradients at Higher Weights

Let's say, as with the Aspen example, you have an ODP climb gradient of 7.6% and elect to reduce that by the TERPS 24% ROC, lowering your OEI climb gradient to (1 - 0.24) x 7.6 = 5.8%. You know you will clear the obstacles because the climb gradient minus the ROC is based on that. Now if you don't lose an engine can you still meet the AEO climb gradient? What follows is my personal theory.

If you are flying a two-engine aircraft you are getting half your climb gradient from each engine. If you lose an engine, your climb gradient decreases by at least 50% because you will also have the parasite drag from the windmilling or seized engine.

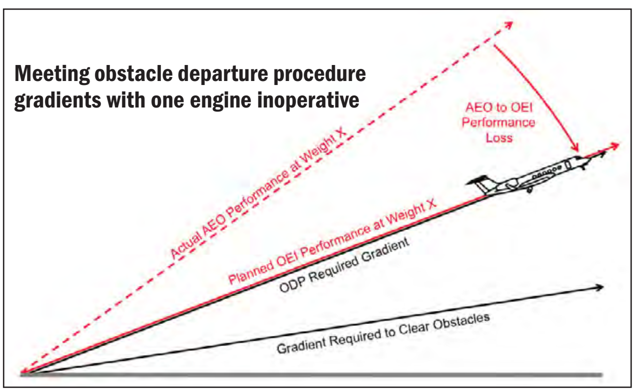
It follows, then, that your all-engine climb gradient will be at least double your one-engine climb gradient. Since you've reduced your target climb gradient by a maximum of 24% and will have double the climb gradient available, you should be OK.

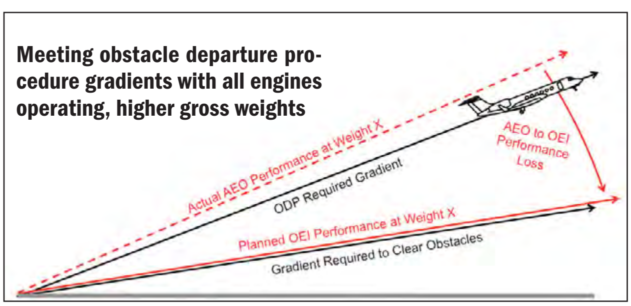
Since the loss of an engine in a three-engine aircraft results in 33% thrust loss and in a four-engine aircraft results in a 25% thrust loss, each aircraft should be OK since the maximum gradient reduction is 24%. In the case of our Gulfstream with a 5.8% OEI climb gradient, we can guess our AEO climb gradient will be at least 11.6%, much higher than the 7.6% obstacle departure procedure requirement.



G450 simulator climb tests, AEO versus OEI

I've tested this theory in a few aircraft simulators and it appears to be valid. In the case of a G450 loaded to near APG weights, the AEO takeoff climb performance was 2.5 times greater than with OEI. Armed with this data, I believe my aircraft will meet the required climb gradient with all engines operating, even after I've increased the gross weight to underperform the climb gradient with an engine failed by the TERPS ROC margin. You can test your aircraft by having the simulator operator freeze the gross weight and run an altitude-versus-distance track on two tries, one flying AEO and another with an engine failed at V1.


Meeting obstacle departure procedure gradients with one engine inoperative


Meeting obstacle departure procedure gradients with all engines operating, higher gross weights

Rationalizing Your Margin of Safety

Picking a departure obstacle avoidance strategy is not as straightforward as one might think. Simply choosing to load the aircraft up so the AEO climb gradients are met with OEI does assure distant obstacle clearance and departure procedure compliance, but it does not assure all low, close-in obstacles are avoided. Electing to increase takeoff gross weight erodes the aircraft's vertical margin of safety, but in many cases the combined margins are unnecessarily wide. Using departure obstacle analysis software provides pilots with the ability to narrow the lateral margins so as to discount obstacles that are miles off course with the additional assurance that low, close-in obstacles will be avoided too.

But in every case where the vertical margin is decreased, pilots must understand how much of a margin is left over before they can decide if they are safe "enough." Let's return to our Aspen example to bring theory into practice.

▶ **Strategy One:** Our G450 was grounded in Aspen with a maximum takeoff weight of 47,000 lb. We could have flown for an hour and expected to top every obstacle within a few miles by a vertical margin that included the 24% ROC in TERPS as well as the 0.8% net takeoff path. This strategy fails to address low, close-in obstacles.

▶ **Strategy Two:** We could have increased our takeoff weight to 55,720 lb. by removing the TERPS 24% ROC. We still have the 0.8% net takeoff path vertical margin, but this isn't much when looking down on those jagged cliffs north of Aspen. If we found ourselves just 1 nm right of course, we would pass the mountain at 4.5 nm by just 218 ft. This strategy also fails to consider low, close-in obstacles.

▶ **Strategy Three.** Using computerized terrain and obstacle analysis software, we can increase our takeoff weight to over 69,000 lb., enough to fly to the east coast. We are assured of clearing all low, close-in obstacles, as well as those that are more distant. We must fly much tighter lateral tolerances and will end up with the same reduced vertical margins as found with the second strategy.

Modern aircraft have a way to address the tighter lateral tolerances. Navigating to within 3,000 ft. of course line is pretty easy if you ensure your GPS is operating with a good receiver autonomous integrity monitoring (RAIM) check and you are able to set your course deviation indicator to give you ample warning of a deviation. All of this electronic wizardry will be for naught, however, if you fail to "step on the good engine" and eliminate all adverse yaw with rudder.

The vertical performance is more problematic. In our Aspen example we are cutting our vertical margin over the most demanding obstacle from 500 to only 218 ft. How much of that margin will remain if you encounter a 10-kt. tailwind a few hundred feet in the air? What about a temperature inversion? Finally, if the rudder isn't perfect, any adverse yaw will erode that vertical margin further. Even in ideal conditions, crossing that shear mountaintop with only 218 ft. is sure to set off the enhanced ground proximity warning system.

Picking a Strategy

It has been said that the safest way to fly is to never leave the ground. Of course that also has an adverse effect on one's paycheck. We are constantly required to weigh "the safest way" with "safe enough." In our Aspen example, there is a tradeoff between how much fuel and how many passengers you can carry versus the vertical clearance you can hope for in the event of an engine failure. I can't pick a strategy for you since you may not be flying the same type of aircraft and your risk tolerances are surely different than mine. But I can offer my strategy as a possible template.

Whenever I go to an unfamiliar airport I run an airport obstacle analysis using APG software. If the charts say I can load up to maximum weight on published procedures, I know I can rely on my airplane's built-in performance computer and know I will beat all obstacles while meeting AEO climb gradients. Of course I need to do this for every departure because obstacles (manmade and natural) are constantly changing.

If the software says I am obstacle limited, I will consider the gross weight specified for published procedures only, and even then only as an absolute maximum. The winds and temperature at altitude have to cooperate for this plan to work.

I then brief the crew that we are about to take off with reduced vertical and lateral clearances and we will need to do a GPS RAIM check. Then I'll brief the other pilot on what I expect from each of us in the event of an engine failure.

I have been using airport obstacle analysis software for 10 years and I could further say I have been doing so without incident. But I haven't lost an engine in all that time. I do practice in the simulator a lot and my favorite place to practice is Aspen when loaded to APG weights. You need to see that cliff at 4.5 nm getting closer with the EGPWS going crazy to really understand how narrow that 0.8 net takeoff path percent margin really is. My aircraft has synthetic vision and a flight path vector that assures me through it all that I am not going to hit that mountain. It is still unnerving, nonetheless.

Back to Aspen. Five years after our original scenario I was back in Aspen with a new airplane and a new company. Our dispatchers were as despondent as the rest of the crews in the FBO. I loaded up our Gulfstream V to the weight we needed to make the East Coast, which split the difference between the strategy one weight and the maximum strategy three weight found in the APG software application. We departed on time and I am sure there were a few crews stuck on the ground wondering, "are those guys operating recklessly or are we missing something important?" **BCA**