One Engine Inoperative Takeoff Planning and Climb Performance

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Have you declined to accept a Standard Instrument Departure (SID) because the aircraft you are flying cannot comply with the SID climb gradient if an engine failure occurs? Have you ever reduced your takeoff weight so that you can comply with the SID climb gradient if an engine failure occurs? Have you ever delayed your flight because of low visibility or low ceilings which required a climb gradient published on the SID or Obstacle Departure Procedures (ODP) in which your aircraft with one engine inoperative could not satisfy? If you answered yes to any of these questions, you are not alone. You are also not alone in that you may have unknowingly and needlessly declined to fly a SID or ODP, reduced your takeoff weight, or delayed your flight due to your One Engine Inoperative (OEI) takeoff planning. In the end, how confident are you that you are planning your one engine inoperative takeoff without jeopardizing safety, exceeding the operational limits of your aircraft, or needlessly reducing your aircraft’s payload capability? The objective of this paper is to promote operator knowledge, operator application, and operator training issues surrounding transport airplane takeoff performance, Parts 91 and 135 operators alike, specifically showing that the current practice of planning for OEI takeoff obstacle avoidance and compliance with TERPS criteria is inadequate and potentially dangerous.

Regulatory Requirements

Starting with a brief and general overview of two regulatory requirements to set the stage for the purpose of this article include first, Part 25 aircraft certification requires an aircraft to be able to maintain various positive climb gradients to the end of the takeoff path, which is 1,500 feet above the takeoff surface or at which the transition from the takeoff to the en route configuration is completed, whichever is higher. One item to note is that Part 25 does not require that the climb gradient clear all obstacles. Second, operators of Part 25 Transport Category aircraft operating in accordance with 14 CFR Part 135 are required to undertake certain one engine inoperative takeoff planning tasks. FAR 91.175 (f)(4)(i) requires commercial operators of large transport category, turbine-powered transport category, or commuter category airplanes departing an airport under IFR to have a procedure for avoiding obstacles in the event of an engine failure on takeoff, and that ensures compliance with the applicable airplane performance operating limitations requirements under Part 135, subpart I for takeoff at that airport. Methods of complying with this rule include either developing your own procedure or using a contract company to develop avoidance procedures.

One Engine Inoperative Planning Methods

The most widely used OEI planning method compares a climb gradient published on a SID or ODP with the OEI climb gradient obtained from the Aircraft Flight Manual (AFM) (usually the 2nd segment OEI climb gradient), and this is where problems arise and which is the focus of this paper. It has been frequently observed during training events and line flying that OEI takeoff obstacle avoidance is often based on TERPS (SIDs/ODP) IFR departure procedure climb requirements. In doing so this results in a number of problems. The most common problems as stated previously are those where pilots needlessly self-impose constraints that limit their operational flexibility. Because there is an overwhelming belief that it is a requirement to fly the assigned SID/ODP in the event that an engine fails, pilots needlessly decline TERPS procedures, reduce takeoff weight or delay flights because their aircraft cannot maintain OEI takeoff climb gradient published on the SID or ODP.

The next set of problems that arise are less obvious but no less important. These include the failure to consider low close-in obstacles not accounted for by TERPS criteria (Figure 1), extrapolation of performance data beyond the performance chart design and procedures published in the AFM, failure to account for max takeoff thrust time limits, and pilots using a single linear OEI climb gradient based on a "spot climb gradient" that is not representative of the true slope of the OEI flight path. In addition, standard and/or nonstandard acceleration altitudes are not used or taught consistently.

As a consequence of the obscurity and lack of understanding related to the integrated system components of takeoff performance computations, the variability of AFM aircraft performance charts, TERPS and departure charting requirements and limitations, Part 25 aircraft certification requirements, and the difficulty in obtaining obstacle information in the takeoff path, the ability for pilots to determine exact flight paths and takeoff weights is problematic, thus relying on SIDs and ODPs is a convenient way to manage OEI performance planning. However, failure to account for critical differences between the TERPS criteria, the Part 25 OEI takeoff certification rules, and the operating rules OEI takeoff obstacle avoidance contained in Subpart I,
Differences Between TERPS and One Engine Inoperative Criteria

There are differences between TERPS and one engine inoperative criteria, including the lateral and vertical obstacle clearance requirements. TERPS criteria are based on normal operations (all engines operating), thus TERPS all engines operating criteria and one engine inoperative obstacle clearance requirements are independent. One engine inoperative procedures do not need to meet TERPS requirements. Furthermore, compliance with TERPS all engines operating climb gradient requirements does not necessarily assure that OEI obstacle clearance requirements are met. TERPS climb gradients are developed for normal operations and are constructed using a continuous climb gradient. SIDs and ODPs are intended to be used by aircraft with all engines operating and are expected to maintain a 200 feet per mile climb gradient unless a greater gradient is specified. If a higher or non-standard climb gradient is required, it is published. SIDs and ODPs are not intended for one engine inoperative flight path guidance, either laterally or vertically.

While SID climb gradients are often established for obstacle clearance purposes, a SID climb gradient may be established for reasons other than obstacle clearance. A SID climb gradient may be established to meet an ATC climb requirement or to meet procedure design criteria such as early or immediate turns after departures. While ODP climb gradients are primarily established for obstacle clearance purposes, they may also be needed for DME/DME reception when using RNAV based departure procedures. As a pilot, you may have no knowledge as to whether a SID is published for obstacle clearance or otherwise. The consequence here is that you may unnecessarily decline the SID or reduce takeoff weight in the event of an OEI takeoff to comply with a published climb gradient for which there is no obstacle to clear in the first place.

An engine failure during takeoff is a non-normal condition, and therefore takes precedence over noise abatement, air traffic, SIDs, ODPs, and other normal operating considerations. This correctly implies that you are not required to maintain the SID or ODP profile, either laterally or vertically. Of course, once in flight this is not the time to “wing it” and alter your flight path. Planning prior to takeoff is mandatory. Advisory Circular 120-91, Airport Obstacle Analysis, provides guidance in developing procedures meeting the OEI takeoff obstacle clearance rules found in Subpart I, Part 135. The two important points that were just discussed are: 1) As a part 135 operator you are required to have a procedure to avoid obstacles in the event of an engine failure on takeoff; however this procedure is not required to mimic any SID or ODP for the runway you are departing or to be filed in the flight plan with ATC, and 2) if you have an alternate procedure and your all engines operating climb performance meets or exceeds the SID/ODP published climb gradients, you do not need decline the SID or ODP, delay your takeoff for better weather, or reduce your payload. In effect, you have removed any self-imposed operational constraints. While this article has primarily focused on U.S. operations; it should be pointed out that ICAO PAN-OPS allows for contingency procedures as well.

Using SIDs or ODPs for OEI obstacle clearance leads us to additional areas of concern in which our following example will highlight. During your OEI before takeoff briefing at an airport with a SID or an obstacle departure procedure, maybe you’ve briefed the OEI procedure in this manner, “if we lose an engine after V1 and before V2, we'll maintain flaps 10, gear up and we’ll follow the SID/ODP until reaching the published altitude and once above the obstacles, we'll return to the airport using the ILS RWY 31.” In this scenario, using a SID or ODP for obstacle avoidance, you may find yourself in a quandary. Have you considered what your acceleration altitude will be or when you’ll reduce engine thrust from max takeoff thrust to max continuous thrust? Of course this is a generic briefing, however pick any airport with a SID/ODP with a nonstandard climb gradient and ask yourself, if an engine fails on takeoff what altitude will I level off to accelerate, clean up and reduce power from max takeoff thrust to max continuous thrust?

Unlike TERPS, which bases obstacle clearance on an uninterrupted surface defined by a gradient, the Part 25 OEI net takeoff flight path is constructed from a series of synthesized segments that do not form a continuous gradient. The Part 25 OEI net takeoff flight path is evaluated against known obstacles within the lateral accountability area defined by either Subpart I or AC 120-91. Because of the segmented nature of the net takeoff flight path, comparison of a single OEI climb gradient against a TERPS gradient will not ensure obstacle clearance along the entire OEI net takeoff flight path.

Furthermore, the OEI second segment climb gradient (net or gross as chosen by the manufacturer) that is published in the AFM
is intended for use on the OEI net takeoff flight path charts. These charts are most often referred to as the Close-In and Distant Obstacle/Flight Path Charts. Part 25 requires that the OEI second segment net takeoff flight path extend to a minimum height of 400 feet above the runway. In the past, Gulfstream published G150 second segment OEI net takeoff data to an altitude of only 400 feet above the runway; however this has since been changed to heights greater than 400 feet AGL, while the Lear 35 AFM publishes its OEI second segment net takeoff flight path data to 1500 feet AGL; while other aircraft manufacturers have been known to extend the data to much higher altitudes. In many circumstances, comparing a particular OEI climb gradient obtained from the AFM to a climb gradient published on a SID or ODP extrapolates performance data beyond the instructions and procedures provided in the AFM. In our example, extrapolating the older G150 AFM performance data beyond 400 feet AGL up to 5000 feet AGL is not approved by the FAA.

Next, TERPS gradient does not account for low, close-in obstacles described in AIM 5-2-8(c)(1). These obstacles are critical when the aircraft does not lift off until close to the departure end of the runway or when aircraft is climbing at its minimum rate, both of which are frequently experienced with an engine failure on takeoff at or shortly after V1 speed. Unfortunately, not all SIDs or ODPs note these close-in obstacles since this charting requirement was not in place prior to TERPS change 19. Therefore, an operator comparing the OEI climb gradient to the TERPS climb gradient may be missing critical obstacles at the beginning of the OEI net takeoff flight path where the available performance margin is at a minimum. The failure to follow the procedures provided in the AFM and the guidance contained in AC 120-91 means that commercial operators following TERPS procedures may not be meeting their obstacle clearance obligations for departing under IFR as stated in 91.175 (f)(4) and Subpart I of part 135.

Moreover, Part 25 OEI criteria incorporate an acceleration altitude or segmented climb gradient, SIDs and ODPs do not. It is nearly impossible to determine an acceleration altitude for OEI operations while using a SID/ODP for obstacle clearance. For example, what if the SID requires a 500 feet per minute climb gradient to 5,000 feet above the airport? Do you feel comfortable leveling off at 400 feet AGL or 1500 feet AGL to accelerate and clean up? Maybe you've decided the best course of action is to maintain your current configuration until 5,000 feet AGL (or whatever the SID/ODP call for) before accelerating and cleaning up. This leads us to another area of concern. Most jet engines have a five minute max takeoff thrust time limit. What altitude can you climb to in your aircraft with OEI without exceeding the five minute max takeoff thrust time limit? Many nonstandard climb gradients published on SIDs and ODPs are required to significant heights above field elevation, thus exceeding the time limit for use of max takeoff thrust. In the example above it will take 10 minutes to climb to 5,000 feet AGL at 500 feet per minute. You'll need to climb at 1,000 feet per minute with one engine inoperative to comply with a five minute max takeoff thrust time limit, hardly realistic.

Training

Due to the lack of guidance from Flight Standards Information System Order 8900.1, Volume 4, Chapter 3, Part 142 training centers are not technically out of compliance when teaching the use of TERPS procedures for OEI obstacle avoidance procedures, the use of these procedures can lead pilots into precarious positions, both safety and operationally detrimental. A more advantageous method of complying with the requirement to have a procedure for avoiding obstacles in the event of an engine failure on takeoff and that ensures compliance with applicable airplane performance operating limitations is to use alternate OEI takeoff procedures. In doing so, pilots are sure to operate their aircraft in the safest and most operationally efficient state in which it was designed for.

Related Resources


This FAA Advisory Circular contains information on developing takeoff and initial climb-out airport obstacle analyses and in-flight procedures to comply with the takeoff limitation requirements of parts 121 and 135


FAA Aeronautical Information Manual Section 5-2-8, revised August 27, 2009, covers Instrument Departure Procedures (DP), Obstacle Departure Procedures (ODP) and Standard Instrument Departures (SID)

FAA AFS-410 Airport Obstacle Analysis Web Page [http://www.faa.gov/about/office_org/headquarters_offices/avs/offices/afs/afs400/afs410/obstacle/]

View the FAA Flight Standards Service Flight Technologies & Procedures Division Flight Operations Branch (AFS-410) web page on Airport Obstacle Analysis.