GPS Approach Concepts

With the onslaught of GPS procedures, there are some important items to know before taking the plunge.

By Wally Roberts

A FEW YEARS HAVE PASSED since the FAA rushed into its approval of GPS non-precision instrument approach procedures. There were Phases I, II and III overlays of several thousand existing VOR, VOR/DME and NDB instrument approach procedures. This happened about the time the Air Force declared the GPS satellite constellation operational and, in the process, the intended orderly progression and pilot orientation/familiarity processes got short-circuited by time compression of the phases.

The technical standard order (TSO-C129) that sets forth the general specifications for the IFR-approach approved airborne avionics came along about the same time. Although the avionics manufacturers were required to implement certain functions, the pilot/avionics interface wasn't well defined.

Unlike VOR, ADF or ILS, a pilot familiar with one manufacturer's box can't simply fire up another manufacturer's box and shoot a demanding GPS IAP to minimums. A pilot proficient in the use of Brand A's IFR GPS box could very well not even be able to figure out how to turn on Brand B's box, much less use it safely for IFR operations. Not only would Brand A's pilot not be able to shoot the approach to minimums, he/she might not be able to get safely past the IAF!

Frustration factor

Many general aviation (GA) pilots feel frustrated by the manner in which the GPS IFR avionics standards were implemented. Overlay approaches would have made more sense and been far more user-friendly had a to-from, bearing-selectable system similar to VOR/DME been implemented. Although I agree with the RNAV, waypoint-to-waypoint implementation for stand-alone GPS approach procedures, it's a dismal, counterintuitive system for overlay of existing NDB and VOR approach procedures. This is particularly so with complex VOR/DME approaches.

Some complex VOR/DME approaches are inherently unsafe when flown with GPS avionics, a fact missed by the FAA in its rush to suddenly have thousands of ready-made GPS approach procedures.

Core TSO specs

TSO-C129 sets forth the following core requirements for airborne IFR approach capable GPS avionics:

• Receiver Autonomous Integrity Monitoring (RAIM). RAIM is active in all phases of flight, but becomes particularly critical in the final approach segment where an out-of-tolerance condition is more likely to cause some makes of receivers to effectively shut down. RAIM is roughly analogous to a "fail" flag appearing because the ground transmitter has failed. RAIM is actually monitoring GPS constellation geometry, to prevent a sudden gross failure of a GPS satellite from causing position information to perhaps suddenly become several miles in error.

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• Course deviation indicator (CDI) scale sensitivity. The spec requires automatic scaling of +/- 5 nm for en route mode, +/- 1 nm for terminal mode, and +/- 0.3 nm for approach mode.

Terminal mode is intended to be active for the initial approach segment when within 30 miles of the airport, and for the intermediate and missed approach segments. Approach mode is only for the final approach segment, with auto-transition from terminal to approach CDI sensitivity starting two miles prior to the final approach waypoint (FAWP). All other segments, including feeder routes, airways and initial approach segments more than 30 miles from the airport are intended to be flown with en route CDI sensitivity.

• Non-modifiable approach database. The entire approach sequence, from the initial approach waypoint (IAWP) through to the end of the missed approach segment, must be contained in an integral database which cannot be modified by user input into the GPS avionics. Only the entire database can be modified by replacement with an updated database.

The feeder segment(s), if any, aren't included in the required integral database—this is important because it's necessary for the pilot to build any required feeder route correctly; i.e., fly the procedural centerline of the feeder route from the feeder waypoint (FWP) to the IAWP, rather than making the mistake of "to-to" homing on the IAWP. (See "GPS Feeder Routes," September 1996 *IFRR*.)

Airline-driven RNAV specs

The airlines made a false start into the world of RNAV in the 1970s. In the process they jointly agreed upon certain RNAV specifications, known as ARINC 424. These random navigation specifications, although more optimally suited for a moving map display with full route nav database, became the default standard for all FAA-approved RNAV systems, including IFR GPS.

The airlines will probably never use GPS avionics in the form of the stand-alone IFR boxes of today. Rather, GPS will become the primary nav sensor for the flight management system's lateral nav sub-system and electronic moving map display. The ideal implementation of IFR GPS in any airplane, GA or air carrier, would be to have a good pictorial presentation of the GPS flight plan route, including the full instrument approach or departure procedure, and a full route database of all airways and feeder routes.

Basic GA box

It's beyond the scope of this article to describe specifically how each avionics manufacturer has implemented the required TSO specs into its IFR GPS box. Instead, I'll discuss the TERPs and operational aspects of GPS approaches that are common to all operations.

Without a good moving map to augment, or even just maintain situational awareness, the en route or approach chart must be oriented carefully by the pilot and related to the information provided by the GPS box. This is the point to state what should be etched in stone as a cardinal rule: *The way a vendor resolves route sequencing ambiguities in its box can only be mastered by the pilot with lots of practice and, in any case, such hard-learned knowledge may have little, if any, value with a different vendor's box.*

The FAA realizes this, but it seems to be too late to go back to the drawing board and create a full-blown set of mandatory, comprehensive and uniform specifications for all vendors. The FAA is presently wrestling with writing generic GPS guidance for the AIM, an almost impossible task.

TERPs protected airspace

The illustration on the right is from FAA Order 8260.38A, "Civil Utilization of Global Positioning System (GPS)," which is a supplement to the TERPs Handbook. Although a bit busy at first glance, it shows the segments of the GPS instrument approach:

• Feeder routes are the same width as VOR airways: a 4-mile primary area either side of centerline with an adjacent 2-mile secondary area. Unlike VOR airways beyond 51 miles from a VOR station, GPS routes never expand. This is because the errors are linear with GPS, unlike the angular system that results from ground-based nav aids. The required obstacle clearance (ROC) in the primary area is 1,000 feet (2,000 feet in mountainous areas).

• Initial approach segments have the same width as feeder routes at more than 30 miles from the airport. Initial approach segments within 30 miles of the airport have primary areas two miles in width, with an adjacent one-mile wide secondary area. Where an initial segment begins more than 30 miles from the airport, the 2-4-4-2 width ramps down to 1-2-2-1 at a 30 degree angle when within 30 miles of the airport. Primary area ROC is 1,000 feet.

• The intermediate segment retains 1-2-2-1 width until four miles prior to the FAWP, where it ramps down to a one-mile primary width, with an adjacent secondary width of 1 mile, or 1-1-1-1. Primary area ROC is 500 feet.

• The final approach segment always ramps down from 1-1-1-1 to 0.5-0.5-0.5-0.5 at the missed approach waypoint (MAWP). Primary area ROC is 250 feet.

• The missed approach criteria aren't shown, but they are similar to other TERPs missed approach criteria. Thus far, the FAA hasn't tightened down GPS missed approach protected airspace because one of the reasons a missed approach might be flown during a GPS procedure is due to a RAIM

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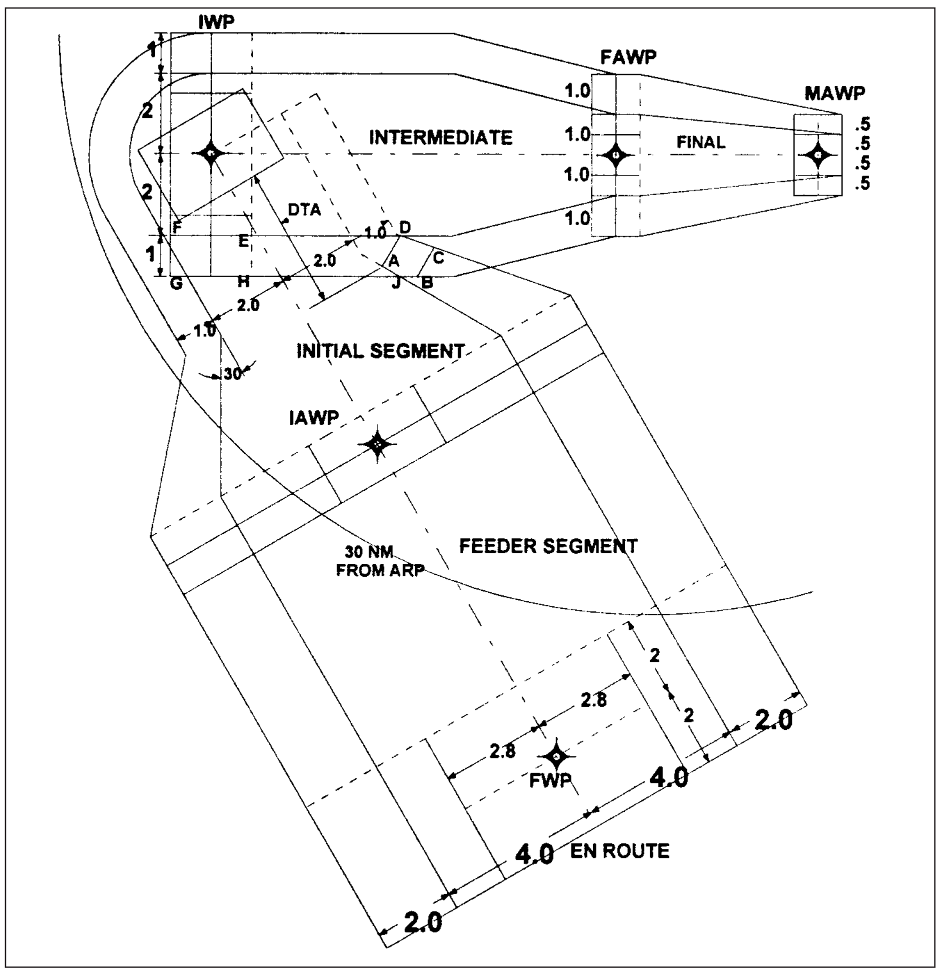

The segments of a GPS instrument approach from FAA Order 8260.38A. Note the final approach segment primary area is only 0.5 nm either side of centerline, which is closer to ILS tolerances than the typical non-precision approach. Abbreviations: ARP - Airport Reference Point, FWP - Feeder Waypoint, IAWP - Initial Approach Waypoint, IWP - Intermediate Waypoint, FAWP - Final Approach Waypoint, MAWP - Missed Approach Waypoint.

GPS Approach. . .

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warning during final approach, which means the missed approach could be flown as a dead-reckoning segment.

GPS fix tolerance assumptions are linear, just like the rest of the system. They are as follows:

	En Route	Terminal	Approach
Cross Track	2.8 nm	1.5 nm	0.5 nm
Along Track	2.0 nm	1.0 nm	0.3 nm

You might ask: why do the fix tolerances vary with approach mode, when accuracy is generally constant with the linear GPS system? The obvious answer is the variable sensitivity of the CDI scaling. There is also the issue of integrity of the system. The RAIM integrity assumptions vary with en route, terminal and approach modes. More on this later.

Approach sequencing and arming

Some IFR GPS boxes auto-sequence to the approach mode, while others require the pilot to arm the approach mode. *It is imperative that the approach mode be armed before the airplane is within 30 miles of the airport.* The arming of the approach mode is what activates sequencing of CDI sensitivity to conform with the decreasing widths of the approach segments shown on page 11. Some vendors' boxes will lock you out approaching within three miles of the FAWP if you failed to arm approach mode, while others rapidly change from five-mile CDI sensitivity to 0.3-mile sensitivity.

I cannot generalize about approach mode arming beyond what is said in the preceding paragraph, simply because of the variances between manufacturers. I understand at least one manufacturer advocates its box always be flown with the approach mode armed. All boxes *should* auto arm passing the IAWP, provided the IAWP is within 30 miles of the airport, but always double check it.

When being radar vectored by ATC to the final approach course, a short turn onto final near the FAWP is best avoided, simply because of the CDI sensitivity change that occurs when within 2 miles of the FAWP. Because of the CDI scale changing from 1 mile to 0.3 miles, it's too easy to misinterpret the sensitivity change as either a non-existent strong wind or tracking error on the opposite side of course. For instance, suppose the CDI needle is 1/2-scale to the left, two miles prior to the FAWP. You've got an intercept angle set up, but the needle suddenly moves even further to the left, even to full scale. This is the result of CDI sensitivity changing from 1 to 0.3 of a mile, but could appear to be a bum intercept when it's not.

More about RAIM

RAIM is always active in an IFR GPS box. The nuts-and-bolts of RAIM is well beyond the scope of this, or any pilot-oriented article. What is important to know is that RAIM monitors accuracy *approximately* to the following limits: en route - 2 nm, terminal - 1 nm, and approach - 0.3 nm. This should make it clear why the GPS fix tolerances vary with the mode, although the system is linear. It's a mix of accuracy, integrity and CDI scale sensitivity.

When an out-of-tolerance condition is detected by the RAIM algorithms, there's a five-minute "coast" factor; i.e., the out-of-tolerance condition will be tolerated for five minutes before the RAIM warning is displayed to the pilot. This is often misunderstood by pilots, who mistakenly believe they have five minutes of coast time to press on after a RAIM warning is displayed. That is incorrect: when the RAIM warning is displayed, it's time to miss the approach and get on VOR navigation. If en route, a RAIM warning means it's immediately the time to revert to VOR navigation.

RAIM requires a minimum of five GPS satellites, or four satellites with barometric input. If RAIM is available with less than six satellites in view, and it detects an errant satellite, it doesn't know which one has gone bad. If six or more satellites are in view, and one becomes errant, RAIM determines which satellite has gone bad and excludes it from consideration. There is no RAIM warning in this case.

RAIM warnings are conservative and can be "false," but the pilot has no way to determine this. The future wide area augmentation system (WAAS) will provide additional assurances of integrity and less false warnings.

Predictive RAIM

All IFR GPS boxes are required to have a RAIM prediction routine, a fact overlooked by many pilots. This feature permits the box to tell you whether RAIM will be available at destination. If RAIM isn't available, you cannot shoot the approach. The fact that destination RAIM has been available for the past 30 days in a row doesn't mean it will be available today or tomorrow.

The FSS briefer has access to RAIM prediction tables. During your FSS briefing, obtain a RAIM prediction for your destination airport. Also, run the GPS box's RAIM prediction as part of your aircraft preflight. Finally, if on a longer flight, run another RAIM prediction about 45 minutes prior to destination, especially if the destination airport has only a GPS approach. It takes at least 45 minutes for the Air Force's GPS command facility to receive information about an errant satellite, so an aggressive RAIM stance is good airmanship.

Overlay vs. stand-alone

As I said at the beginning of this article, many complex VOR/DME approaches are fraught with human-factor traps when flown as GPS overlay approaches. It's the wise pilot who will practice complex overlay approaches during day-VFR conditions until he/she is confident to safely fly the approach during dark, stormy conditions. Waypoint sequencing traps can occur in overlay approaches where the FAWP is also the course-reversal IAWP and perhaps even the missed approach holding fix. Also, don't forget that on-airport, no-FAF VOR and NDB overlay approaches have a pseudo-FAF four miles from the VOR or NDB facility.

The customary 10-mile procedure turn must be remain within *six* miles of the pseudo-FAF.

Stand-alone GPS approaches are far easier to fly than most overlay approaches, because they are designed with the GPS to-to-waypoint concept in mind. What you see on the chart is what you get. But, as I said earlier, the chart needs to be oriented carefully to avoid a loss of situational awareness. For those who can afford it, a first-rate moving map can enhance situational awareness a lot.

Integrity of the box's database

GPS is a complex, space-based system. Unlike a VOR, DME, NDB or LOC ground transmitter, how do we really know whether those GPS waypoints are for real? Jeppesen is the only provider of GPS databases for IFR boxes. Jepp does some "reasonableness" testing of GPS waypoints by doing the math to check for bearings and distances, which are compared to the FAA's source document. For those who complain about Jepp's database prices, you might ask: why isn't there any competition? I suspect Jepp has a fair amount of liability exposure, which is part of what you're paying for. It's well worth the price to have Jepp doing the double-checks.

The FAA rushed into GPS much too fast. International aviation interests, although impressed with GPS's potential, don't like using a system controlled by the U.S. The standards are in a state of flux, both because of international concerns and the experience GA interests are gaining in using esoteric, unfriendly IFR GPS boxes.

If GPS approaches are important to you today, by all means go for it. Shop the various IFR boxes carefully, though. Most important: ensure you really know how to use your vendor's box, and don't assume you know much about how to use the other vendors' boxes.

The altitude information provided by any GPS box, even an IFR unit, isn't a backup altimeter. The vertical errors are at least 150% greater than the lateral errors, and aren't subject directly to any integrity or accuracy check.

I won't delve into using VFR GPS units for IFR. As I said in my article, "Lost Com: Let's Get Real" (March 1996 *IFRR*), in an emergency don't hesitate to use such a unit. But, for routine operations, it's a form of IFR Russian Roulette to use a VFR box for instrument approaches.

Some folks feel they can forego that DME set because they have an IFR GPS. Well, not until WAAS arrives, at the earliest. You need that VOR and DME to not only revert to in the event of a RAIM warning, a good VOR/DME fix cross-check before descending into the rock canyon with GPS is good insurance.

Wally Roberts is a retired airline captain, former chairman of the ALPA TERPs Committee and an active CFII in San Clemente, CA.

End Notes

Many thanks to Steve Jackson in the FAA TERPs Standards Development Branch for his time spent with the author in researching this article.

The publication, "FAA's Plan for Transition to GPS-Based Navigation and Landing Guidance," should be required reading for all IFR pilots and can be obtained from:

FAA, AND-500
1250 Maryland Ave., S.W.
Washington, D.C. 20024

It can also be obtained on Internet:
http://asd.orlab.faa.gov/files/gpstrans.htm