How Wide Is That Intersection?

What you need to know about that wiggly crossing radial or bearing on which you sometimes bet your life.

By Wally Roberts

PREVIOUS ARTICLES IN THIS series have discussed instrument approach procedure (IAP) vertical and lateral obstacle clearance parameters. This article will delve into the nuts-and-bolts of where an IAP segment begins from a criteria standpoint. This is just as important as the other components of obstacle clearance because descent prior to entering a segment of an IAP can sting as much as any other transgression of protected airspace.

The practical use of multiple step-down fixes in the intermediate and final segments is limited to DME.

Breaching protected airspace

There are essentially two possible breaches of obstacle clearance during the execution of an IAP: (1) flying out of the lateral limits of the protected airspace trapezoid; or, (2) flying through the floor of the trapezoid by either failing to adhere to the minimum specified altitude for the segment, or failure to adequately maintain the electronic glideslope in the case of an ILS final approach segment.

Number (2) above has three subsets: (a) failure to maintain the minimum altitude set forth for the segment being flown; (b) in the case of the missed approach segment, failure to exceed the 40:1 upward slope of the missed approach's protected airspace; and, (c) failure to adhere to the limits of the fix or position that defines the next lower segment of an IAP. This article is concerned with the limits of item (c)—the segment's defining-fix entry point.

Defining the limits

TERPs, Chapter 2, Section 8, "Terminal Area Fixes," sets forth the accuracy requirements for the various IAP fixes, whether formed by a VOR, LOC or NDB radial/bearing intersection, or by DME, ATC radar or 75 MHz marker beacon. Table 1 (below) lists the assumed error limits for the various terminal area fixes for purposes of primary TERPs protected airspace areas (secondary areas to the sides of VOR and NDB courses assume greater, but less likely to occur, errors).

VOR, LOC or NDB radial/bearings have both along-course and crossing-course accuracy values because the fix is the intersection of two angular courses. On the other hand DME, ATC radar and marker beacon fixes are stand-alone fixes, which are independent of the errors associated with the primary navigation facility.

The flyability factor

Figure 1 (above right) and Figure 2 (on right) show the intersection fix limits for the IAF/IF and FAF, respectively. (Figures 1 & 2 and all the other accompanying illustrations are from the TERPs handbook.) The intersection-fix IAF or IF can be so sloppy as to consume up to 50 percent of the length of the succeeding intermediate segment. However, the intersection-fix FAF cannot normally have more than one mile of error on the worst side of the fix.

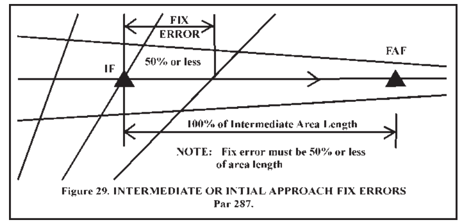

Figure 1. The intersection-fix IAF or intermediate fix can be so sloppy as to consume up to 50 percent of the length of the succeeding intermediate segment.

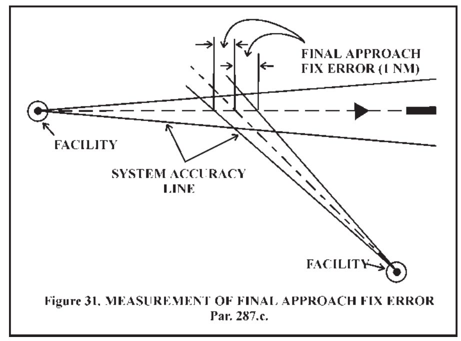

Figure 2. The intersection-fix FAF cannot normally have more than one mile of error on the worst side of the fix.

These limits are to protect for the flyability of the IAP.

In the case of the IAF or IF, distance for descent is the only consideration, whereas for the FAF both descent considerations and timing accuracies for the MAP must be considered.

Figure 3 (page 11) and Figure 4 (page 11) show the different applica-

Table 1. ERROR LIMITS FOR TERMINAL AREA FIXES

FACILITY	ALONG-COURSE ERROR	CROSS-COURSE ERROR
VOR	+/- 4.5 degrees	+/- 3.6 degrees
NDB	+/- 5.0 degrees	+/- 5.0 degrees
LOC	+/- 1.0 degree	+/- 0.5 degree
ATC Radar	+/- 500 feet or 3% of the distance to the antenna, which ever is greater.	Not Applicable
DME	+/- 0.5 miles or 3% of the distance to the antenna, which ever is greater.	Not Applicable
Marker Beacon	Outer/middle/inner ILS markers: +/- 0.5 miles. ("Airway" markers have differing values, but are obsolete.)	Not Applicable

tion of intersection-fix error assumptions for descent gradient application and obstacle clearance area, respectively.

Refer to Figure 2 again. It seems pretty good that the intersection-fix FAF is limited to one mile of error on the worst side of the fix, for that isn't more than 20 percent of the typical five-mile final segment. But, there's an escape clause for the procedures designer. The intersection-fix FAF worst side fix error can be as large as two miles, provided a buffer after the MAP is applied before the missed approach 40:1 surface begins. This explains those really sloppy intersection-fix FAFs that some of you have encountered. Such an application, although okay for timing to a missed approach, doesn't help much in timing to find a runway in marginal visibility conditions. Figure 5 (below right) shows application of this final approach fix error buffer.

As an alternative to the MAP buffer, the procedures designer can instead raise the MDA by 15 feet per 1/10 mile of excessive FAF error, or use a combination of the MAP buffer and this MDA adjustment. The pilot, of course, doesn't have a clue about what has been done. (Another reason these types of IAPs are "non-precision.")

The slippery-slope

"Paragraph 289" is one of those paragraph numbers committed to heart and mind by all purveyors of TERPs. For those few pilots who understand Paragraph 289, a form of fear is added to heart and mind. I don't know the origins of this slippery paragraph, but suffice it to say that some sharpshooter, either from the FAA or some industry lobbyist armed in the "go" detent, decided that full FAF obstacle protection was too restrictive in mountain country. As a result, the powers-that-be decided that "existing obstacles located in the final approach area within 1 mile past the point where a fix can first be received may be eliminated from consideration by application of a descent gradient of 1 foot vertically for every 7 feet horizontally."

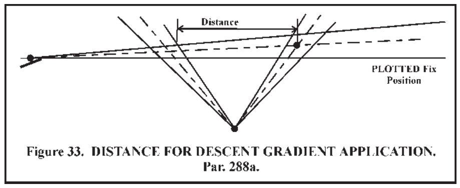

Figure 3. Application of intersection-fix error assumptions for descent gradient application.

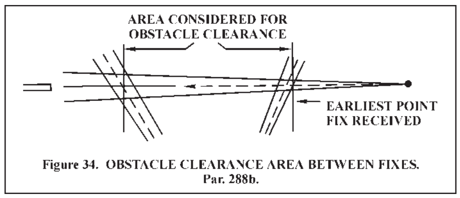

Figure 4. Application of intersection-fix error assumptions for obstacle clearance area.

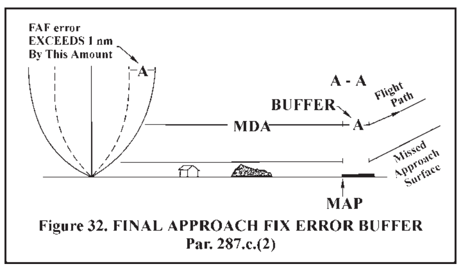

Figure 5. As an alternative to the MAP buffer, the procedures designer can instead raise the MDA or use a combination of MAP buffer and MDA adjustment.

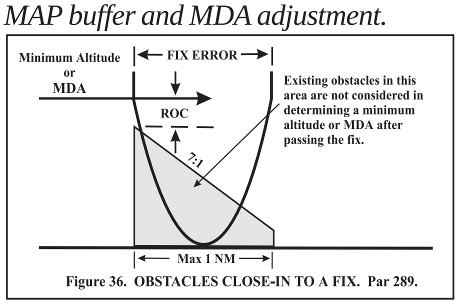

Figure 6. Obstacles located in the final approach area within 1 mile past the point where a fix can first be received may be eliminated from consideration by application of a descent gradient of 1 foot vertically for every 7 feet horizontally.

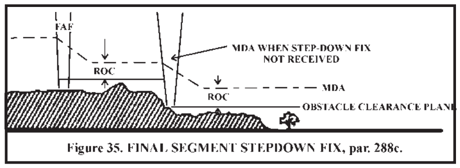

Figure 7. Application of final-segment step-down fix criteria where minimums are to be published both for reception and non-reception of the step-down fix.

Figure 6 (below left) graphically shows this application. Although the fix in this figure looks similar to a marker beacon, this could very well be a one-mile-wide intersection-fix FAF, and from a crossing NDB bearing instead of a VOR radial. (More on NDB errors later.)

Paragraph 289 states that "obstacles which receive this treatment shall be noted on the procedure." The presumed intent is to highlight the obstacle with an icon so the wary pilot will think twice about giving any sloppy FAF or final segment step-down fix an early confirmation. But, for years the FAA didn't require chartmakers to actually chart Paragraph 289 obstacles, although the administrative note appeared on the official Form 8260-5. Since no pilots I know fly IAPs with the official form, only the chartmakers at Jeppesen and NOS had any knowledge of the application of Paragraph 289. This is the stuff that comes from years of lack of active pilot-group participation in the highly technical TERPs process.

Step-down fixes

The initial segment (within certain limitations) can have more than one intersection-fix step-down fix, but all such fixes, from the IF to the last final segment step-down fix must be from the same crossing facility. This presumably does not restrict the use of a different crossing facility for a step-down intersection fix in the initial approach segment. The intermediate and final segments can only have one intersection-fix step-down fix each.

Where DME or ATC radar is used, there's no limit to the number of step-down fixes in any segment, except ATC won't normally buy into such a program—so the practical use of multiple step-down fixes in the intermediate and final segments is limited to DME.

All multiple step-down fixes must be stated in whole mile increments. This has variously been interpreted to mean 2.0, 3.0, etc.; or 2.3, 3.3, etc.

Could be misleading

Figure 7 (on left) shows the applica-

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How Wide. . .

(continued from page 11)

tion of final-segment step-down fix criteria where minimums are to be published both for reception and non-reception of the step-down fix. The illustration is a bit misleading because the option of Paragraph 289 could be applied to either the FAF or the step-down fix.

Dual minimums (with and without the last step-down fix) are published, except for IAPs that require DME (XXX/DME in the title) or NDB IAPs which use a VOR radial to define the step-down fix (it's presumed that all IFR airplanes have VOR capability). Dual step-down minimums aren't established for less than a 60-foot decrease in MDA.

Obstacle clearance between fixes

Figure 4 shows the basic concept of application of obstacle clearance for fix error. Figure 8 (on right) shows the procedures designer how to dovetail the complex geometric fix-error quadrangles of Figure 4 into easily workable rectangles. What bias this throws into the system error assumptions set forth in Table 1 is anyone's guess. With DME fixes, this is a conservative application, but not necessarily so for either a VOR radial or NDB bearing.

Fix displacement math

Figure 9 (on right) shows the procedures designer the trigonometric areas that must be considered to mathematically determine fix displacement factors. With this information at hand, those of you who are math whizzes can audit your favorite fuzzy intersection-fix FAF.

Holding at an intersection fix

Figure 10 (page 13) shows the application of TERPs holding pattern criteria at an intersection fix. At least three of the four corners of the fix displacement area must be contained with the primary area of the holding pattern template. As you can see, holding at a fuzzy intersection is betting that navigation system errors are both random and correctly quantified (more on that following).

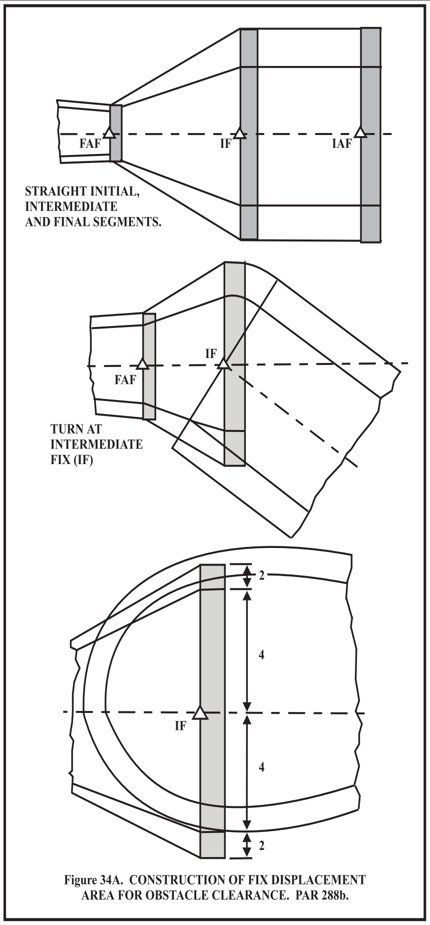

Figure 8. Obstacle clearance area for fix displacement shown in Figure 4.

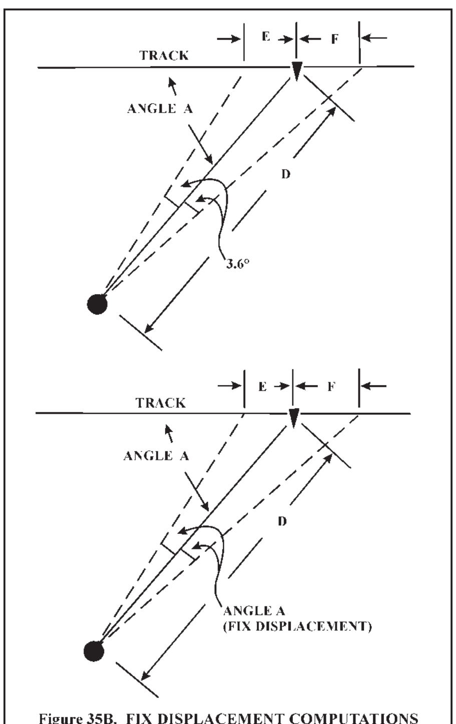

Figure 9. Areas that must be considered to mathematically determine fix displacement factors.

FAA assumptions

In the early 1960s, when TERPs criteria were being developed, the United States believed it had a better way to build the IFR "mousetrap" than our international friends. Although the U.S. fell pretty much into agreement with the rest of the aviation world about ILS and DME, the FAA did some VOR radar-tracking studies in the early 1960s to justify the 4.5-degree primary along-track system error value.

No objective studies were done to validate NDB system error assumptions, so the five-degree number is wildly presumptive. The lack of critical fix locations, low volume of flight operations, and lack of massive obstacle features at the limits have saved the day. If the sides of the trapezoids of all on-the-tail NDB IAPs had concrete walls, and there was a high volume of operations, the accident rate would be astounding.

Even with VOR, the accident rate along Victor airways would be astounding for route segments beyond 51 miles from the facility (where the angular system errors meet the airway's rectangular containment area) had Victor airways hugged high terrain masses at the limits, and had there been significant, sustained levels of IFR flight operations at critical altitudes over the long term.

Assuming the FAA's early 1960 studies were statistically valid, the secondary area of a critical-length VOR airway or IAP protects to a statistical confidence level of 99 percent. That means over the long term, one percent of instrument flight operations will breach containment where system error is equal to the width of the trapezoid.

In Category III autoland operations, where the ultimate obstacle (the runway) must be dealt with on every low-visibility landing, the FAA is forced to be much more conservative. Autoland operations are predicted to fail only once in approximately 10 million operations.

In preparation for this article, I asked the FAA to provide me with the raw components of the various errors that comprise the total for VOR system error. The department responsible for maintaining the FAA's instrument standards has lost track of these data. This is likely the result of the massive downsizing and exodus of non-ATC talent from the FAA over the past several years. This doesn't so much point to any dramatic lack of safety in the system as it does to a general deterioration in trust of the system to continue to deliver the safety targets needed for an acceptable level of safety over the long term. The VOR and NDB systems are perhaps particularly vulnerable for their remaining lives.

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Practical aspects

How do you best protect yourself from the weaker areas of the IFR terminal instrument procedures system? For starters, avoid using NDB IAPs, except at airports where you really know the layout of the terminal area. Avoid the use of VOR (and especially) NDB crossing radial/bearings where DME can be used as an alternative. Also use DME to constantly monitor along-track position on Victor airways and on IAPs, where authorized in non-DME-required IAPs. Consider avoiding the use of NDB and VOR IAPs where the final approach segment is near the limits for distance from the primary facility (30 miles for VOR with FAF, 15 miles for NDB with FAF).

There's a reason the "odd-ball" stretched-to-the-limits IAPs aren't often found at major airports. Such marginal IAPs couldn't stand the exposure to high-volume air carrier operations. Keep that concept in mind when considering some strange, to-the-limits IAP.

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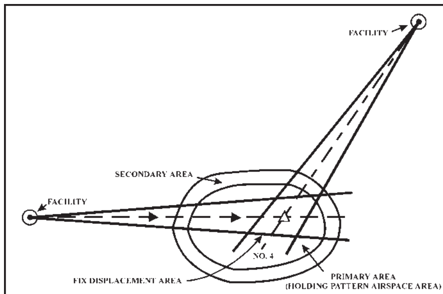

Figure 37. HOLDING PATTERN TEMPLATE APPLICATION. Par 292.

Figure 10. TERPs holding pattern criteria at an intersection fix. At least three of the four corners of the fix displacement area must be contained with the primary area of the holding pattern template. Holding at a "fuzzy" intersection is betting that navigation system errors are both random and correctly quantified.

End Notes

Although all the illustrations in this article are from the TERPs handbook, each was redrawn by our CorelDraw expert Phil Salisbury to ensure high quality.